Petter Tolnes Ingebrigtsen

The Power of Power

A Qualitative Study of the Enablers and Inhibitors to Norwegian Hydrogen Diffusion

Master's thesis in Globalization and Sustainable Development
Supervisor: Markus Steen
May 2020

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Abstract

Transitioning to a low-carbon society manifest a highly political process. Norway, alike the rest of the world, is required to reconfigure production and consumption practices if it is to meet envisioned climate targets. In Norway, the energy carrier of hydrogen has been touted as a promising solution towards decarbonisation because of the clean and versatile nature of this element. Yet, diffusion of hydrogen in sectors such as energy supply and transport are confronted by several barriers. Overcoming them, are contingent on political support and a coordinated mobilisation of resources. For these reasons, the particularities of power and politics are emphasised as crucial components if hydrogen is to realistically provide future sectors with clean energy. This thesis provides an in-depth analysis on factors that both enable and constrain the diffusion of hydrogen. The findings are subsequently discussed within a multi-level framework, to which a more transparent understanding of power and politics in transition becomes illuminated.

Preface

Although this master thesis is concerned with explaining how power and politics enable or constrain the diffusion of hydrogen in Norway, the underlying motivation is really about seeking to find out why overcoming the perils of climate change manifest such a difficult endeavour. This piece however, while hopefully contributing to the debate on sustainability, only manage to capture the tip if the iceberg. Indeed, far more challenges exist out there. Hydrogen is no panacea, but reconfiguring practices of production and consumption with the help of this element is largely viewed as a step in the right direction.

In hindsight, the undertaking of this project constituted an invigorating passage, characterised by both frustration and passion. Ironically, it is bizarre to note that the process of writing this master thesis, executed under the banner of my graduate programme, *Globalisation and Sustainable Development*, was effectively confronted by globalisation itself, through the poignant spread of the pandemic Covid-19.

While the finalisation of *The Power of Power*, depended on the author's ability to maintain focus, motivation and quality throughout the entire span of the project, it could never been done without the perseverance of my supervisor, and the zeal of my family and friends. To the invaluable help and support of Markus Steen, I am most grateful. Thankfulness is further extended to my former supervisor while conducting my internship in Indonesia, Ståle Angen Rye, and my boss, Nanang Indra Kurniawan, at Universitas Gadjah Mada. Your knowledge and support have not gone unnoticed. A final thank you is directed to the Institute of Geography, and my University as a whole, the last 5 years have without doubt, been gratifying.

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List of Abbreviations

CCS	Carbon Capture Storage
CO_2	Carbon Dioxide
EU	European Union
FCH	Fuel Cells and Hydrogen Joint Undertaking
FME	Centres for Environment-friendly Energy Research
FME CenSES	Centre for Sustainable Energy Studies
GHG	Greenhouse Gases
GDP	Gross Domestic Product
H_1	Hydrogen
H_2	Hydrogen gas (molecular hydrogen)
IFE	Institute for Energy Technology
IPCC	Intergovernmental Panel on Climate Change
MLP	Multi-level Perspective
MoZEES	Mobility Zero Emission Energy Systems
NGOs	Non-Governmental Organisations
NHF	Norwegian Hydrogen Forum (Norsk Hydrogenforum)
NPRA	Norwegian Public Road Administration (Statens Vegvesen)
NSD	Norwegian Centre for Research Data
OPEC+	The Organization of the Petroleum Exporting Countries
R&D	Research and Development
SDGs	Sustainable Development Goals
SINTEF	Stiftelsen for Industriell og Teknisk forskning
SNM	Strategic Niche Management
TIS	Technology Innovation Systems
UN	United Nations
WCED	World Commission on Environment and Development

1.0 Introduction

"Understanding structural change is one of the greatest challenges of social science" *(Avelino & Rotmans, 2009)*

Today, the world is confronted by fundamental challenges to sustainability. Between 2030 and 2052, global warming is projected to reach 1.5°C above pre-industrial levels if it continues to increase at the current rate (IPCC, 2018a). The need for power has risen to become an essential trait of modernity. But as the power that fuels vital socio-technical systems, such as energy supply or transport, are associated with non-sustainable production and consumption practices, drastic efforts to reconfigure these systems are required to achieve rapid and deep decarbonisation (Geels, Sovacool, Schwanen, & Sorrell, 2017). As the world of nations are approaching the meridian of the United Nations' 2030 Sustainability Goals, renewables, such as solar, wind and hydropower, have increasingly acquired a more prominent position in the energy diet. Yet, transformation of socio-technical systems is argued to require a much wider range of energy technologies. For that purpose, clean hydrogen is presently enjoying a growing wave of interest as a promising pathway to a low-carbon future (Hulst, 2019).

Concurrently, in 2019, the Norwegian government announced plans to unveil a hydrogen strategy by 2020 in conformity to the ambitions in its envisioned green leap (Knutsen, 2019). However, as paths to sustainability are found to be aggravated by strong-path dependencies and potential resistance from powerful incumbents (Köhler et al., 2019; Markard, Raven, & Truffer, 2012), seeing hydrogen decarbonise existing systems is found to be an undertaking confronted by a multiplicity of barriers. As such, this piece has taken upon the task of seeking to understand the different barriers that presently inhibit the diffusion of hydrogen toward a low-carbon future. This is done by assessing hydrogen within the territorial borders of Norway, guided by Geels' (2002) multi-level perspective on socio-technical transitions, coupled by theoretical insights on power and politics from Avelino (2017); Avelino and Rotmans (2009). Drawing from these contributions, this thesis aims to establish a greater sense of understanding to how power and politics enable and constrain transitions based on an analysis of hydrogen's barriers and opportunities in Norway's energy and transport sector.

The analysis is based on data that was generated through in-depth interviews with informants of relevant expertise and knowledge in the Norwegian hydrogen world. Additional substance is further extracted from state-of-the-art research on hydrogen. From the process of data generation and the subsequent analysis, it was found that the Norway's regulatory framework and support to hydrogen is disadvantageously inadequate at present. Indeed, promising development are taking place, with pilot projects and development contracts that take use of hydrogen technology. But to meet criteria of sustainability transitions, where hydrogen or hydrogen technology reconfigures modes of production and consumption at a certain scale, present endeavours are found to be limited. Surprisingly, it was not found any explicit evidence of opposition against hydrogen from actors posited in the regime. However, given barriers found related to cost, level of matureness and safety aspects, it is possible to foresee future opposition, but at the time of this thesis' finalisation, these remain speculations, yet possible journeys for future research inquiries on hydrogen in Norway.

1.1 Delimitations

Hydrogen is found to be an element of great versatility, where the picture of opportunity is big. Accordingly, hydrogen has the potential to become utilised in various sectors, not exclusively limited to energy supply or transport, but also in industry processes and in heating buildings. Opportunities outside the sphere of energy and transport, including maritime, are for the sake of time and length not included. As such, findings related to power and politics may therefore not display the whole picture. In any case, this also implies that future research on hydrogen may be conducted in these sectors.

1.2 Research Questions

This thesis operationalises the following two research questions:

RQ1: How does power and politics enable and constrain the diffusion of hydrogen in Norway in respect of its [Norway's] proclaimed transition to a low carbon society?

To this end, it is deemed important to delineate relevant barriers and opportunities. To satisfy this need, a secondary RQ is formulated as follows:

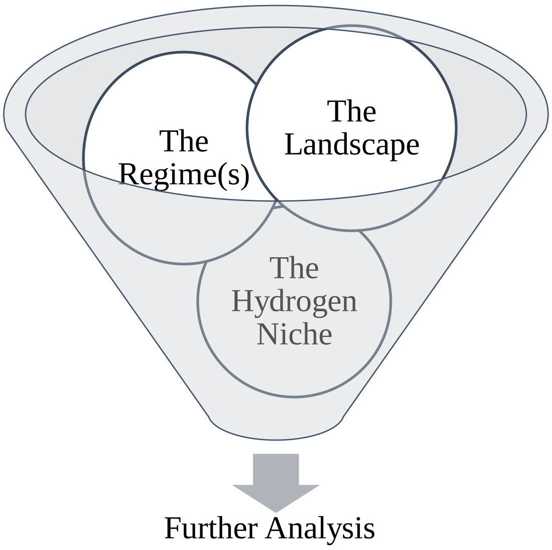
RQ2: What barriers and opportunities are presently blocking or enabling the diffusion of hydrogen in Norway?

Again, both questions are delimited to Norway's energy and transport sectors. Further overview is provided in the following section, were the structure of this thesis is elaborated.

1.2 Structure of this Thesis

Henceforth, the *Power of Power* is structured accordingly. The rest of the 1st chapter bridge the introduction of this thesis with a review of relevant literature in the field of sustainability transition research. Here the reader will be presented with the most common streams of research, and why variables such as power, politics and hydrogen are interesting in this research. Leaping to the 2nd chapter, the literature review is complemented by a more detailed unpacking of the relevant terminology, concepts and theories employed within this thesis. The 3rd chapter assess the choices of methods, the credibility of this research, ethical considerations, and its limitations. The 4th chapter is partially structured in conformity with the three levels of the MLP assessed in the 2nd chapter, which consists of three levels of analysis. As such, the first half of this chapter begins by introducing the upper level (the landscape), the meso level (the Norwegian context and regimes of scrutiny), and finally the niche level, in which the barriers and opportunities of hydrogen becomes explicitly alleviated. The figure below, illustrate the author's thought process in structuring this chapter.

Figure 1.0 Funnel of Analysis



After each level of analysis has been examined, the acquired data is further complemented by insights were power and politics come to show in more detail. This chapter ends with an assessment on how actors mobilises resources in favour of hydrogen. The 5th chapter, returns to a greater extent more back to the theories in the 2nd chapter, in applying them into the discussion of the findings, in order for a conclusion to take place, which is located in chapter

6. At the end of the conclusion, some policy recommendations are in the end alleviated, followed by a bibliography in chapter 7 and an appendix with the interview guide.

1.3 Literature Review

In line with the increasing acceptance of anthropogenic strain on the environment, sustainability-oriented research on the transformation socio-technical systems have received considerable interest since the end of the 1990s (Markard et al., 2012, p. 955). This relatively new field of research represents contributions with diverse understandings of transformative change. With the intention of constructing an additional contribution to the field, reviewing the current state of the art is paramount[1]. Essentially, what sparks the spectrum of researchers to indulge themselves within this discourse, is linked to the grand challenges of climate change, loss of biodiversity and depletion of natural resources (Köhler et al., 2019, p. 3). Here, patterns of non-sustainable trajectories are commonly identified at the heart of each inquiry. In the literature, trajectories of this nature, are defined in relation to world's dependency on fossil fuels (Jacobsson & Bergek, 2004), air pollution and greenhouse gas emissions (Markard et al., 2012) rising levels of consumption (Vogler, 2017), and humanity's transgression of planetary boundaries (Koistinen, 2019).

This ever-growing field of interest has undergone years of enrichment from a diversity of scholarly disciplines such as science and technology studies, evolutionary economics, ecological economics, ecology, political science and environmental studies (Lawhon & Murphy, 2011, p. 357). Correspondingly, we are able to locate a wide array of themes within this field, such as studies on renewable energy technology (Jacobsson & Bergek, 2004; Saeedmanesh, Mac Kinnon, & Brouwer, 2018), which have provided valuable insights to the difficulties of transforming the energy sector. Other contributions looks more specifically into how technological change is locked into technological regimes (Kemp, Schot, & Hoogma, 1998; Unruh, 2000). A lock-in may be understood as an extreme form of path-dependency that inhibits the diffusion of renewable technologies despite their apparent environmental and economic advantages (Unruh, 2000). Whereas scholars such as Unruh, centred attention at the

[1] The method of reviewing literature was mainly conducted by going through relevant articles, published in peer-reviewed scientific journals, such as Science Direct, Research Gate and Sage Publications. Key words were employed during the process of exploration, such as: Sustainability transitions + power + politics; Socio-technical transition + sustainability + power + politics; Sustainability transition + hydrogen + power + politics; Sustainability transitions + Norway. Searches were conducted through various search engines, such as google scholar and NTNU's library website (Oria). Books were also deemed relevant and useful in the review.

prevailing regime, (Geels, 2002) focused on how innovations at the niche level may destabilize the regime in question. Contributions have also aimed to capture the nature of states in the sustainability transition literature, see Johnstone and Newell (2018). Both power and politics are highlighted as important aspects of sustainability transitions. Accordingly, the role of the state and powerful actors enjoys emphasis. Of prominence here are Geels (2014); Normann (2015); Roberts et al. (2018). Though these honourable mentioned only captures a fraction of the diversity of the existing literature, they provide an overview over some of the general themes touched upon.

To simplify what the overall entanglements of sustainability transition research denotes, the following definition is found useful.

> "…all scientific articles that are concerned with the analysis of the institutional, organisational, technical, social, and political aspects of far-reaching changes in existing socio-technical systems (e.g., transportation or energy supply), which are related to more sustainable or environmentally friendly modes of production and consumption" (Markard et al., 2012, p. 959),

may be placed under the umbrella of sustainability transition research. The reach of this umbrella further covers empirical, conceptual, and methodological contributions (Ibid.).

Though the journey of sustainability focused research began over two decades ago, challenges akin to global warming are by no means vanquished. As noted with high confidence by the Intergovernmental Panel on Climate Change's (IPCC) 2018 report,

> "without social transformation and rapid implementation of ambitious greenhouse gas reduction measures, pathways to limiting warming to 1.5°C and achieving sustainable development will be exceedingly difficult, if not impossible, to achieve" (IPCC, 2018b, p. 448).

Already by 2016, mean temperature had reached 1 °C above pre-industrial levels (Vogler, 2017, p. 394)

Over the last decade, there have been calls in the literature for future improvements at the particularities of power and politics (Markard et al., 2012, p. 962), both which are fundamental components in sustainability transitions (Markard, 2017). This view is extended in more recent contributions, such as in the 2017 Sustainability Transition Research Network, which identifies power, agency and politics as key direction for further research (Roberts et al., 2018). This is for example emphasised by how powerful incumbents are able to slow the pace of energy transitions (Ibid., p. 307), or by how many political and public debates are predominantly focussed on standard, relatively short-term economic issues (In Loorbach *et al*., 2016, Koistinen, 2019, p. 11).

Building upon this inquiry, a specific phenomenon, or case, is required to enrich the understanding of power and politics in sustainability transition. Where theoretical insights to the particularities may be extracted from existing publications, such as (Avelino & Rotmans, 2009) and (Geels, 2014), exploration for a suitable cases can be found in the politics itself, such as in government communications, roadmaps or strategies.

Political heavyweights, such as the EU, greatly emphasise the criticality of new technologies, sustainable solutions, and disruptive innovations as means to meet commitments made to the 2030 Sustainable Development Goals (SDGs), see (European Commission, 2019). In the literature, renewable energy sources (e.g. wind, solar, and biomass) have already attracted a substantial amount of attention (Markard et al., 2012, p. 961). More recently, hydrogen as a sustainable alternative to fossil fuel has appeared to gain traction, both in the literature, but also on the political agenda. Relevant contributions here are Saeedmanesh et al. (2018) or Acar and Dincer (2020). Most noteworthy perhaps, is hydrogen's ascendancy to the world's energy watch dog, the International Energy Agency, agenda, see (IEA, 2019a). Furthermore, the EUs' highly ambitious Green Deal, gave prominent notice to hydrogen as it pledged to neutralise the continent's greenhouse emissions (European Commission, 2019).

By virtue of the many promising particularities of hydrogen, becoming romantic of it appears tempting. It is the most abundant element in the universe, and status as the cleanest energy alternative (Acar & Dincer, 2020). Added with great versatility, hydrogen may be supplied to industry, such as oil refining or ammonia production; in transport, for automobiles, shipping and aviation; in building, such as for heating; or in power generation, for example by storing energy from renewables (IEA, 2019a). But, diffusion of hydrogen is confronted by significant barriers, such as exceedingly high cost, insufficient regulatory framework and lacking infrastructure and markets. For these reasons, it is believed to highly interesting to undertake a study on not only identifying these barriers and opportunities more closely, but also by seeing how power and politics may open or even constrain eventual commercialisation[2]. To do so, it

[2] Note that this section only speaks of 'clean' hydrogen. It is also possible to produce 'dirty hydrogen', which releases substantial amounts of GHG emissions.

is necessary to further bridge this brief review of literature more explicitly to relevant theories and concepts. As such, the following chapter unveils the operationalised terminology in further detail, before unpacking how the multi-level perspective and power theories will be utilised in this contribution.

2.0 Theoretical departure for the study on Sustainability Transitions

By standing on the shoulders of its pioneers, the answer to the grounding question 'how can we study sustainability transitions?' becomes increasingly more transparent. In light of Markard et al. (2012), (Geels, 2010) and (Köhler et al., 2019) review of theoretical and conceptual approaches on how to study sustainability transitions, this project were represented with an appropriate point of departure. Insights from earlier contributions are held in high value given the multi-dimensionality of sustainability transitions. As such, building on established concepts and theories from the range of methodological routes taken by transition researchers are deemed critical in order to ease the passage of this research. In correspondence with Owens, Baylis, and Smith (2017, p. 4), it is impossible to decide which of the millions of facts matter without a theory. In other words, when accounted for and understood, both theories and concepts will belong within toolbox at disposal for this research.

Among the contributions on sustainability transitions, there are four theoretical frameworks which have gained great prominence. These are, Transition Management (TM), Strategic Niche Management (SNM), the Multi-Level Perspective (MLP) or Technological Innovation Systems (TIS) (Markard et al., 2012, p. 957). These frameworks are by no means an exhaustive list of theoretical approaches to study sustainability transitions. For example, valuable insights may be gathered from other scholarly disciplines, such as political science, management studies, sociology, economic geography and modelling (Markard et al., 2012, p. 956). What gives the four highlighted frameworks above particular prominence, is that they all adopt systemic views of far-reaching transformation processes of socio-technical systems (Ibid.). While each of these frameworks are useful for inquiries on sustainability transitions, this thesis will limit its attention to Geels' (2002) MLP. Reasoning to why, is explained in section 3.4.2.

But, before the unzipping of the MLP is carried out, conceptual clarifications require the initial attention. First, what are socio-technical systems? Second, what are sustainability transitions? Also, how do we understand sustainability? These concepts will be accounted for in the following paragraphs. When accounted for, this chapter will unpack the MLP more explicitly, followed by how power and politics can be studied in this thesis.

2.1 What are Sociotechnical Systems?

In the transition literature, sectors such as energy supply, water supply, or transportation are understood as socio-technical systems (Markard et al., 2012). Common for systems of this nature, is the interlinkages of technologies, infrastructures, organizations markets, regulations, and user practices, which in concert provide particular services to society (Geels et al., 2017). Viewing the nexus of these aspects as part of one large system are useful for the purpose of studying transitions, where complex processes and interactions are placed within one systemic framework. Instead of viewing a particular technology, regulation or user practice in absence other interrelated components, a more holistic reality is theoretically depicted through utilization of socio-technical systems.

Stability in socio-technical systems is attributed to the presence of highly institutionalized formal and informal rules that have co-evolved with certain technologies and solidified into practices and routines (Fuenfschilling & Binz, 2018, p. 735). While the components within a socio-technical system are to some extent, always subject to incremental change (Köhler et al., 2019, p. 2) do not entail that socio-technical transition automatically unfolds. Transition studies often distinguish between different socio-technical transitions when the given system have moved from dynamic state of equilibrium to another in a non-linear manner (Avelino & Rotmans, 2009, p. 544). The set of processes that relinquish the trajectory of a system, involve reconfigurations along the components of that system, including landscapes with technology, policy, infrastructure, scientific knowledge, and cultural practices towards sustainable ends (Newell & Mulvaney, 2013, p. 2). However, what is deemed sustainable is up for interpretations, due to the contested nature of this 'fuzzy' concept. This is discussed in more detail in section 3.2 and 3.3.

In essence, when discussing socio-technical systems in relation to transition, we are dealing the dichotomous interrelationship between the "qualitative and continuous nature to people and the quantitative, discrete nature to technology" (System Innovation, 2017). While the language of 'whole system thinking" is indeed complex and difficult to navigate through, it is frequently utilized in research on energy policy, as a fruitful method to understand social challenges such as sustainable energy (Robertson Munro & Cairney, 2020, p. 1).

2.2 What are Sustainability Transitions?

As noted above, studies on sustainability transition represents a prominent field of research within the transition literature, and have been developed rapidly since the grand attempt to review the literature (in, Markard et al., 2012).

Simply, sustainability transition may be conceptualized as,

"…long-term, multi-dimensional, and fundamental transformation processes through which established socio-technical systems shift to more sustainable modes of production and consumption" (Markard et al., 2012, p. 956).

Key here, are "more sustainable modes of production and consumption", central components within a socio-technical system. Moreover, unlike socio-technical transition, sustainability transitions are usually guided by clear policies. Sustainability transitions are initiated with a clear purpose, often resting on sustainability targets (e.g. The Kyoto Protocol or the SDGs) aiming to overcome challenges in the economic, social and environmental realm. Transitions of this nature is a long haul, taking several decades to unfold (Köhler et al., 2019, p. 3).

There are many reasons why sustainability transition takes up such a degree of time. One reason is that radical 'green' innovations and practices often take a long time from its early stages of development to widespread diffusion (Ibid.). Existing systems are also found difficult to destabilize, which make diffusion a difficult task as incumbents may demonstrate resistance to new technologies and practices (Ibid.).

In addition to being associated with a long time unfold, Markard (2017) further emphasise the relevancy of normativity, in that they often are value-laden and contested. Sustainability transitions are further associated with uncertainty, complexity, being context dependent and, power and politics. As individuals and groups will disagree about the desirable direction of transitions, and how they should be steered in the sense that transition potentially may produce winners and losers, it is obvious to why transitions represent a highly political process (Köhler et al., 2019, p. 6). To understand these particularities more closely, it is deemed necessary to explore its normative nature more in detail.

2.3 How do we Understand Sustainability?

Sustainability is a value-laden multidimensional concept associated by heterogenic definitions and is still subject to debate and controversy. Consequently, there are multiple grounds to which sustainability policy, strategy and research might rest upon. The most widely used definition of sustainable development, is that articulated by the Brundtland Commission in the late 1980s, “Meeting the need of the present without compromising the ability of future generations to meet their needs” (WCED, 1987, p. 43)

Yet, it implies several normative challenges is implied with this definition. For instance, what is the needs of the present? For whom is the need of the present? What authority decides what the needs of the present are? Whenever the definition of sustainable development defined above is utilized, we are in practice anchoring the performance in the present on a series of comparisons and contrasts with anticipated futures and recollected pasts (Garud, Gehman, & Karnøe, 2010) (in, Garud & Gehman, 2012, p. 3). Defining the needs of the present based on a fixed present, a status quo, also faces the reality that the world is in constant change. What we deem important today differs from that of a generation, a century or a millennium ago, as well as the spatial context where given needs reside. Thus, in light of the technological advances of the present, the same logic is likely to equally apply in the future. The dynamism of human societies prompt those with an interest in the underpinnings of sustainability to question how we are supposed to reconcile the present with that of the distant future.

Sustainability transitions, though vital to overcome the grand challenge of climate, must also produce overall benefits across society, not just the certain groups or regions. In other words, the desirable pathway of the transition must consider ‘for whom’ this drastic reconfiguration of practices is done for. Currently, the present is demarked by a rising inequality of access to safe and affordable energy, even in affluent nations (Healy & Barry, 2017, p. 451). Greater recognition to the potential and perceived socio-economic costs of decarbonizing policies, such as negative impacts on fossil fuel energy workers and communities affected by the transition is thus needed (Ibid.).

According to Jenkins, Sovacool, and McCauley (2018, p. 67), failure to adequately engage with questions of justice throughout the transition process is dangerous, which may lead to aggravated poverty, entrenched gender bias and non-participation as outcomes or by-products of ‘blinkered’ decision-making. Eames and Hunt (2013, p. 58) note that also a ‘low carbon’ transition also has the potential of distributing cost and benefits just as unequally as historical fossil-based transitions if the social pillar of sustainable development is not sufficiently addressed, (in, Jenkins et al., 2018, p. 67).

The term ‘just transition’ is too increasingly gaining prominence in the sustainability debate. It calls for a greater mindfulness to that justice as societies move towards economies free of CO_2

emissions (McCauley & Heffron, 2018). In addition to the crucial challenge of mitigation, aspects such as health, well-being, education, jobs remain important aspects that the majority of humanity aspires to acquire and safeguard. The quality of the environment in which we all reside is also of importance. If abused, negative externalities may challenge the needs of the present and possibly, the future as well. For these reasons, approaches to sustainable development must seek to integrate and balance economic, environmental and social concerns instead of trading them off against one another (Carter, 2007 in Pike et al, 2014, p. 139).

Thus, acknowledging the normative nature and the fuzziness of sustainable development, it becomes clear why it does not obtain a monolithic understanding. In fact, over 50 different definition of the concept has been counted (Vogler, 2017, p. 389). Accordingly, how governments, business and civil society, engage in the contemporary debate on climate change and sustainable transition may diverge. This may be present in how they view and mobilise their resources for the purpose of a transitioning, and whether they seek to influence or simply just adapt as inactive bystanders and how they articulate their sustainability commitments.

Above I have presented the theoretical underpinnings of socio-technical systems, sustainability transitions and the contested nature of sustainable development. This have been done with the intention of illuminating some of the fundamental challenges in relation to sustainability transitions. A sustainable transition of the present non-sustainable trajectory is one of the most daunting tasks of humanity. However, as sustainability are understood unevenly, the articulated purpose of required transitions, by powerful international organizations, such as the United Nations and the European Union, may face resistance.

Along the contested nature of sustainability transitions, overcoming obstacles related to power and politics in achieving a sustainable transition is of vital importance, as there are powerful incumbents exercising great influence within the existing regime that maintain vested interests in present codes of conduct. For this reason, a more encompassing theoretical framework will be elaborated, in which the investigation on hydrogen may be studied with the incorporation of power. The framework will then be applied to the empirical findings in subsequent chapters, where the barriers and opportunities of hydrogen development in Norway, in relation to power are discussed.

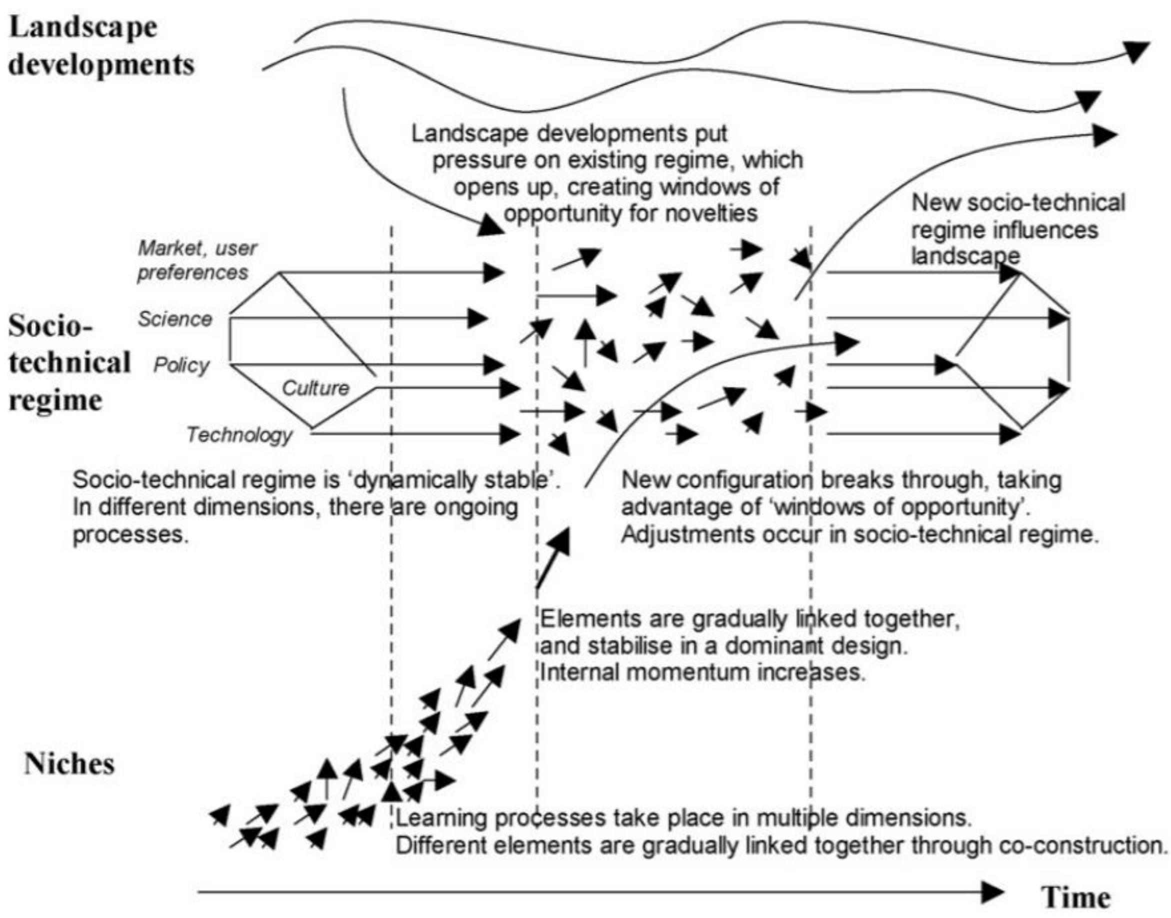
2.4 The Multi-Level Perspective

In undertaking whole system research for the purpose of tackling contemporary societal issues related to sustainability, a widespread convergence has revolved around the interdisciplinary approach of the Multi-Level Perspective. The MLP, is defined by Geels (2011, p. 26), as a middle-range theory the that conceptualize the overall dynamic patterns in socio-technical transitions. It features as a highly versatile analytical framework that combines concepts from evolutionary economics, science and technology studies, structuration theory and neo-institutional theory, and has found room in a broad range of contributions in the transition literature (Geels, 2010, 2014; Milfont & Markowitz, 2016). Central concepts in this regard are regimes, niches, landscapes, actors, trajectories, social networks, innovations, rules and institutions (Geels, 2011, p. 26). To avoid confusion, the regime denotes 'the deep structure' or 'grammar' of a socio-technical system (Fuenfschilling & Binz, 2018, p. 735). Whereas the landscape is more what surround the system (Avelino & Rotmans, 2009, p. 560). Various actors operate within these levels, as proponents or opponents of transition, or even something in between.

In essence, the MLP view transitions as non-linear processes that reflects the outcome of the interplay of developments from three analytical levels: Niches (the locus of radical innovations), socio-technical regime (the locus established practices and associated institutions that stabilize the existing system) and the exogenous socio-technical landscape Rip and Kemp (1998), Geels (2002), (2005) (in, Geels, 2011, p. 26). The niche represent the lowest and the least stable level in this framework, where innovation and learning occur and where social networks are built by firms, entrepreneurs, scientists and policy makers, who (ideally) desire to advance more sustainable alternatives to those of the present (Lawhon & Murphy, 2011, p. 357).

The core logic of the MLP asserts that when niche innovations build up internal momentum, developments at the landscape level creates pressures on the existing regime, an event of destabilisation may occur, creating a window of opportunity for the diffusion of niche innovations. This development rest upon the assumption that transition occurs due to social interaction between the respective actors (Geels, 2011, in Koistinen, 2019, p. 38). As these processes align, a breakthrough for 'green' innovations to mainstream markets may unfold, where they will struggle with the existing regime in multiple dimension (economic, technical, political, cultural and infrastructural (Geels, 2014, p. 23). The regime is where the transition unfolds, as a result of the pressure from the niche and landscape. A transition of a socio-technical regime is depicted in Figure 2.0 below.

Figure 2.0 A Dynamic Multi-level perspective on System Innovations



Source: Adapted from Geels (2004), by (Genus & Coles, 2008, p. 1438)

2.4.1 Former Case Studies

To illustrate with the case of Germany's unfolding energy transition, niches such as wind, photovoltaic (solar power) and biogas were gaining increasing momentum at the turn of the millennia (Geels, 2017). These technologies were able to break through due improvements in price and performances, support from industrial coalitions, positive cultural framing, and generous policy support. Whereas the existing regime in nuclear power, experienced long-lasting tension due to a powerful antinuclear movement as well as political pressure from the labour/green Party coalition (Ibid., p.1242). As these technologies matured within their protected markets facilitated by the 2000 Renewable Energy Act, support to nuclear power exacerbated following the 2011 Fukushima accident. The shock triggered the decision to phase out nuclear power and to embrace energy transition as the political dogma (Ibid.)

Windows of opportunities are key. Yet, successful exploitation of these windows has not always the case success. Normann (2015) analysis of offshore wind in Norway between 2005 and 2012, for instance, showed how favourable conditions emerged due to exogeneous developments. Despite substantial political support to offshore wind, the very institutional alignment with the technology were insufficient in order to exploit the opportunities at the time (Ibid., p. 16).

2.4.2 Justifying the MLP

To this thesis, the MLP stands out as theoretical framework with some advantages. Most transparent, it has been widely utilized in analysis on green innovations and transition since its inception. The literature review remarked that there has been calls to improve understandings of power and politics in sustainability transitions. Geels (2010), noted that the MLP had mostly treated the dimensions of power and politics in an ad-hoc way (p. 506).

Yet, as the transition literature has evolved, improvement on these particularities have followed suit. In Geels (2014) piece, a detailed assessment on how to incorporate power in the MLP was introduced, which delineated various ways the existing regime can and are resisting voices of transition. Additional prominent contributions that approach paradigms of power and politics are Avelino and Rotmans (2009); Bakker (2014); Koistinen (2019).

Lastly, as this thesis requires a visible link to globalisation due to this thesis' attachment to the master programme of globalisation and sustainable development, the MLP proves itself as reasonable framework for the study of sustainability transitions as it can be understood as a global model of transition that captures the overall process (Geels & Schot, 2010, p. 29).

2.5 Actors and Sustainability Transitions

Sustainability transitions involves a variety of actors. Developments leading to more sustainable modes of production and consumption does not occur in a vacuum. From the literature, we have learned that sustainability transitions are contested and guided by policy, thus making aspects such as power and politics prominent. As such, the relevance of actors within any serious analysis on sustainability transition is paramount. Various types of actors may be explored both at niche level and at the incumbent socio-technical system of the MLP. Traditionally, a dichotomy between supporters and opponents of transition have been highlighted in the literature (Bakker, 2014, p. 61). According to Geels (2014, p. 26), policy makers and incumbent firms often form core alliances at the meso-level, for the purpose of maintain status quo. Opposing actors can be exemplified by traditional energy companies that base their business model on fossil fuels or an actor with strong interests in maintaining the current regime (Koistinen, 2019, p. 40).

However, viewing the relationship between supporters and opponents of transitions have been criticized for being too simplistic as it does not cover possible variation among actor strategies within these two categories (Koistinen, 2019, p. 39). For example, Bakker (2014) asserts that different types of actors may display ambivalent strategies, both in terms of support and resistance. In the real world, the categories in which an actor may be confined may overlap with other categories. Moreover, actors typically possess some form of power and resources which they may employ to further their interests.

2.6 Incorporating Power into the Analytical Framework

To recap, the core logic of the MLP, is that innovations at the niche level build up internal momentum (through learning processes, price/performance improvements, and support from powerful groups) (Geels, 2014). When internal momentum from below (the niche) occurs in concert with changes from the landscape, a window of opportunity at the regime level may unfold, in which the diffusion of niche innovations destabilizes the existing socio-technical system, provided that the nice technology is sufficiently matured. Falling short on the other hand, limits the niche and their advocates' ability to exploit opportunity windows (Normann, 2015, p. 3). In the event of the alignment of these processes, green innovations may breakthrough into the mainstream markets. If the struggle with existing regime proves successful, meaning that green innovations manage to solidify their position at the meso-level, a sustainable transition can be said to have unfolded, provided that deeper modes of sustainable production and consumption ousted juxtaposing modes.

In accordance with sustainability transitions, the MLP acknowledge the relevance of power and politics in its explanation on how transitions of socio-technical system unfold. These particularities of sustainability transitions are evident in how the regime maintains the status quo, and how niches build up internal momentum to challenge and destabilize the regime.

Among the various processes necessary to accomplish a transition of a sustainable nature, it is possible to identify power dynamics, as long as adequate analytical tools are ready at our disposal. For these reasons, a conceptual framework on how the particularities of power and politics can be understood in relation to sustainability transitions will be presented below.

2.7 Power and Politics in transitions

Both power and politics are viewed here as vital conditions in alleviating and constraining sustainability transitions. According to Lasswell (1936) (in Köhler et al., 2019, p. 6), understanding the politics of transition implies attention to "who gets what, when, and how. Politics is further inextricably linked with the notion of power (Ibid., p. 7). In this piece, these particularities are used to illuminate the importance of actor's capabilities in sustainability transitions, what resources they mobilise, and which they refrain from mobilising due to existing barriers or shortcomings in the existing technological solutions.

Existing conceptualisation of power are rich. From a philosophical point of view, it is possible to follow Luhmann's (1984) interpretation of power as a social medium (Avelino & Rotmans, 2009, p. 549). This interpretation dictates that the medium of power is always available in society. It does not say how power is exercised, nor by whom. Power here, is understood as an inherent part of society.

But for our purposes, emphasis on identifying how power is exercised and by whom, resembles to a greater extent with the interest of this contribution. Politics for instance, are an inherent part of the activities associated with governance, be it at the regional, state or supranational level. Avelino and Rotmans (2009, p. 550) conceptualize power in line with its etymological roots '*to be able*', which refers to an ability, capacity or dispositional property.

Hence, an actor's ability to mobilize resources or affect a set of outcomes reflects a degree of power exercise. As such, power may therefore be explicitly be understood as the ability to act and control. For example, if any given actor decides to mobilize resources for a particular reason, the actor is believed to possess some form of control over the mobilized resource(s) in order to be able to act.

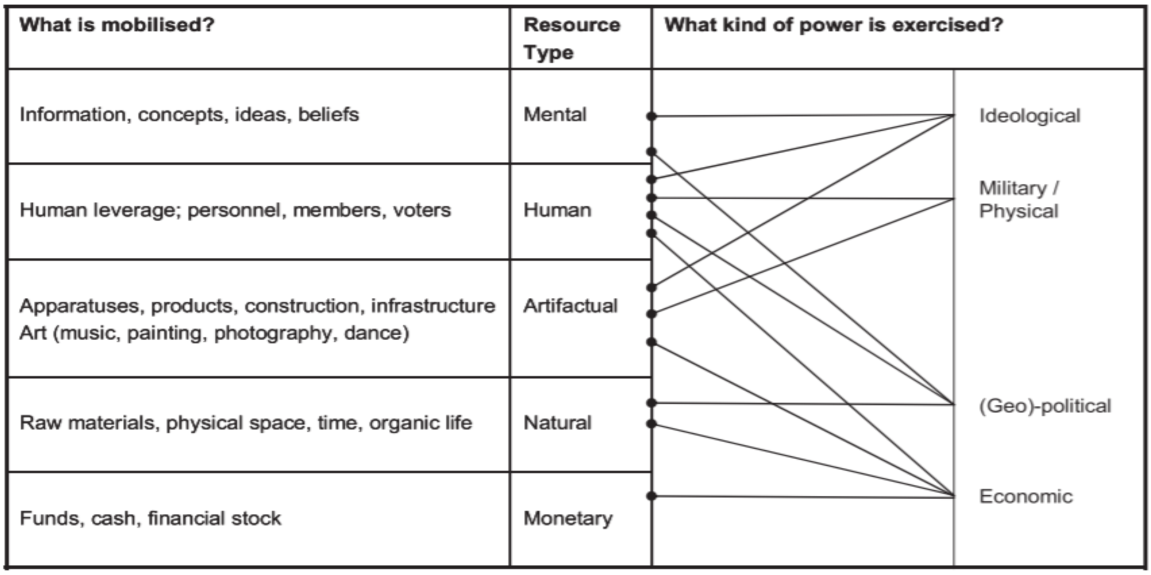
In the real world, resources may take many shapes and forms. According to Avelino and Rotmans (2009), the diversity of resources may be differentiated in the following typology: human resources (e.g. personnel, members, voters, clients, fans etc.), Mental resources (e.g. information, concepts, ideas and beliefs), monetary resources (e.g. funds, cash and financial stock), artefactual resources (e.g. products, technology, constructions or infrastructure) and natural resources (raw materials, physical space, land and organic life) (Avelino & Rotmans, 2009, p. 551). Common for the mentioned resources is that they can be owned. Institutional phenomena on the other hand, though maintained through the exercise of power, they cannot be owned.

Table 1.0: A Typology of Resources[3]

Human Resources - Personnel, members, voters, clients, fans	Mental Resources - Information, concepts, Ideas and Beliefs	Artefactual Resources - Products, technology, constructions, infrastructure
Monetary Resources - Funds, cash, financial stock	Natural Resources - Raw materials, physical space, land and organic life	

What is more, resources are interrelated to one another. Meaning that in order to mobilize one type of resource, additional types may be required (Avelino & Rotmans, 2009, p. 551). For instance, actors that mobilizes resources with the intent of supporting a green transition, require resources from each type in order to meet their goal. On the other side, policymakers and incumbents may resist pressures from the niche, for example by forming alliances at the regime level with the intent of maintain status quo (Geels, 2014, p. 26). Each of these strategies can be classified as different types of power exercise. In her more recent contributions, Avelino provides a depiction over the different forms of power that are being exercised, see table 2.0.

Table 2.0: Types of resource mobilisation and power exercise



What is mobilised?	Resource Type	What kind of power is exercised?
Information, concepts, ideas, beliefs	Mental	Ideological
Human leverage; personnel, members, voters	Human	Military / Physical
Apparatuses, products, construction, infrastructure Art (music, painting, photography, dance)	Artifactual	
Raw materials, physical space, time, organic life	Natural	(Geo)-political
Funds, cash, financial stock	Monetary	Economic

[3] The positioning of the different resource in the figure above does not imply any greater hierarchical status compared to the next, as each type may find itself as the object of power.

Source: (Avelino, 2017)

Sustainability transitions involves various actors, in which they perform heterogenous roles, as opponents, proponents or a mix of the two. How actors' rationales are operationalized depends on the respective actor's current and projected interest in relation to the emerging system (Bakker, 2014, p. 61). As such, we may further delineate how different types of power is exercised in relation to stability and change.

In (Geels, 2014), a typology between various ways regime actors use power to resist fundamental system changes, in which instrumental, discursive and structuralist forms of power are alleviated. Avelino (2017, p. 510) proposes a different way to understand power in relation to transitions. First, rather than viewing power as something an actor may choose to use or not, it is argued that power is always exercised rather than possessed. Within a paradigm where power is viewed as an ability to change or to create something new on the one hand, and an ability to reproduce the existing, three distinct ways of power may be distinguished: Reinforcive, innovative and transformative power (Ibid.).

2.6.1 Reinforcive Power

Reinforcive power refers to actors capacity to reinforce and reproduce existing structures and institutions (Avelino, 2017, p. 508). In previous publications by (Avelino & Rotmans, 2009), this type of power was referred to constitutive power[4]. This phrasing of reinforcive power is meant to distance itself from terms such as institutional or structural, in order to emphasise that power is ultimately exercised by actor, rather than by institutions or structures (Avelino, 2017, p. 508).

2.6.2 Innovative Power

Innovative power refers to the capacity of actors to create new resources (Avelino, 2017, p. 509). To gain a sense of what this type of power implicates, I propose to view it in relation to Schumpeter's essential fact about capitalism: the gale of creative destruction[5]. The act of creating a new resource can be regarded as an act of power, in which the introduction of new resources mitigates the dependency on older resources. For example, innovations in hydrogen

[4] This form of power exercise refers to the ability to constitute a distribution of resources. Where to constitute means to establish, institute or enact it (Avelino & Rotmans, 2009, p. 552). Within this type, institutions and structures represent the means through which resources are distributed, and as a result, enabling a social order (Ibid.)

[5] According to Schumpeter, creative destruction describes the "process of industrial mutation that incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one" (Tülüce & Yurtkur, 2015, p. 721)

technology, such as fuel cells or electrolysis technology may be regarded as novel resources with a qualitative capacity to reconfigure actor's dependency on existing resources, such as access to or supply of fossil natural resources. In other words, innovative power reflects a twofold type of power, by actor's inception of the new resource as the first, and second, the resource acting by itself. However, the potency of these type of power rests upon conditionalities such level of visibility and plurality (Arendt, 1958, p. 200, in Avelino, 2017). Hence, as novel innovations occur at the niche level, its architects would be wise mobilise its aggregate of resources in possession in order display the benefits of the new resources to other actors, the market and prospective users.

2.6.3 Transformative Power

The last distinction of power to be unzipped is that of transformative power. Actors who obtain a capacity to develop new structures and institutions and acts upon it wields what Avelino (2017, p. 509) calls transformative power. Structures and institutions may take various forms, be it legal structures, physical infrastructures or economic paradigms (Ibid.). As of what is meant by new, is further explicitly defined as 'reconfigured' and 'renewed', rather than something entirely novel. The basic idea is that actors who possess transformative power and acts upon it may alter or replace the existing structures and institutions by recombining, transposing and reinventing specific elements (Haxeltine *et al*., 2016, in Avelino, 2017. p, 509). In Avelino and Rotmans (2009, p. 559) it is suggested that incumbents usually possess more power relative to actors at the niche level, in the sense that they mobilise more resources compared to niches.

Incumbent actors at the regime may resist transformative power in various ways. Geels (2014) for example, builds and argument with insights from Hajer, (1995) and Lindblom (2001), that policymakers and incumbents' firms are particularly powerful in respect of shaping public discourse, by virtue of their position and access to media.

For example, the Norwegian multinational energy company Equinor (former Statoil) has in recent years launched a massive advertising campaign in Norwegian media outlets (Øvrebekk, 2020), evidencing its capacity to communicate and shape public discourse through its access to media. As regime actors seek to resist transformative changes that may threaten their vested interests according to MLP, transformative power may not 'enough' to transform these reconfigurations for good. For that purpose, actor's need to complement its transformative capacities with reinforcive power in order to reinforce the renewed and reconfigured structures and institutions (Avelino, 2017, p. 509).

What is key here, is that even though niches are able to wield less power relative to the regime, the latter does not necessarily exercise power over the niches. This is because niches can exercise different types of power, such as innovative power, which in the words of Köhler et al. (2019, p. 7), provides them with a certain level of independence from regimes.

3.0 Method

The arts of social science dispose its fellowship of researchers with a wide range of tools for data generation. This chapter delimit those deemed appropriate for this inquiry, and how they were applied for the purpose of data generation and analysis. As highlighted in the review of literature, a specific phenomenon, or case, was required to enrich the understanding of power and politics in sustainability transition. In common parlance, a case study documents a particular situation or event in detail in a specific socio-political context (Simons, 2014, p. 455). Though the bounded context of this piece is partially fluid, given globalisation and climate change neglect of territorial boundaries, Norway represents the main spatial context in which examination of the phenomenon, hydrogen, is applied in. To satisfy the purpose of this thesis, making use of the right tools is crucial. In the words of Moses and Knutsen (2012), when inappropriate tools are employed, a worker can inflict great damage (p. 3). The same logic equally applies for researchers of social sciences.

Hence, in order to infer understanding to the ‘how’ and ‘what’ of this in-depth examination of hydrogen, a two-fold research approach is operationalised in this qualitative analysis. Interviews status as the primary tool for data collection, complemented by findings from existing state-of-the-art publications on hydrogen and sustainability transition, and relevant government documents and newspaper articles.

The subsequent segments of this chapter provide additional clarifications and justification to the methods employed in this research, as well as the trustworthiness of this thesis’ findings, and its limitations.

3.1 Empirical Methodology

This thesis applies a qualitative research approach. Corbin and Strauss (2015) broadly defines qualitative research as a category of research approaches that produce findings without reliance in quantitative measurement or statistical analysis (In, Hamilton & Finley, 2020, p. 1). At the most basic level, qualitative research methods provide a systematic way to collect, analyse, and present nonnumeric data about a particular subject (Frattaroli, 2012, p. 222). Interviews are one the most frequently used method to generate data (King & Horrocks, 2010, p. 6). Data may also be collected through method observation, diaries or from other forms of text, such as reports, communications, and scientific publications. However, the choice of methods should be justified in relation to the purpose of the research in question (Ibid.).

Given that the objective of this thesis aims to explore how power and politics enable and constrain the diffusion of hydrogen in Norway, its compatibility with a qualitative research approach is fitting, as these methods have record of explaining how things are (Hamilton & Finley, 2020, p. 1). Though quantitative approaches are useful for the purpose of measuring aspects of the social world, with great precision and accuracy, the rational of qualitative approaches put greater emphasis on the aspect of interpretation (King & Horrocks, 2010, pp. 7, 11). Hence, the this thesis pay loyalty to a qualitative research approach, as it provides a facilitating framework for the understanding of phenomena, such as power and politics, in a context-specific setting, such as the development of hydrogen in Norway viewed in a multi-level paradigm.

3.2 Data Collection

Given limitation of the author's pre-existing knowledge on hydrogen, an initial deep dive in existing literature was required to rectify the instruments of scrutiny. Thus, before the interview processes and analysis of relevant documents could be initiated, the onset of this project was characterised by a systematic review of existing publications, as unpacked in chapter 1.3. Relevant publications were mainly extracted from peer-reviewed scientific journals, such as Environmental Innovation and Societal Transition; Renewable and Sustainable Energy Reviews; Research Policy; European Journal of Social Theory; Technology Analysis & Strategic Management. Relevant publications were throughout the review plotted into an excel spreadsheet, where their info was systematised according to the publications' author(s), year of publication, journal, key words, and abstract. The spreadsheet also came to include relevant book chapters, dissertations, historical narratives, and newspaper articles.

As a result, the subsequent process of data generation were backed up by a navigable data base of existing publications, which insights were paramount in the construction of the interview guide, and in guiding were to place the lens of investigation in the analysis of documents. Of special notice, the media, played an invaluable role to this thesis, both at the onset this research, but also throughout the entire span of the project. As the development of hydrogen is not exclusive to Norway, vital intelligence may be extracted from far-away developments around the world. Through the exploration of newspaper sources over the internet, this project was able to gain nearness on a wide array of occurrences in the hydrogen world, without having to spend time and money on distant travelling.

As the acquisition of knowledge of hydrogen and sustainability transition reached a sufficient threshold, the primary bulk of data collection were initiated, through the employment of qualitative interviews. This method was deemed beneficial due the need of acquiring context specific insights regarding the developments of hydrogen in Norway. As noted by Bernard 2006; Patton 2002; Richards and Morse 2007, (in, Frattaroli, 2012, p. 224) qualitative interviews are often used to collect data from an authoritative source on the subject of interest.

Correspondingly, this project strategized to schedule interviews with leading experts and actors in the Norwegian hydrogen world. In total, 5 interviews were carried out, where one of them included two informants, bringing the final number of interviewees up to 6. The interviews were conducted during the months of March and April. Whereas the first round of data collection focused on obtaining a broad overview of the literature, the interviews were conducted on the basis of seeking to understand how the informants perceived the barriers and opportunities of hydrogen in the context of Norway's sustainability transition, and how the aspects of power and politics explicitly or implicitly related to their answers.

3.3 Semi-structured Interviews

Interviews may be performed in various ways. One may for example deem group interviews as preferable to individual ones or find greater comfort in conducting the interview face-to-face rather than over technological medium, such as a video meeting. The very length and rigidity of the interviews is also important to reflect upon prior to the purposive conversation. For this paper, decisions were based on situational conditions to which I was both enjoying and constrained by. Indeed, the spread of Covid-19, and the Government's decision to put Norway under lock-down effectively placed a straight-jacket to how the interviews could be carried out. As a result, the option of face-to-face interviews was accordingly ruled out.

With the advance and disposition of technology, opting for virtual interviews emerged as the obvious choice. Remote interviews further involve some advantages relative to face-to-face interviews. First, the barrier of physical distances is essentially eliminated, saving both the need to undertake expensive and time-consuming travels (King & Horrocks, 2010, p. 80). Another positive trait associated with remote interviews, is that they are argued to give participants a greater sense of anonymity as the interview is not conducted face to face (Joinson, 2001; Opdenakker, 2006, in Ibid.).

In terms of rigidity, a semi-structured interview approach was favoured. In contrast to an unstructured interview, this approach provides put the researcher in greater control over the topics in question, while simultaneously stimulating responses that are reflective, rather than fixed, which is more the case with structured interviews (Given, 2012). Posited in the middle of this continuum, semi-structured interviews, encourage a degree of deviation while maintaining control of the process. Due to the complexity of the topic of investigation, the interview guide sought to capture a wide array of themes in order to capture the whole picture. Questions of an open-ended nature was formed, as it was assumed that multiple perceptions, or understanding of reality exists out there. Though this paper is written in English, the questions in the interview guide were asked in Norwegian, because this project was carried out in Norway with Norwegian speaking informants. This choice was further legitimised by knowing that it may have been harder to recruit willing participants if the interview were to be carried out in a foreign language. In the Appendix of this thesis, a translated version of interview guide is located.

3.4 Choice of Informants

A general rule of thumb to keep in mind during the task of recruiting informants is to choose informants who are able to express themselves in a reflective manner in light of the topic of investigation (Tjora, 2013, p. 145) As noted, qualitative interviews are often used to collect data from an authoritative source. With a scholarly background where the arts of social science dominate, such as theories on development and international relations, explicit insight in technological niches, such as of hydrogen, has been limited. Therefore, recruitment of informants rested on the basis of acquiring resource persons with a close relationship to hydrogen, such as employees in hydrogen businesses and clusters, NGOs concerned with sustainability, and researchers on hydrogen.

In other words, a strategic sampling procedure was employed, which contrast to that of quantitative surveys in that the informants are not approached based on representing the overall populace (Ibid). Accordingly, the sampling criteria was simple. If a prospective informant displayed some form of expertise of authority on the matter of hydrogen, he/she was deemed a valuable asset. Initially, relevant informants were identified by looking through the members of Norway Hydrogen Forum’s websites, see (Norsk Hydrogenforum, 2020c). The method of sampling here bear similarities to the ‘snowball method’, where the size, and the potential size of informants expanded as the interviews were carried out. This method is widely utilized in studies where it may be difficult to gain access to relevant informants (Tjora, 2013, p. 151) As such, each mail and interview included a question in the end, asking if they could recommend additional resource persons to the study.

Potential interviewees were contacted via email, where the general purpose of the envisioned project was accounted for, as well as the duration of the projected interview, my role in the project, and what was implied by participating in the project. The email further included an uploaded document from the Norwegian Centre for Research Data (NSD), which delineated the more formal aspects attached to the project, such as institutional belonging, rights of the participants, and ethical consideration. While sampling criteria predominantly aimed to gather informants with expertise on hydrogen, the final sample displayed variation in terms of age and gender. The level of education was on the other hand very high, though different academic backgrounds were displayed.

3.5 The Interviewing Process

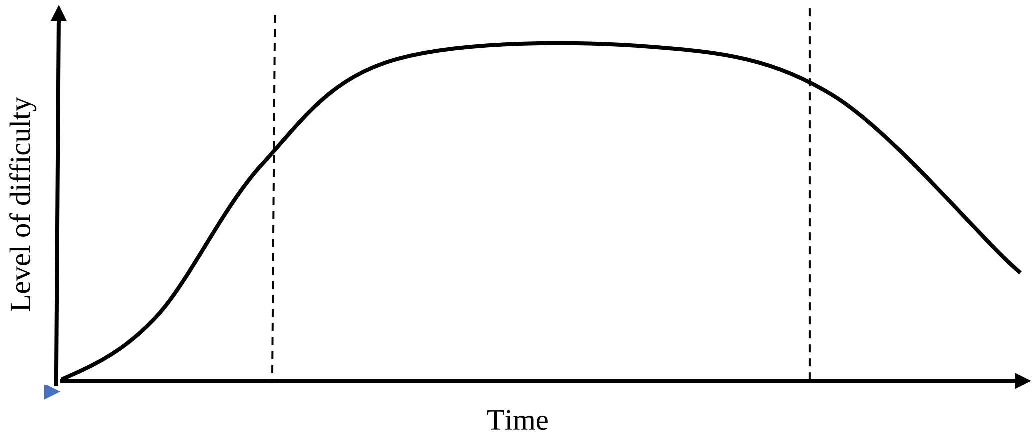
The interviews followed the guidance of a preformulated questions, structured into 7 different themes. Prior to each interview, the informants were asked which medium they personally preferred to conduct the interview over. Microsoft Teams constituted the main platform, over which 5 of the interviews were conducted. One interview was also conducted over the phone.

Before the themes were engaged upon, the informants received a brief presentation about the author of the project, the topic of investigation, and a reasoning to why this case requires enrichment. Again, the rights of the interviews were repeated. This was done to make the participants feel confident that their rights were maintained and to demonstrate a sense of professionalism. Even though the matter of recording was accounted for in the email correspondence, it was once again asked whether they felt confident in being recorded. Assessment of the ethical considerations of recording is dealt with in more detail in section 3.8.

When the formal underpinnings had been accounted for, the interviewees were asked some introductory questions to ease the transition to the main questions. When sufficiently warmed up, the conversation elegantly transcended onto the main questions of scrutiny. Figure 3.0 below depicts the overall interviewing process, in which the y-axis represents the questions' level of difficulty, while the x-axis represents the time span of the interviews. The most difficult questions were posed in the middle of the interview, whereas the first and latter part were more introductory and finalising in nature.

The dotted lines indicate where in the interviews the main questions of interest were posed. Though, it should be emphasised that each interview did not mirror the others. As some informants devoted extra time to certain themes. Therefore, having time to ask every question were sometimes not possible. In addition, the interview guide in the appendix is only that, a guide. Sticking to closely to it, would erode the purpose of semi-structured interviews, and it would also be highly interruptive to constantly stop the informants as they expressed their view.

Figure 3.0 Illustration of the Interview Process



3.6 Qualitative Data Analysis

By the time of completion, the next task at hand was that of transcribing the conversation. As each interview lasted for at least 45 minutes or more, this process manifested a time-consuming endeavour. With the help of a recording device, complemented by notes taken during the interviews, the transcripts were able to mirror the utterances of the conversation in the form of raw data.

Though qualitative data analysis software exists, and available for download for student of NTNU, such as Nvivo are highly convenient, inability to make this program function properly forced the analysis to be carried out more traditionally. Hence, the data analysis was carried out on Microsoft Word. Indeed, employing a sophisticated data analysis package would have been helpful, ruling it out did not cause issues of significance, since the final sample of informants were no larger than six.

When carried out, the subsequent focus was redirected towards generating interpretations from the raw data located in the transcriptions. For this purpose, it was necessary to cancel out the non-relevant noise in the data set. In conformity with the research question of this thesis, relevant utterances were categorised under specific labels, such as “barriers”, “opportunities”, “safety concerns” “power’ and “politics”. As time passed by and more interviews were conducted, a general pattern gradually emerged, adding support to the validity of the findings. Aspects concerned with the trustworthiness of this paper is assessed in section 3.8.

In addition to the analysis of the interview data, this thesis' findings are further reflected by analysis of complementary sources, such as government documents, existing literature, newspaper articles and historical antecedents. To understand the policy context of the case(s) of investigation, existing documents are invaluable (Simons, 2014). Utilising existing data, both in the form of primary and secondary data, is one of the hallmarks of case study research, which additionally enhances the credibility of the data (Patton, 1990; Yin, 2003, (in, Baxter & Jack, 2010, p. 554). Hence, patterns of Norwegian hydrogen diffusion are further viewed in relation to additional internal and external developments. Indeed, it would have been challenging to infer credibility to this project finding without public documents at its disposition. Similar conclusions made be drawn from the external context, in which access to insights on development occurring beyond the territorial borders of Norway were crucial when aligning this project findings within in a multi-level paradigm that includes an external landscape within its scope of analysis.

3.7 Evaluation of Validity and Reliability

Patton (2001) states that validity and reliability are two factors which any qualitative researcher should be concerned about while designing a study analysing results and judging the quality of the study (in, Golafshani, 2003, p. 601). According to Lincoln & Guba (1985), terms such as "credibility, "neutrality, "dependability" and "applicability" or "transferability" are believed to be essential when considering the quality of the research (In, Koistinen, 2019, p. 70). Validity may be understood based on whether the means of measurement are accurate and whether they are actually measuring what they are intended to measure (Golafshani, 2003, p. 599). Next, reliability is understood in terms of whether the results are replicable (Ibid.).

A common strategy for testing validity, is through means of triangulation (Ibid., p. 603). The data occurring in this project stems from a variety of sources, interviews, peer-reviewed articles, government reports, communications and newspapers. Indeed, this thesis' findings echoes data generated from interviews. As noted, the informants were recruited based on their qualifications. Some informants were also recruited with the help of 'insider' assistance since the snowball method was employed. King and Horrocks (2010, p. 32) notes that there is some risk associated with this method, as it may cause the final sample to be overtly biased.

It is acknowledged here that certain informants do work with active promotion of hydrogen. Therefore, it may the case that some aspects that would speak against hydrogen diffusion were not alleviated. To address this concern, the sample of informants were balanced with researchers of high competence. Moreover, to ensure the accuracy, control bias and the credibility gathered data, the claims of the informants were cross-checked with additional secondary sources. Indeed, the use of newspaper articles further involves the possibility of bias. For this reason, the primary news brand utilised for data generation was Reuters, who ranks as the second most trustworthy news brand in the world according to GlobalWebIndex report in 2019 (Reuters, 2019). But for more local occurrences, employing data from Norwegian newspapers was further deemed necessary. Though their overall ranking may not necessarily match that of Reuters', careful treatment of newspaper articles, including Reuters, sought to overcome possible bias.

To further ensure that this thesis in fact answer what it intends to investigate, the questions in the interview guide aimed to adhere to theoretical insights employed in this thesis, as well as important co-existing factors that influence diffusion of hydrogen. Instead of only asking what various actors are doing to push hydrogen, the question also aimed to see how the geographical context influences Norway's proclaimed transition to sustainability, and what explicit resources have been, and are, initiated to this end.

Moreover, as the interviews were conducted in Norwegian, rather than English, it is important to acknowledge that some statements may have been misinterpreted as they were translated into English. To avoid this error, the informants were presented with the translated interpretation of their statements over email, in order to make sure that they were understood correctly.

The replicability of this research, therefore, depends to a certain extent on what choices future inquires make, such as choice of theory. As Tjora claims, a high degree of reliability is not necessarily contingent on the ability of future researchers to come to the exact same findings (2013, p. 206). What is of importance, is rather the ability to point to the different factors that led this research to its alleviated conclusions, for instance the author's pre-understanding or the sample of informants (Ibid.).

Overall, the trustworthiness of this research is believed to be of high standards because of the variety and quality of sources employed. Neither the findings nor conclusion of this thesis diverge from the nature of the data accumulated by the interviews, which after all, represent a reliable form to gather solid facts and infer general patterns (Moses & Knutsen, 2012, p. 131).

3.8 Ethical Consideration

Given that each interview was conducted either online or over the phone, there are some ethical consideration to bear in mind. Though, as King and Horrocks (2010, p. 97) argues, the ethical principles of interviews do not change in an online environment. However, in the absence of visual contact, which was the case with the phone interview, it is important to establish the identity of the participant (Ibid., p. 86). Being aware of this issue, this concern was overcome by cross-checking their backgrounds, as found online, with their presentation of themselves. Correspondence over mail prior to the interview furthered added confidence to the nature of their identity. Arranging the interview at a specific time also reduces the risk that some impersonator might pick of the telephone and attempt to pass themselves off as the participant of interest (Ibid.).

However, the main ethical considerations to consider, is that of which relates to confidentiality and consent. Due to nature of the internet, one can never promise absolute confidentiality and anonymity to the participants (King & Horrocks, 2010, p. 100). But, to reassure this project's informants on this matter after the best ability, several measures were undertaken to minimise this risk. First, each participant received an information form in the first email. The form, approved by NSD, presented what topics would be touched upon, how their personal information would be treated, how the data will be used, how it will be recorded and the duration of the project. It was emphasised in the first email, as well as at the onset of the interview that their choice to participated is voluntarily. Furthermore, it was asked again whether it was okay that the interview got recorded, and that they could take back the consent at any time. In the event of being cited, the participants were informed that they would be sent their citations in advance of the submission date. Secondly, this inquiry did not involve asking question on sensitive topics, such as age, gender, race, income, extremism, or even terrorism. Nevertheless, to ensure confidentiality, each transcription was saved in a safe drive, agreed upon by the NSD. In addition, each of their names in the transcription was changed into pseudonyms, which only I could recognize. In the unlikely event of which the storage driver is compromised, their names will not suffer the same fate.

3.9 Limitation(s)

A key aim throughout this study, has been rooted in the rational of being able to understand what inhibits or enable sustainability transition to unfold. Both power and politics have been assumed to play key roles. But as limitation goes, initial attention should be allocated to the position of the author of this project. Sustainability transition has grown to become a grand field of literature, often from highly experienced authors. This work on the other hand, reflects a relatively short acquisition of experience in a highly complex field of study in the arts of social science. As such, some of the key findings from the analysis may not necessarily be revolutionary in nature. Meaning that the level of ambition in this project had to be aligned with the formal requirement of this master thesis, especially regarding that of time and length. This is viewed as a limitation.

It was further envisioned that this thesis would to a greater extent incorporate insight from alternative niche technologies, such biofuels or wind power. However, constrained by both time and length, lessons from other sectors, regions and technologies turned out to be limited in this piece.

Additionally, because of the ongoing pandemic, caused by Covid-19, which prompted the government to put Norway under an effective lock-down, acquisition of relevant informants proved highly difficult. Prior to the lock-down, this project envisioned a sample of at least 10-15 informants to extract data from. However, the sampling processes was diseased by lack of responses to participation requests. Consequently, only 6 participants manage to find time and express willingness to collaborate. Though these insights were highly valuable, the amount of data generated came to be significantly lower than it would have been in a more normalized situation. Therefore, the findings of this thesis may reflect a somewhat limited degree of insight into the hydrogen world. To rectify this important limitation, insights from secondary literature and newspaper articles sought to bridge this gap.

With this project's limitations accounted for, the overall tools employed in this thesis has been accounted for. In the next chapter the reader will be presented with how these methods and theories are operationalised in the form of empirical data and analysis.

4.0 Empirical Findings and Analysis

The upcoming chapter presents this thesis' relevant empirical data, both from the interviews and additional sources. The first part of the analysis is structured in accordance with the three levels of the MLP by starting off at the overall surrounding atmosphere that nation states find themselves in. Here the readers will become familiarised with one of the buzzwords of the twentieth century, namely globalisation. Additionally, this chapter aims to give life the exogenous landscape level in the MLP by letting it breath alongside the concept of globalisation. Room is further given to actualise the non-sustainable trajectories akin to the global energy and transport regimes due to their close attachment to fossil fuel. When all of these points have been accounted for, this chapter will posit the contextual situation of Norway, before moving more explicitly into the domain of hydrogen. The latter part of the analysis treats aspects such as power and politics more in detail in light of the findings accentuated in the earlier segments of this chapter.

Finally, insights from this project's informants are brought forth in this chapter. In the text, they are given different codes to distinguish them from one another. These codes are labelled with 'I', for informant, suffixed by a number, hence I1, I2, I3, I4, I5 and I6.

4.1 Globalisation, Global Energy Regime and The Landscape

Although globalisation as a term has been subject to increasing popular usage over the past four decades, there appear to exist considerable confusion about what it really means (Dicken, 2015, p. 4). First of all, globalisation is not a term, but a concept. In academia, it is commonly used as concept that explains how the human world has been woven more tightly together. McGrew (2017, p. 16), defines globalisation as the widening, deepening, and increasing velocity of worldwide interconnectedness. Gilpin on the other hand, defines globalisation as the integration of the world-economy (2001, p. 364), whereas Giddens explain globalisation as the intensification of worldwide social relation which link distant localities in such way that local happenings are shaped by events occurring many miles away and vice versa (1990, p. 21, in McGrew, 2017).

While the world has undoubtedly steered towards a direction of deep integration, evidenced by the global reach of trade, finance and production networks (Dicken, 2015, p. 6; McGrew, 2017, p. 21), patterns of contemporary globalisation are criticized for being at odds with the earth's carrying capacity (Bhatasara, 2011). As opposed to older dangers, the risks of the present, caused by modernisation and global industrialisation, are global in reach, endangering all life on the planet (Beck, 1992).

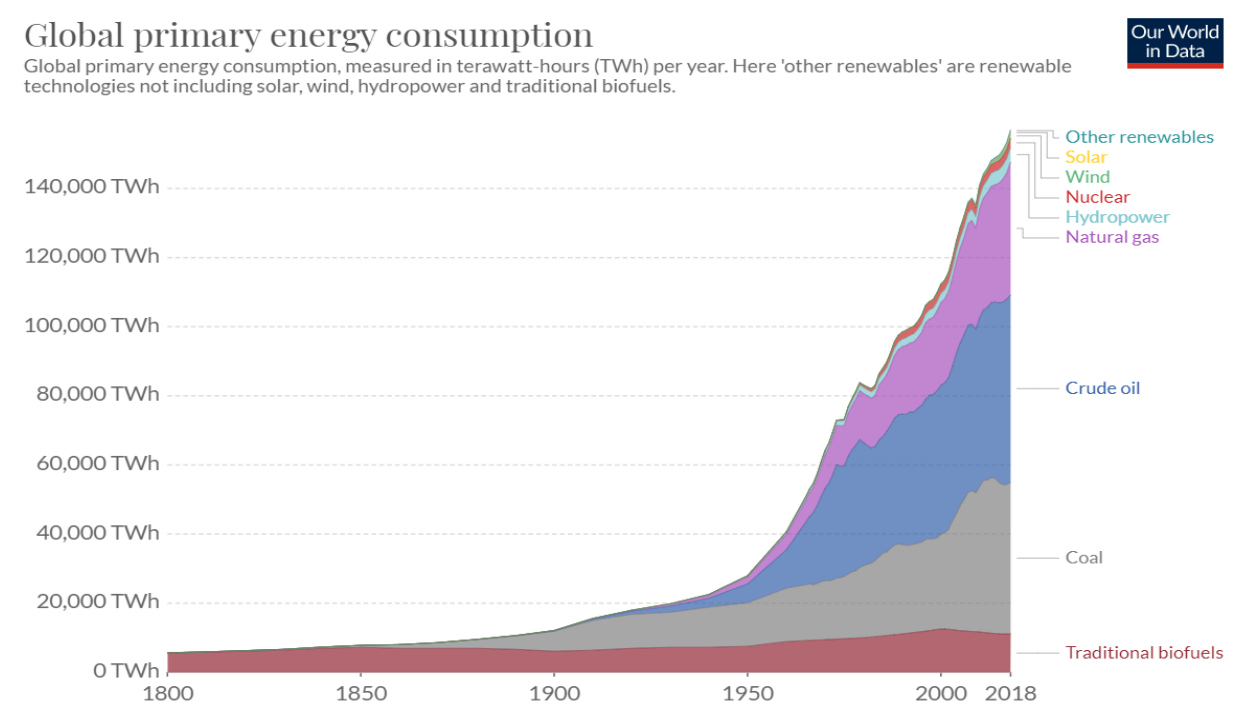
However, we should be careful in claiming that the grand challenge of global warming or climate change are directly caused by globalisation, even though it is argued to have helped stimulate the present predicament (Vogler, 2017, p. 386) . For deeper understanding, it is proposed to look closer into some of the key drivers of globalisation. Findlay and O'Rourke (2007), evidence globalisation by assessing the historical trends of trade, investment, technology and movements of people.

Today, fossil fuels, such as oil and natural gas, serves a vital position on the global energy market. Oil, the wheels of trade, together with natural gas, provides the world with 58 per cent of the global demand for energy (Norsk Petroleum, 2020). More than half of the oil produced, serves to fuel the sector of transport, including on-road, maritime and aviation (Ibid.). Oil, manifest a commodity in which have played an important part in shrinking both time and space, subsequently connecting far away civilizations to one another.

Globalisation is a concept that may be operationalized for the purpose of understanding and explaining the world (Osterhammel & Petersson, 2003). But to understand the world, especially from a sustainability perspective, it is of crucial importance to give room to role of commodities such as oil. This is because the role of oil in current socio-technical regimes represent a significant engine to globalisation, that cannot be neglected discussing energy regimes and sustainability transitions, as it by no doubt belongs to their deep grammar (i.e. established rules and practices).

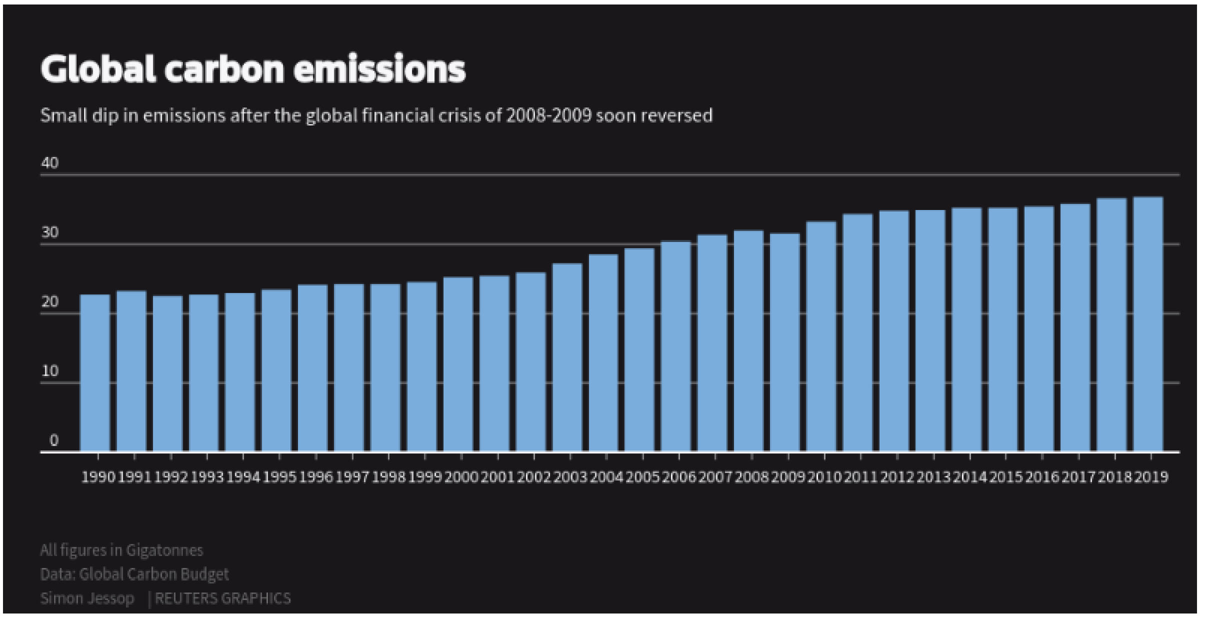
Though the sales of electric vehicles have set new records, production and demand for oil are assumed to continue in IEA’s future energy scenarios (IEA, 2020). In terms of natural gas, the IEA assumes the volume of production and demand will continue to surge within the next decades. As this section aim to highlight, the worlds’ dependency on fossil energy, including oil, natural gas and coal, elucidate key challenges to the sustainable transition of human societies. The regime is viewed in respect to the established rules and practices. For illustrative purposes, graphs and statistical figures are valuable as they present the viewer with quick glance of the current rules and practices, see figure 2.0 and 3.0 displaying the rising demand for fossil-based energy and rising rates of GHG emissions.

Figure 4.0 Global Primary Energy Consumption



Source: (Ritchie & Roser, 2018)

Figure 5.0 Global Carbon Emissions



Source: (Kerber, Green, & Jessop, 2020)

Key to the debate on sustainability, is the importance and challenge of mitigating greenhouse gas emission to a minimum. As such, the world has to undergo transition from an energy system dominated by fossil-fuels to a low-carbon one (Ritchie & Roser, 2018), which manifest a fundamentally political process (Burke & Stephens, 2018). As knowledge regarding human-infused environmental damage have become more widespread and accepted, states have shown an increasing willingness to address the concern of climate change, evidenced by the increasing convergence of international climate summits (Vogler, 2017, p. 388). Owing to the growing consensus among nation states and its inhabitants regarding climate are key scientific bodies, such as the Intergovernmental Panel on Climate Change (IPCC), providing policymakers with the most recent scientific findings, projections and policy advise, see (IPCC, 2020).

Policymakers may further rely on additional bodies concerned with climate-related research, as well as technology- and innovation research, such as from governments own Research and Development (R&D) organs or think tanks and industrial clusters, both nationally and internationally. Advances in science and technology has never before been as accessible as in present era of globalisation, where digitalisation have enhanced the velocity of networking and knowledge sharing (Dicken, 2015). Simply consider the increasing attention on sustainability transitions in the last few decades, reaching an output up to 500 articles alone in 2018 (Köhler et al., 2019, p. 2) compared to around 60 peer-reviewed contributions in 2012 (Markard et al., 2012, p. 955). Also, Technology roadmaps, such as the European hydrogen Roadmap, are increasingly used by governments to inform and promote technological transitions (McDowall, 2012, p. 532).

Therefore, one might argue that governments have all the necessary data needed – and have had for quite some time now- in order to initiate action towards a rational corrective policy in the face of climate change, for example by eliminating pervasive subsidies favourable to non-sustainable modes of production and consumption. Yet, subsidies continue to co-exist with fossil fuel-based industries. Unruh (2000) coined this phenomenon, where industrial economies have become locked into fossil-fuel based technological systems, as carbon lock-in, explaining government's inability to undergo pre-cautionary action that would relinquish existing systems on sustainable trajectories.

4.2 The Exogenous Landscape

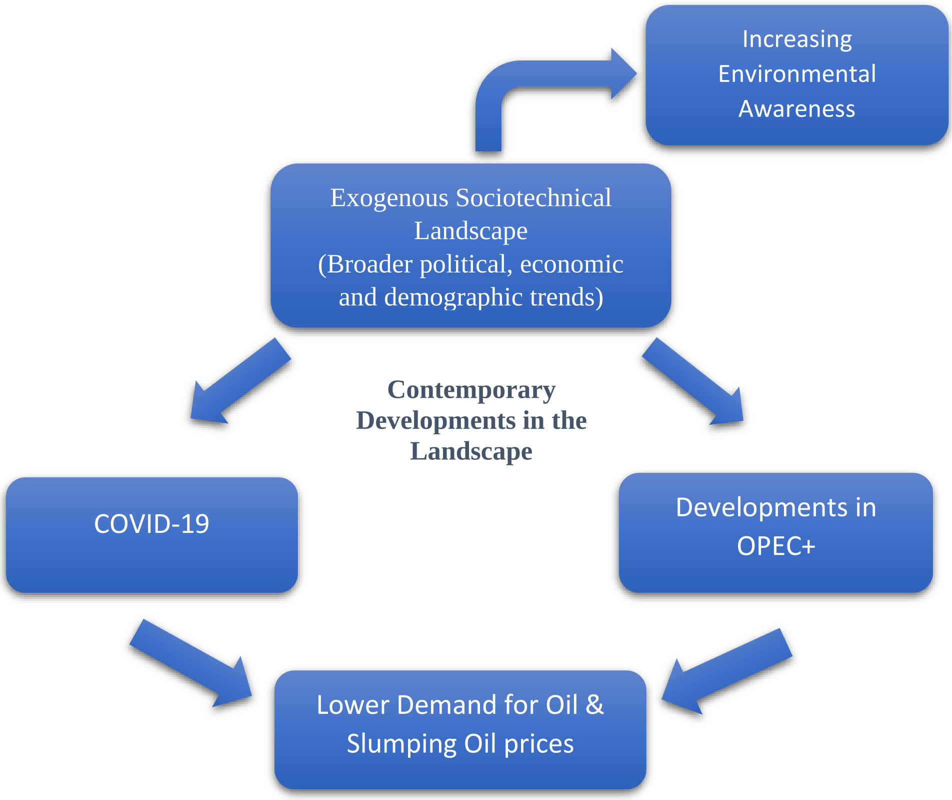
Under the right conditions however, the sturdiness of socio-technical regimes is not irrevocable. Although commodities such as oil, gas and coal have been key contributor in binding the world of nations closer together, it may also be viewed as its weakness. In the event of unforeseen developments in the landscape, such as slow-changing trends (e.g., demographics and ideologies) or shocks (e.g., elections, economic shocks and plagues), the soil in which the regime's foundation rests upon may crumble, catalysing a room of instability in which niche innovations may take advantage of (Geels et al., 2017, p. 1242).

Owing to the increasing worldwide interconnectedness, the potency of developments and shocks in the landscape should not be neglected. The structures that actors operate within reflects some of the key challenges that constrain sustainability transitions to successfully occur. On the other hand, instability, developments, and flows that occurs in the exogenous landscape also presents opportunities to change (Köhler et al., 2019, p. 4), such as the flow of information and sharing of skills and competencies.

To exemplify, over the past decades there has been an increasing acceptance anthropogenic strain on the environment. As a result, the landscape has experienced slow-changing trends of increasing climate awareness. A recent study for instance, conducted by international climate change biologists, found that there has been a significant increase in people's interest in climate change, based on internet key words searches, such as 'climate action' and 'climate emergency (Williams, 2020).

Similarly, a word-count analysis of British newspapers, found that public attention to climate change increased from 2004 to 2009, fuelled by events such as Hurricane Katrina in 2005; Al Gore's movie *an inconvenient Truth* 2006; the *Stern Review* in 2006; and the *Fourth Assessment Report* from IPCC in 2007 (Geels, 2014, p. 33). In 2019, the world witnessed a massive coordinate convergence of young environmental activist taking to the streets, spearheaded by Greta Thunberg, denouncing government's effort to tackle the climate change (Gjerstad, 2019; Goering, 2019; Taylor, 2019). According to Avelino and Rotmans (2009), landscape developments of this kind may be understood in relation to niches challenging the regime, causing a 'bottom-up' power vacuum may occur and weakening the regime (p. 561). The illustration below, aims to provide a depiction of relevant development occurring in the landscape in accordance with the MLP.

Figure 6.0 Contemporary Developments in the Landscape



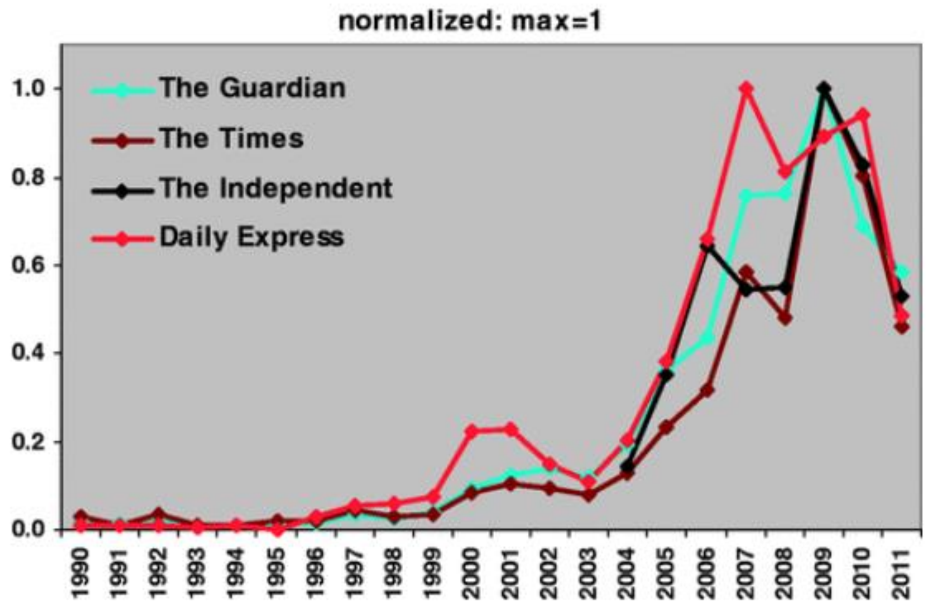
Conversely, A 'top-down' power vacuum can be caused by developments in the landscape such as international crisis (Ibid.). Paralleling the first quarter of the 20th century, the onset of 2020 has witnessed trends of economic downturned and plunging demands for oil as the pandemic Covid-19 have forced politicians to ground aircrafts, vehicle use and quarantined millions of people (Hiller & Hampton, 2020). In addition, disagreement between Saudi Arabia and Russia in the formation known as OPEC+ in early March further exacerbated the ongoing price volatility of oil (Gamal, Lawler, & Astakhova, 2020). According to a recent report by the International Monetary Fund (IMF), the global economy is projected to stagnate sharply by -3 per cent in 2020, a stagnation worse than that of the 2008-09 financial crisis (IMF, 2020).

Though the true impacts of these developments are yet to be seen, they illustrate the very degree of interconnectedness of the global energy system, how small events may snowball into something bigger – creating windows of opportunities for the diffusion of new innovations. Head of the European Commission's climate cabinet noted that "we could use these circumstances, were load of public money are going to be needed into the energy system, to jump forward towards a hydrogen economy” (Chesteny & Abnett, 2020).

However, the current trends that at present dominates the news picture effectively challenge the momentum of present climate awareness. The same findings from the word-count analysis in British Newspapers for instance, further revealed that attention to climate change plunged as the stock markets crashed in 2008-2009, as depicted in figure 7.0 below. Chaos may indeed be a ladder to diffusion, but whether one is to move upwards or downwards in respect of transitioning the energy and transport system depends on how these rare windows of opportunities are acted upon.

It is also worth repeating that sustainability transitions are long term. Meaning that we should remain cautious to the credibility of claims made in regards of the future impact of developments in the landscape. Hence, to strengthen our understanding of the barriers and opportunities akin to sustainability transitions, in this case with hydrogen, more narrow levels of analysis are required. As such, the following sections aim to reconcile this multi-level analysis with insights from the prevailing regime in Norway followed by an assessment of the promises and pitfalls of a prospective solution to decarbonisation, namely hydrogen.

Figure 7.0 Yearly Number of Articles in UK National Newspapers Containing the Words 'Climate Change'



Source: (Geels, 2014, p. 32)

4.3 The Norwegian Context

"It's important to acknowledge that the relative costs of energy are context-dependent and vary across the world."(Ritchie & Roser, 2018)

The Kingdom of Norway's energy odyssey reveals some interesting particularities in the debate on sustainability. Here we have a country at the periphery of Europe rich in natural resources, with a long history of producing energy, both fossil and renewable. Owing to its geographical location, Norway possess favourable conditions for renewable energy production. Its abundance rivers and waterfalls have been utilized for energy production since the early 1900 and comprises today a large share of Norwegian energy production. Hydroelectric power plants comprise to about 95 per cent of electricity production nationally (Energifakta-Norge, 2019b). At the same time, Norway has acquired a well-known reputation as an active oil and gas exporter since the end of the 1960s. Although Norway only saturates 2 per cent of the global demand for oil and 3 per cent of the demand for natural gas, it supplies about a quarter of the EUs' consumption of natural gas (Norsk Petroleum, 2020a).

By the power vested in the Government, the country's wealth and opulence of natural resources have been managed with active state intervention since the onset of the twentieth century, where foreign ownership of Norway's hydroelectric industries became increasingly subjected to government concessions (Sanders, Sandvik, & Storli, 2019, p. 9). Throughout the continuance of the latter century, resource nationalist policies echoed the shifting governments emphasis, or reinforicive power, in maintaining control of its natural resources, more recently exemplified by Norway's oil adventure[6]. The historical developments of Norway, including the hand given by its geography, are here viewed as important variables when one is to approach its socio-technical regimes, assessed in section 4.4.

The rents of Norway's petroleum industry provided prosperity, both economically and socially, through means of responsive and responsible government, fortified with strong labour market institutions (Moses & Letnes, 2017, p. 11). Yet, it is argued here that the pillar of the environment, based on GHG emissions, remained comparatively neglected. Indeed, the authorities were from the very start aware of the potential threats associated with operating on the Norwegian continental shelf. This concern was especially connected to its heavy reliance on the fishing industry. Drilling for instance, is still banned in around Lofoten (Ibid., p. 193).

[6] Shortly after the discovery of oil on the continental shelf of Norway, the authorities introduced strong control. International oil companies with stakes in the North sea found themselves under closer governmental scrutiny, taxation and regulations (Moses & Letnes, 2017, p. 69)

But, though the introduction of environmental frameworks, such as the 1981 Pollution Control Act, addressed environmental concerns (Ibid.), Norway's trajectory aligned with its pledges made to the Kyoto Protocol and the Paris Accord remain incompatible to this day (Climate Action Tracker, 2019)

At the turn of the millennium, some market mechanism was introduced taxation on CO_2 in 1991, and a climate quota system in 2005, integrated with the EUs quota system (Norsk Petroleum, 2020b). Nowadays, clear efforts to tackle the alarming concerns of climate change have become more entrenched into politics and political Party programmes. The Conservative Party of Norway (Høyre), has made several commitments as the leading incumbent party of Government, in relation to climate change and mitigation of GHG emissions.

Norway has among else, made commitments to the Kyoto Protocol, the Copenhagen accord, and more recently the Paris Accord. An overview of Norway's climate commitment is depicted in table 4.0 below. Though successive governments have demonstrated commitment to the grand challenge of climate change, exemplified by taxation on CO_2, rainforest conservation efforts, and advocacy for international climate agreement, Moses and Letnes (2017, p. 220) notes that the ability of Norway to play this role, depends entirely upon its dirty little secret: the money comes from oil.

Table 3.0 Norway's Pledges and Targets

Status	*Ratified*	*Yes*
Paris Agreement	2030 unconditional target(s)	40% below 1990 by 2030 [44% below 2010 by 2030]
	2030 conditional target(s)	Carbon neutrality
	Condition(s)	Norway will adopt a binding goal of carbon neutrality no later than 2030
Copenhagen Accord	2020 target(s)	30-40% below 1990 by 2020
	Condition(s)	Global Comprehensive agreement after 2012, with major emitting parties agreeing on reductions in line with achieving the 2 degrees Celsius target
Kyoto Protocol (KP)	KP Target 1 (2008-2012)	1% above 1990
	KP Target 2 (2013-2020)	16% below 1990
Long Term Goal(s)		Low carbon society by 2050 Reduction in GHG emissions by 80-95% from 1990 reference

Source: (Climate Action Tracker, 2019)

4.4 Norway's Socio-technical Regimes (Energy and Transport)

With the overarching context accounted for, this section will provide condensed assessment to the underpinnings of the how regimes such as energy and transport are understood in this thesis. They are treated along one another as the relationship between them is of particular importance in Norway (Tomasgaard et al., 2019, p. 6). These regimes may be defined in terms of the current rules and practices.

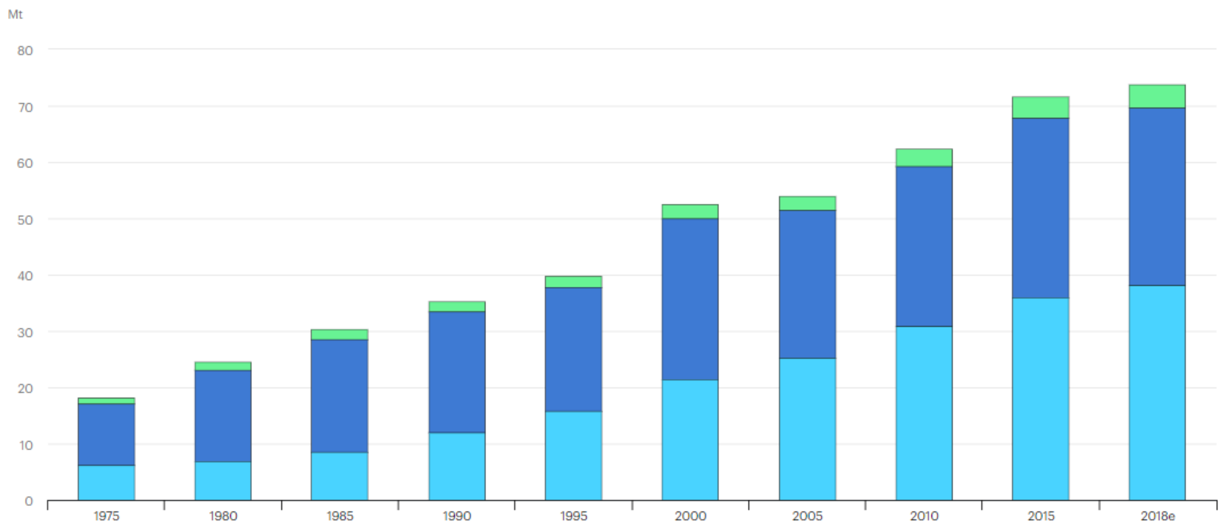
Norway's energy regime is characterised by well-established practices in renewable energy production from hydroelectric powerplants and a substantial offshore activity. While a large share of the energy consumed in Norway stems from the hydropower industry, the oil and gas industry serve to supply a significant share of energy demand in foreign markets as well as in the domestic transport market, including maritime (Energifakta-Norge, 2019a; Norsk Petroleum, 2020a).

Accordingly, the current transport market can largely be characterised by the share of vehicles and vessel running on fossil fuels. On-road combustion vehicles account for about 90 per cent the market share (SSB, 2020). The current status of technology in the shipping industry displays a similar story (Regjeringen, 2019b, p. 26). In short, Norwegian energy and transport regimes are still characterised by practices embedded in environmentally harmful fuels, most prominently in the domains of transport and export.

Due to current practices attached to fossil energy, each of these regimes enable GHG emission to linger on, both domestically and globally. Within its own borders, emissions from the transport sector, including maritime, amounts to about 25 per cent of Norway's GHG emissions (Tomasgaard et al., 2019, p. 20). Outside, Norway supplies both oil and gas in large quanta, such as to the EU, which indirectly, serves to release emissions in foreign markets. As mentioned however, the relationship between GHG emissions and the grand challenge of climate change has not gone unnoticed. In fact, it has been a key driver for policymakers and incumbents to alter the strain on the environment. Therefore, when viewing the current practices of socio-technical regimes, it is also important to note that policy, science, industry and user preferences are increasingly aligning with towards a sustainable agenda. These developments are largely viewed in relation to shifting trends in the exogenous landscape, arguably amplified by globalisation.

In table 3.0 above, Norway's pledges and targets are mapped out. To meet these targets, the government has, among else, identified a number of opportunities for the diffusion of various sources of energies and technologies in the on-road and maritime transport sector, see (Samferdseldepartmentet, 2017) and (Regjeringen, 2019b). Important developments are also occurring outside of Norway's borders, where its closest trading partner, the EU, envision to become the first climate neutral continent in the world by 2050 (European Commission, 2019), which implies that consumption practices (in terms of energy usage), are likely to be drastically altered, as demands for hydrogen is projected to increase in the future, see graph below.

Figure 8.0 Global Demand of Pure Hydrogen, From 1975 to 2018[7]



Source: (IEA, 2019b)

The path to sustainability is however highly context dependent. There is no one-shoe-fits all solution applicable to every country or region. Nor is there only one 'correct' pathway to achieve sustainability and ultimately a low-carbon society. Vital socio-technical systems, such as transport and energy, may overcome their fossil dependency on fossil resources by switching to a diversity of renewable solutions and carriers of energy. In regards of the blessings of Norway's disposition of natural resources, cleaner energy for consumption may derive from variety of sources, such as solar, wind, tidal to hydro-electric, biomass and, last but not least, hydrogen.

The latter, hydrogen, which the bulk of empirical analysis and discussion will revolve around henceforth, possess some particularly interesting qualities to Norway as a global energy actor and its journey to sustainability. Because the coupling between the sector of transport and energy production is especially important in Norway, this thesis aims to answer the research question by gathering insights of both, as it is understood that this twofold deep-dive will provides the best overall understanding.

As the quotation positioned at the very onset of this chapter expresses: "It's important to acknowledge that the relative costs of energy are context-dependent and vary across the world". The context of any given country is crucial if one is to understand the pathways different

[7] The bottom segment denotes demand to refining, the middle to ammonia production and the upper is for other usage

countries choses and find suitable. By reading between the lines, the context provides important clues, be it geographical traits, system of government, variety economy, composition of its inhabitants and culture, and transnational interconnectedness. As the informants of this project emphasised, when it comes to Norway and hydrogen, it is important to acknowledge where the strength of this country are, as they pointed to Norway's comparative advantages as a maritime nation and as an energy producer, including both fossil and renewables.

Nevertheless, hydrogen being a niche comes with certain baggage. Especially if its proponents most ambitious hopes are to be met - where hydrogen eventually replaces fossil fuels. For this reason, the next section aims to present a sober assessment of the realities facing hydrogen, such as what opportunities are realistic, and what barriers the niche currently encounters.

4.5 Niches of Hydrogen

As noted, the MLP aims to capture interactions between three analytical levels, the niche, the regime and the landscape, and how their interaction may lead to a possible destabilisation of the existing socio-technical regime through a combined interaction of exogenous and niche pressures. The latter, the niche, refers to protected spaces, including innovations, technologies, actor configuration and institutional arrangements that transform and replace (during windows of opportunities) modes of production and consumption within a socio-technical system (Johnstone & Newell, 2018, p. 73). The two sections above aimed to illustrate some of the deep grammar embedded in socio-technical systems. Fossil fuels remain highly relevant internationally, to which Norway is a committed producer of. Indeed, fossil fuels finds its way to the Norwegian consumer market, but a large share of energy consumed also stems from renewable sources, such as hydroelectric power. These are important traits to keep in mind as hydrogen emerges to the spotlight of scrutiny.

4.5.1 Hydrogen – 'Fool Cell' or Cellvation?

In 2019, the well-known technology entrepreneur and board member of Tesla Inc., Elon Musk, slams the technology of hydrogen cars as "mind-bogglingly stupid" and as "load of rubbish" (D'Allegro, 2019), potentially evidencing how EV incumbents may feel threatened by the emergence of hydrogen vehicles. At the same time, hydrogen receives glamorous reviews from EU officials, were it is alleviated to the status of the 'holy grail' (Chesteny & Abnett, 2020). Proponents especially, exerts enthusiasm towards hydrogen in sustainability themed debates, where it is views as a potential fuel that may replace fossil fuel in internal combustion engines (Acar & Dincer, 2020). Contesting viewpoints belong well within stories on sustainability transition. Diverging schools of thoughts on sustainable solutions reveals, to a certain extent, challenging branches along the path to sustainability.

Though, fuel cells vehicles and EVs may very well co-exist in a low-carbon society, and even benefit from one another, the desirability of the directions of sustainability transition remain present due to notion that different pathways may create winners and losers (Köhler et al., 2019). As assessed below, hydrogen requires major money if a momentum is to gain foothold. Several additional barriers are also standing in its way to commercialisation. For this reason, to understand the importance of politics and power in regard to hydrogen diffusion, it is deemed paramount to unzip the oddity of hydrogen. Knowing the nuances of articulated solutions of hydrogen is of great importance for policymakers in the endeavour of distilling sound environmental policy and in guiding green transitions. With this in mind, the following paragraphs present both what opportunities and challenges hydrogen faces.

4.5.2 Hydrogen – A Nuanced Assessment

Hydrogen is in the wind. Carrying number 1. as its atomic number on the periodic table, hydrogen status as the lightest element in the world and makes up 75 per cent of the universe's total mass. Within the realms of our planet, hydrogen (H_1) is usually found in combination with oxygen (O_2), thus exposing itself as water (H_2O). While hydrogen commonly presents itself within an aquatic shape, it is presently in the wind, politically speaking. Hydrogen is the cleanest fuel available, with heating values three times higher than petroleum (Acar & Dincer, 2020, p. 3397).

To the pressing need to decarbonize the world's energy and transportation systems, hydrogen is as noted advocated to play a valuable role by a multiplicity of actors and scholars. In December 2019, the EU released an ambitious communication, mapping out requirements that need to be undertaken in order to become the first climate neutral continent in the world, in which hydrogen received prominence, see (European Commission, 2019). Hydrogen as a sustainable pathway for EUs energy transition is more explicitly detailed in Europe's Hydrogen Roadmap, see (FCH, 2019).

Moving the lens up north to a key exporter of energy to the EU, Norway. With long experience of producing energy, including hydrogen, Norway too seems to be taking some initial steps in favour of a future hydrogen economy. At the high tables of politics, hydrogen in a low-carbon future has especially been endorsed by Norway's former Minister of the Environment, Ola Elvestuen (Elvestuen, 2018). In line with the Government's aim of reducing GHG emission by

2030, Prime Minister Erna Solberg recently emphasised hydrogen as one of Norway's green opportunities, along with ocean windfarm and extraction of subsoil mineral resources (Frafjord, Lydersen, & Skodje, 2020). Though an official blueprint for a hydrogen future has not been made public, the government announced last year that it will by 2020, submit a box fresh hydrogen strategy (Knutsen, 2019).

In addition to its increasing political attention, hydrogen receives support from research and innovation institutes. To Norway, work conducted by Norwegian based scientific bodies are especially prominent. In 2019, fruitful collaboration between FME CenSES, FME MoZEES, NTNU, SINTEF and IFE, on the matter of hydrogen's role in carbon free society, resulted in an extensive report that promote hydrogen's green qualities from a scientific point of view, see (Tomasgaard et al., 2019). In line with visions down in Brussels, both Europe's Hydrogen Roadmap and Tomasgaard et al. (2019) project hydrogen to play an central role in decarbonizing a diversity of sectors, such as: energy supply and storage, transport, industry and heating.

However, knowledge and experience regarding hydrogen is by no means recently discovered nor recently articulated to the public. Hydrogen has been in the wind before. Going back to the early 2000s, United States' President Bush expressed great enthusiasm in favour of hydrogen in his 2003 State of the Union address, sparking great attention to the opportunities of hydrogen across sections of the green movement, to coal and nuclear lobbies and industrial energy and automotive giants (Eames & McDowall, 2010, p. 673). Similar trends were visible in Norway as well. Prior to the financial crisis of 2008, authorities, business and industrial actors in Norway expressed positive support in regards of hydrogen, exemplified by the HyNor Project[8].

Yet, the heyday of hydrogen remained short-lived. The HyNor project did not live up to its expectations as it was premature and is today considered as a failure (I3). Today, about 3 per cent of the world total energy consumption are directed to the production of hydrogen, in which the bulk of production stems from fossil sources of energy (DNV-GL, 2019, p. 3). If hydrogen truly is as beneficial as proclaimed, why have its worldwide portion of the energy mix remained marginal? Though the answer is complicated and multi-dimensional, the infamous figure of Tesla Inc. views regarding fuel cells provides an interesting point of departure.

[8]A national development project led by Hydro, that aimed at establishing hydrogen highway between the cities of Oslo and Stavanger (Equinor, 2005). According to a HyLAW report, the HyNor project left part of the population with the impression that hydrogen fuel cell cars were a hype (Damman & Gjerløw, 2019, p. 9).

4.5.3 Hydrogen – Not so Suitable After all? Lessons from the Transport Sector

First, hydrogen is not classified as renewable energy. Hydrogen is an energy carrier. It is not a natural source of energy such as solar, wind or tidal energy. Hence, hydrogen requires to be processed by energy in order for it to become a carrier of energy (Acar & Dincer, 2020, p. 3397). Engineers and natural scientists are fully aware of hydrogen's shortcomings. Constrained by the laws of thermodynamics, hydrogen is associated with only modest energy efficiency and significant loss of energy along every node in the conversion chain (I1).

If hydrogen is to be incorporated into the transport system, it must first be produced, stored, transported (either as liquid or gas) and eventually supplied before it can be consumed as in input fuel. Unfortunately, every node along the conversion chain subtracts a specific amount of energy from its initial potential possessed at the feedstock stage. Compared to battery solutions, a vehicle using hydrogen fuel cells are only able to make use of ¼ of the energy from one unit, while battery vehicles are able to capture ¾ from one unit (I4). As such, advocates of hydrogen must operationalize genuinely well-articulated arguments if hydrogen is to be favoured over purely electric solutions, which already enjoys a substantial position in Norway.

Hydrogen's journey to the Norwegian automobile market can be characterised as a bumpy road of energy inefficiency, cost, lack of infrastructure, users, and gaps in the regulatory framework. Fuel cell vehicles enjoy many of the government incentives that also apply to BEVs, such as exemptions on VAT, excises, and annual payments as well as the ability to drive in the carpool lanes (I5).

Another thing to keep in mind is that these incentives are largely user oriented. Fuel cell vehicles faces two significant issues in this regard. First, it has a limited dispersion of users. Presently, the visibility of hydrogen as an input fuel, and hydrogen vehicles are, miniscule at best. Around 200 hydrogen cars and 5 buses and two lorries roam the highways of Norway's transport system (I1). Far less compared to EV, which currently captures an ever-larger share of the Norwegian market relative to vehicles running purely on fossil fuels (Regjeringen, 2019a). On the user side, preferences are stagnating in for traditional combustion vehicles while surging for EV, where there has been an increase of 574.5 per cent of electrified personal automobiles between 2014 to 2019 (SSB, 2020).

Secondly, there is a lack of hydrogen related infrastructure. In comparison with EV, which acquires both a market and infrastructure. Here, the chicken and the egg analogy is worth addressing. Prior to EVs highly successful penetration of the automobile market in Norway, the chicken already existed – the infrastructure (Ursin, 2018). Followed by highly beneficial incentives deployed by the government, a market was subsequently created (Ibid). Hydrogen on the other hand, lacks both.

There are few hydrogen stations currently under operation. While the network of supply stations appears to be under expansion, most station under development will end up being located in urban areas in the south and western part of Norway as depicted at the Norwegian Hydrogen forum's preliminary map over stations in Norway, see (Norsk Hydrogenforum, 2020a). The need for urban nearness at a certain scale is further reflected by the locations of the current stations in Norway, where they are only found in spatial proximity of the three largest cities, and even there, the potential market is arguably insufficient, as Norway is a relatively sparsely populated country.

Though efforts to establish a hydrogen highway was initiated, exemplified by the HyNor project, it was set back by largescale electrification and initial lack of fuel cell vehicles (Damman & Gjerløw, 2019, p. 11). More recent efforts to circumvent the barrier of inadequate network of refuelling station was sought through the establishment of a national support scheme in 2017. Yet, the HyLaw project notes in their policy paper that grants have been limited to a maximum of three station per year (Ibid., p. 9).

Production of fuel cells are also found to be quite expensive. Consumers who desires fuel cells too, must also pay a significant amount for hydrogen cars at present, where the price ranges from between 450 000 to 600 000 NOK according to Norsk Hydrogenforum, see (NHF, 2020). The affordability of hydrogen vehicles represents a possible aspect of scrutiny in future analysis of the 'justness' of a hydrogen transition is to occur. Though, for the sake of space, this point will be left relatively untouched in this contribution.

4.5.4 Greening the fleet –Barriers and Opportunities

For Norway to meet its pledges and targets, GHG emissions also needs to be addressed in the maritime transport sector. In 2017, domestic maritime operations, including private use, accounted for 22 per cent of the total emissions released from the transport sector (Regjeringen, 2019b, p. 11). Presently, the maritime realm is said to stand ahead of the most radical reconfiguration in modern times, where the International Maritime Organisation (IMO) announced in 2018 that emissions in international shipping shall be cut in half by 2050 (compared with 2008 levels) (Ibid. 12). According Reve and Sasson (2012), the maritime sector represents one of Norway's strongest and most dynamic industries, covering the entire value chain from research, technological development and design to shipbuilding, equipment, control systems, operations, and knowledge-intensive services, (in, Steen, Bach, Bjørgum, Hansen, & Kenzhegaliyeva, 2019, p. 10).

By virtue of Norway's prominent position as a seafaring nation, the interview's tended to converge around the potential opportunities for hydrogen within this sector. Most notably, Norway possess a long coastline, along where multiple fjords carve their way inwards through the mainland that requires passing by ferries. Coupled with this geographical feature, Norway relies on a substantial oil and gas activity on its continental shelf and vibrant shipping industry.

In line with Norway's climate commitment, electrification of fleet is already well under way according to the government (Regjeringen, 2019b, p. 19). And, as one informant stated "both, from an energy efficiency and economic perspective, stands electricity as the best solution provided its feasible for the given application" (I1). Yet, offshore, electrical solutions often fall short in respect of range. In contrast, hydrogen is argued to be more well-suited for longer distances (I2). Batteries are also found to be unfavourably heavy for many heavy duty and long-distance purposes (I5).

According to Tomasgaard *et al* (2019, p. 24), of the estimated 100 high speed ferries in Norway, it is projected that half of these have the potential to be converted to hydrogen usage. Full scale demonstration and implementation have been limited for maritime hydrogen applications (I1). Widespread bunker infrastructure is lack, and the present production of clean hydrogen has been limited to only pilot projects on hydrogen ferries (Steen et al., 2019, p. 17). Increasingly however, there are signs indicating that a window of opportunity for hydrogen diffusion in this sector is becoming more transparent. In addition to a small grouping of actors displaying interest in hydrogen propulsion, such as fuel cell manufactures, shipyards, and shipping companies (Ibid.), central and lower levels of government also display interest to hydrogen pathways, evidenced hydrogen's prominent position in the government's most recent action plan for greening the fleet, and in regional government's application for financial support to hydrogen related projects, see (Hordaland Fylkeskommune, 2019). The action plan for instance, describes hydrogen as a viable solution for the future, that can replace fossil fuels in shipping where electrification by batteries is not suitable (Regjeringen, 2019b, p. 20). In correspondence with (I2), the plan emphasises the requirement of developing the regulatory framework in parallel with technological developments and piloting.

By now, governmental support to hydrogen in the maritime sector has moved beyond the form of an idea in a roadmap for sustainability to actual measures. This is for instance evidenced in the form of development contracts, offered by Statens Vegvesen – the Norwegian Public Road Administration (NPRA), the authority of permits and grants distribution for domestic ferry services in Norway. Norled AS, who won the bid, will from 2021 operate a fairway in Rogaland county with hydrogen-electrical hybrid ferry (I2; Statens vegvesen, 2020). Moreover, measures to speed up development on hydrogen technology and production have been initiated with governmental support, through the bodies of Enova and Pilot-E. The establishment of Ocean Hyway Cluster, who aim to develop maritime hydrogen solution, received influx of support from the programme of ARENA[9]. Resources are further mobilised by other support programmes, such the Klimasats project where municipalities and regional governments can apply for grants (Miljødirektoratet, 2020b) and the Pilot-E project[10].

Yet, the cost of hydrogen fuelled vessel remain substantial, and continue to status as one of the most prominent barriers to future commercialization. Though, governmental support is surging in the form specific projects, lack of more expedient incentives and gaps in the regulatory framework remains a challenge. The HyLAW project for instance, provided several policy recommendations in order to address legal barriers to hydrogen in Norway. Lack of regulation for design/type approval for hydrogen and fuel cells in ships was deemed the most critical in the Hylaw paper, see (Damman & Gjerløw, 2019, p. 6). Regulatory gaps or lack of explicit requirements for hydrogen were further identified in matters of ship registration, operation and maintenance, approval of landing/ bunkering, and onboard hydrogen transport (Ibid., pp. 5-6).

4.5.6 Hydrogen Production – Barriers and Opportunities

At the onset of each interview, the informants were asked to describe the Norwegian context in relation to production of hydrogen. In response, the interviewees emphasised Norway's long historical experience of Hydrogen production, stemming all the way back to the early 20th century. Presently, hydrogen is mainly used in Norway today in ammonia and fertilizer

[9] ARENA features as one out of three levels in the Norwegian Innovation Cluster Programme, owned in collaboration between Innovation Norway, Siva, and Norway's Research Council managed by Ministry of Trade, Industry and Fisheries (Innovasjon Norge, 2019).

[10] Pilot-E is an opportunity to receive financial grants to Norwegian business, established by Forskningsrådet (The Norwegian Research Council), Innovation Norway and Enova. The projects goal is to stimulate ascendance of new productions and service of sustainable energy technologies so that they may enter the market at a faster rate with the purpose of contributing to mitigating emissions of greenhouse gases. Pilot-E states that it will follow up actors throughout the entire span of development, from the idea phase to the market (Forskningsrådet, 2019)

production, where YARA is a key player, and for production of methanol and oil refinement, with Equinor as a key actor (Tomasgaard et al., 2019, p. 28).

Hydrogen can as noted be produced from large mix of low-carbon sources. For example, with electrolysis technology or with help from non-regulated renewables, such as hydro, wind or solar. Hydrogen produced on this approach will from this point be treated under the label ‘green’ hydrogen. There is also possible to produce clean hydrogen from natural gas, but that production method requires certain technologies, such as carbon capture storage technology (CCS) (FCH, 2019). This mode of production will henceforth be distinguished under the label ‘blue hydrogen’.

The degree of capital intensiveness of hydrogen production represents one key barrier in the domain of production. Though various sources and technologies may be employed for this purpose, production cost remain high when adding the cost of infrastructure, such as production and storage facilities and means of distribution. Production of ‘Blue’ hydrogen for instance, requires access to natural resources, such as natural gas and purifying technology such CCS, and is only cost-effective in great volume production (> 5 million tons CO_2 annually) (Tomasgaard et al., 2019, p. 13). According to Acar and Dincer (2020, p. 3397), the cost of producing hydrogen is almost three times more expensive compared to fossil fuels as it needs to processed with a variety of energy and material resources.

Electrolysis for example, is another promising option for the endeavour of producing clean hydrogen. In essence, through the process of using electricity to split water, hydrogen is produced. This is however, not novel innovation, as Norsk Hydro (now YARA) frequently employed this method as part of their production of fertilizers during the 1900s (Ursin, 2018). Electrolysis are still being used today, and is attracting increasing attention as a pathway to large-scale clean hydrogen production (Saeedmanesh et al., 2018). In Norway, this alternative is becoming increasingly more cost-effective, but eventual competitiveness also depends on exogenous factors, such as the price on fossil fuels, which is highly political influenced, and cheap electricity (I4; (Tomasgaard et al., 2019, p. 14).

Nevertheless, the bulk of the hydrogen produced nowadays is neither green nor blue, but ‘grey’ – steam methane reforming without CCS. Planete Energies reported in 2015 that 95 per cent of global hydrogen production were produced from either wood or fossil fuels (Planete Energies, 2015). The most common way of producing hydrogen happens through reforming natural gas (steam methane reforming). This method, with the absence of GHG capture, accounts for 68 per cent global hydrogen production (Tomasgaard et al., 2019, p. 14). In combination with the rising demand for hydrogen worldwide, emissions from hydrogen production accounts for up to 830 million tonnes of CO_2 annually. To illustrate, that is the equivalent of the United Kingdom and Indonesia's CO_2 emissions combined (IEA, 2019a).

Another approach that may be utilized is to connect hydrogen production to already existing renewable energy systems, such as hydroelectric power stations, wind turbines or tidal power plants. As renewable resources create a significant amount of excess power, favourable opportunities exist in regards of hydrogen considering the argument of energy inefficiency.

> "…finding a promising solution on how to store the otherwise curtailed, large-scale excess renewable energy produced during peak generation times and seasons, followed by use in later demand period is of increasingly important" (Saeedmanesh et al., 2018, p. 169).

Take wind turbines for instance, the amount of energy generated from turbines cannot be planned nor controlled. As such, the co-existence of hydrogen with other renewables for clean energy production status as another possible pathway for Norway's future energy mix considering its comparative geographical conditions. For this purpose, hydrogen via Power-to-gas (P2G) technology represent a promising prospect for policymakers in guiding sustainability[11].

As hydrogen is an energy carrier, rather than a natural source of energy, actors advocating hydrogen may face competition with renewable sources of energy (Ren, Gao, Liang, Tan, & Dong, 2017), and should therefore not be ignored when assessing possible conflicting pathways. Decarbonizing energy systems may for instance involve greater utilization of electricity. Electricity, like hydrogen, can both be manufactured from other renewable resources and low-carbon resources, such as wind, hydro, solar, nuclear and biomass (Lu et al., 2013, (in, Ren et al., 2017). Choosing whether to produce green hydrogen from one of the

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[11]P2G technology is a method where electrical power is conversed into a gaseous energy carrier. By using a P2G approach, hydrogen can be supplied completely from excess renewable energy from wind and photovoltaic sources. In short, when renewable energy production is insufficient, energy generated at seasons of surplus guided towards production of hydrogen allows for a cost-effective approach for long-term energy storage. Utilizing P2G to produce clean hydrogen, may mitigate carbon emissions between 2.5 ajd 14 times (0.04kg CO_2 eq/MJ) compared to firewood (0.1 kg CO_2 eq/MJ) and liquefied petroleum gas (0.57 kg CO_2 eq/MJ) (Saeedmanesh et al., 2018, p. 170)

abovementioned renewables versus electricity depends on various factor, such energy efficiency, cost of production and the matureness of the technology. This debate on hydrogen from renewables vs. electricity from renewables is evident in Norway (Frydenlund, 2017), just as it is in China (Ren et al., 2017).

4.5.7 (Perceived) Safety issues

Another clear barrier to consider, is that of which relates to safety. Hydrogen is not risk-free, it is a potential hazardous gas with explosive properties, which challenge the public acceptance in regards of aspects of safety (2010, p. 673). Indeed, hydrogen may explode, to which the world tragically acknowledged following the awesome explosion of Hindenburg in 1937, curtailing the lives of 36 individuals. The matter of social acceptability is an important component in the MLP, where market and user preferences acquire a prominent position in backing the regime, see figure 1.0. Though the Hindenburg incident belongs to a distant past, hydrogen’s safety record has not able to stay virgin since.

In 2019, a malfunctioning hydrogen tank at a Uno-X station in Sandvika, Norway, caused an explosion (Jensen, 2019), which resulted in Uno-x to suspend all of their hydrogen refuelling station immediately (Norsk Hydrogenforum, 2020a). Ruter, in Oslo, also temporarily suspended the operation of their 5 hydrogen buses (I5). Lack of social acceptability due to a negatively perception on hydrogen’s safety account can affect the willingness to act, the fourth condition of power exercise (Avelino & Rotmans, 2009, p. 556). One month prior to the explosion in Sandvika, a hydrogen storage tank in the rural city of Gangneung, South Korea, exploded, sparking protest among residents who worried about more hydrogen facilities being built (Jin & Chung, 2019).

However, the nuances of hydrogen’s perceived safety issue need to be addressed. Yes, hydrogen is potentially hazardous, and as (I3) noted, there will always linger a somewhat scepticism to things that might explode. Indeed, all types of fuel have some degree of danger associated with them. The blaze in battery fires are also quite spectacular (I3). But as the interviews shed to light, is that hydrogen is greater subject to a somewhat ‘misconception’ regarding hydrogen’s aspects of safety.

Nevertheless, the perceived safety issue of hydrogen is a barrier many (I5), and for those concerned with the development of hydrogen roadmaps within a public policy context for example, must take into account the degree to which hydrogen is desirable from a societal perspective (McDowall, 2012, p. 535). One key finding from the interviews, is that there exist relatively little opposition against hydrogen technology in Norway. Yet, if more accidents are to happen in Norway, fear or scepticism to hydrogen could increase, to which local opposition may become more visible (I1), similar to what was seen in Gangneung.

Another point to consider in this regard, around 200 hydrogen cars currently roam the veins of Norway transport system, and development of hydrogen vessel have just left the drawing board, as assessed earlier. This means that everyone who take use of hydrogen in Norway today is in some sense a first adapter. As (I5) noted in respect of safety,

> "Hydrogen may struggle to attract first adopters at the private consumer level, but big industry players may be willing to be first adopter because they have more technical competence and are generally better at planning. Private consumer may want to see thousands of something on the road before they start using one themselves"

Drawing from these insights, knowledge regarding the safety of hydrogen needs to be communicated outwards, in order to assure the users and markets that this is something to invest in.

4.5.8 Standards – Legal and Regulatory Barriers

Harmonised standards provide a common technical language used by its subscribing actors, such as manufacturers. The basic idea of standards is simple. For example, when purchasing a piece of electronical equipment for a given household, it is expected that its charging interface is compatible with the house's outlets. Nowadays, two charging ports are dominant among the charging infrastructure for EV in Norway[12]. For hydrogen this remains both an issue and a barrier, as alleviated by (I5). A lot of standards are not yet in place and are found to be important to the establishment of hydrogen value chains (Tomasgaard *et al*, 2019, p. 24). In terms of pressurisation, for example, some tanks use 350 bar while others use 700 bar, but for transport and distribution of the fuel it is often 250 bar (I5). There needs to be a discussion about standards that includes type of interfaces, types of technology safety, and regulations to overcome the 'ad-hocness' in the hydrogen world (I5). According to the IEA, harmonising standards will not only remove an unnecessary barrier to investment, but will also benefit trade and environmental tracings of the product (IEA, 2019a).

[12] Type 1, commonly compatible with older models and cars from Asia and North America, and Type 2, commonly compatible with European cars, including Tesla (Elbilgrossisten, 2020)

4.6 Is hydrogen desirable?

Because of projections on future energy demand and the presence of climate change, hydrogen represent a promising pathway. For long, this alternative fuel has been touted as clean alternative to fossil fuels (Chesteny & Abnett, 2020). It is the cleanest fuel available but requires big money and support to unfold and to become affordable. Here, both 'blue' and 'green' hydrogen is possible to become sustainable in economic terms, but that scenario is highly contingent on large scale production and coordination, as well as long-term thinking among its' investors. While return on investment is located at the end of the tunnel, the economic benefits of hydrogen cannot be reaped overnight (I4). Though the incentive behind investments in general may very well be seeing positive return of investment within a short span of time, hydrogen projects requires additional patience, assumedly up to 15 to 20 years (I4). Indeed, private actors with stakes in hydrogen projects are aware of these implications.

The issue regarding Norway's sustainability transition, is that of convincing the public of this pathway, especially, the incumbent government – who's supremacy is based on short four-year electoral cycles. After all, the underpinnings of a democratic system clearly allocate considerable power to the populace as they cyclically walk to the voting ballots. And, even though hydrogen represents a promising pathway from an environmental point of view, it also need to be legitimised in the eyes of the citizens and users, which for instance may be highly concerned with hydrogen's safety record, or that they view other alternatives as more fruitful.

Besides concerns related to sustainability, hydrogen can also be desirable for traditional incumbent in the automobile industry. Compared to EV, fuel cell vehicles have more movable components, as well as overall more components that will require maintenance (I1). Though this may not manifest a factor of great importance, just transition perspective emphasise the importance of maintaining employment opportunities as societies transcends to modes of enhanced sustainability.

In addition, it may further be underscored that a transition to a hydrogen economy may not only be beneficial in environmental terms. Upscaling hydrogen, either in transport or in production, will also generate economic activity (I1), both to the ship construction and shipping industry, and to distributors of technology (Tomasgaard *et al*, 2019, p. 16). Various components may be for instance be manufactured domestically, such as storage tanks, pipelines. Concerns attached to transitions to a low carbon society may also be that employees in the Oil and Gas Sector will lose their jobs. But in the event where 'blue' hydrogen is scaled up, extraction of natural gas will continue to serve the necessary feedstock required for this purpose, thus not making this sector redundant in a low-carbon future.

4.7 Why Power Matter

“Even though every hydrogen-project is expensive, hydrogen is an area that we [Norway] can become world-leading, with relatively manageable environmental instruments” (Elvestuen, 2018) – Former Climate – and Environmental Minister Ola Elvestuen.

Power matters, as it enables its ruler to make things happen, even if opposing parties are to disagree. Similar to in the MLP, the state status as one of the most powerful actors in international politics. Even in the era of globalisation, it represent the most significant force in shaping the world economy (Dicken, 2015, p. 175). At home, they possess considerable power to which they can shape the public discourse and guide domestic industry. Desirability to hydrogen to hydrogen diffusion is in the wind again. Concurrently to the developments in Norway, powerful entities beyond the European continent, such as China, are too displaying considerable interest to hydrogen vehicles. In China, governmental involvement in the economy is large, and hydrogen is promoted by explicit policies, regulation and laws (Ren et al., 2017, p. 11). During the Beijing Olympic games, hydrogen vehicle was put on display, augmenting the niche’s visibility to the world (Ibid.).

Across the sea, Japan and South Korea also demonstrates strong support for the use of hydrogen in transport. With the aim of maintaining a frontrunning position, both countries have drafted a national hydrogen strategy to guide the development of their envisioned future in hydrogen (IEA, 2019c; Nagashima, 2018). These state-backed approaches indicate a clear sense of desirability to hydrogen and illustrates the length certain governments are willing to go to deploy hydrogen into the mix. Similar trends of willingness may further be identified on the European continent, where hydrogen has acquired a priority area for industry in its Green Deal, see (European Commission, 2019).

Drawing from the experience of wind power, global policy-backed action stimulated economies of scale which brought down the deployment cost in roughly a decade (Nagashima, 2018). The current status of hydrogen at present is argued to be comparable to that of renewables at the onset of the millennium, and according to Capgemini, a global technology consultancy body, hydrogen is projected to become competitive in a 10 to 15 years period (Chesteny & Abnett, 2020). But to achieve this projection, major money is required, coupled with a sufficient volume of production, and innovations.

Also, if hydrogen is to be considered as a serious contender for to environmentally harmful fuels, hydrogen must be produced, stored, delivered and utilized in fully sustainable manners (Acar & Dincer, 2020, p. 3397). Presently, Norway enjoys competent actors across the entire value chain in relation to above criteria, such as NEL (e.g. delivering electrolysis and hydrogen fuelling equipment), Hexagon Raufoss (e.g. Storage and Transport) and Equinor (e.g. Experience and capacity to produce blue hydrogen). In addition to actors concerned with technology and production in Norway are clusters, such as Ocean Hyway Cluster, who facilitates workshops and arenas for knowledge conglomeration. Many actors concerned with hydrogen are already ready to act but remain reluctant in the awaiting absence of stronger governmental leadership (I3). Together with Norway's disposition of natural resources, energy and maritime experience and the various R&D communities in Norway, the aggregate resources of disposal, capture the entire resource typology presented in table 1.0 (Section 2.7).

Still, in the event of transforming various segments of the Norwegian economy with hydrogen, there are several barriers that needs to be addressed, including that of desirability. As the interviews shed to light, there is an absence of direct opposition to hydrogen in Norway, apart from some sceptical voices in specific internet forums (I1). Nevertheless, there were an expressed need for greater governmental involvement to that of the present throughout each interview. If hydrogen is to be incorporated into the mix of clean solutions, the State needs to accommodate the niches with greater assurances. For example, the informants alleviated various measures for this purpose, such as more expedient incentives, increased top-down support to regional and local municipalities who does not have sufficient muscles for these ventures, for instance granting rewards for zero emissions requirement in bids for development contracts, and removal of policies favourable to fossil operating actors.

While the central authorities assert that new call for bids should include requirements to zero emissions, the additional cost ends up in the lap of the regional governments, who are tasked with the procurement policy in its respective region (I6). And as it stands, this may prove to be politically difficult considering that regional government also has to justify this risk. After all, at they have a limited budget at disposal, meaning that they also have to balance other needs, for example in the healthcare system or in the educational sector (I6).

> "One of the things we direct attention to, is to make sure that the state budget provides a sufficient framework of revenue to regional and municipal governments, in order for

> them to afford the cost of transitioning to zero-emission technology on ferries and high speed craft ferries" (I3).

In short, regional and municipal governments are found to lack sufficient muscles, or resources, for the risky adventure associated with hydrogen. It should also be mentioned that authorities at regional and municipal level are also aware of other possible alternatives, hydrogen is not the only path to a low-carbon society. And, since hydrogen still lags relatively behind electrical solutions in transport, the former may very well come short in public debates.

4.7.1 Locked in Behaviour?

Though power is not necessarily mobilised to oppose the diffusion of hydrogen in Norway in an coordinated and organised manner, the literature has found that proponents of the established system often attempt to block diffusion of new entrants by influencing the institutional framework so that it continues to be to their advantage (Jacobsson & Bergek, 2004, p. 210). Resistance may in other words be passive (Bakker, 2014, p. 62). Roberts et al. (2018, p. 305), for instance, found that even though governments have made firm commitments to espoused climate targets, evidence of contradictory behaviour is visible in terms of lack of serious measures or continued support to fossil industries through subsidies.

Though this is found to be less the case in Norway, it was found that some diesel ferries in Norway for example, are presently exempted from CO_2 tax[13] (I6). This implies that some means of transport are, in other words, compensated for running on non-sustainable fuel (I6). Consequently, the *de facto* price gap between fossil and zero emission thus increases, amplifying the barrier in disfavour of already expensive hydrogen technology.

Recent trends, however, indicates that fossil fuels will become increasingly subjugated to CO_2 taxation. In a correspondence between former Minister of Finance, Siv Jensen, and Representant of Parliament, Else-May Botten, on the matter of the effect of CO_2 taxation on emission mitigation performance, CO_2 taxation on fossil fuels are sanctioned as it reinforces incentives to develop hydrogen and electrical vessel and put them into use (Jensen, 2018). As codified in the government's action plan for 'Greening the Fleet' pricing of emissions are emphasised the authorities' primary tool in regards of their climate policy (Regjeringen, 2019b,

[13] The CO^2 tax rate stands at 1,33 Norwegian Kroner. Yet vessel of fisheries receives a refund of 1,04 kroner for every litre. According to Teknisk Ukeblad, a total of 523 million kroner were given in refund in 2017, an increase of approximately 100 million from two years before (Fenstad, 2018)

p. 58). From 2020 to 2025, the CO_2 tax will increase by 5 per cent annually, as stated in the action plan.

Whether the maintenance of fossil fuels ‘subsidies’ in specific areas in Norway evidence continuation of locked-in behaviour or rather resemble an echo of the past requires future scrutiny. Nevertheless, the importance of tackling climate change is found to be largely agreed upon across the political spectrum in Norway. Instead, contradictory policy such fossil fuel subsidy may rather reflect diverging roles actors in sustainability transition are playing. The state also relies on economic growth, meaning that it needs to also advance the general interest of capital according to Burnham (1990), (in, Geels, 2014, p. 26). The oil and gas industry for instance, provides a substantial contribution to Norwegian gross domestic product (GDP), both in terms of revenue and taxation, and job creation.

4.7.2 Regime-Actor Alliances

Though Equinor has rebranded itself as a ‘broad’ energy company compared to its former form of Statoil, it remains heavily invested in fossil resources regardless of their overseas experiments with hydrogen and wind. Continued oil and gas exploration is here legitimised in light of projected energy need of present and future generations (Equinor, 2020b). While being multi-national, Norway owns the majority of shares in the company. According to Geels (2014, p. 26), dependency may lead to relational networks and close contact between big business and senior policy makers. As a result of the continuous nearness, in this case between the state and Equinor, the ideas and interest of the industry may become internalized in political way of thinking. A key principle in the way Norwegian natural resources are managed take the interests of companies operating of the Norwegian continental shelf into account when formulating regulations (Norsk Petroleum, 2019). Building on insights from Newell and Paterson (1998, p. 684), fossil energy companies therefore enjoy a privileged position in state policy-making processes, where governments routinely consult and take account of the interest of energy lobbies when proposals are being formulated.

For example, in comparison with other oil and gas producing countries, the Norwegian oil and gas sector is said to maintain high environmental standards (Norsk Petroleum, 2020b). This view was furthered by the former Minister for Oil and Energy, Kjell-Børge Freidberg, who further characterised Norwegian oil as clean and safe (Skarsaune, 2018). This way of thinking has been criticized for being a fairy tale where Norwegian gas will displace production of more polluting fossil fuels in Europe (Øvrebekk, 2019). The ‘clean gas’ discourse receives additional legitimacy in line with the development of technical innovations such as CCS, a precondition for production of blue hydrogen.

In parallel with the clean coal discourse, opponents there view CCS as flimsy promise that the industry advocates in order to acquire new permits (Geels, 2014, p. 34). Support for CCS receives special notice in Equinor's newest sustainability commitment, where a 50 per cent reduction of net carbon intensity is envisioned, see (Equinor, 2020a). Hydrogen too, received importance in respect of their envisioned 2050 energy mix. Despite the fact that CCS is technically feasible, critical voices in respect of blue hydrogen view H_2 promotion as way of greenwashing fossil industries as (I3) explained over email (16^{th}. April 2020). True, the promises of CCS technology represent a pathway to reconfigure means of production to more sustainable ends despite uncertainties related to its commercial viability.

Seeing regime actors promote blue hydrogen illustrates the diversity of resources at their disposal, by being able to defend their position by drawing possessed technical capabilities and financial resources. Indeed, the resurrection of hydrogen in Equinor's energy portfolio good news to advocates of hydrogen in Norway. But it remains to been seen how much hydrogen is to be produced by sustainable methods. Either way, arguments in favour of blue hydrogen, is a narrative that neatly aligns, and legitimise continued exploration and extraction of natural gas, but at the same time do not imply deep structural change as associated with socio-technical transitions.

4.8 Technological Neutrality

Another aspect to consider is that which relates to technology push. In respect of the work conducted by bodies of research in Norway, hydrogen's future reach is treated more carefully due to the principle of technological neutrality (Damman & Gjerløw, 2019, p. 5).

> "Independent research institutes should be careful not to push and promote the application of specific technological solutions to the authorities; in the case of hydrogen and fuel cell technology it is more important to provide input to a predictable and long-term strategy for research, development, and demonstration that eventually can lead to commercialization and application into existing and new markets in transport and industry" (I4).

Moreover, the potential market opportunities for hydrogen is highly different in Norway compared to overseas markets. Unlike the EU, Japan, Korea and China, Norway stands as a relatively sparsely populated country. While hydrogen vehicles are deemed beneficial in terms of range, eventual commercialization of hydrogen vehicles in Norway needs to take into account the importance of economies of scale when assessing its market potential due to present costs. The relative size of the Norwegian on-road transport market constitutes a challenge for the diffusion of hydrogen technology. As (I4) noted, it is what happens further down in Europe, and the rest of the world, that is important. Canalizing large-scale subsidies in order to acquire, say, 1 million hydrogen vehicles on Norwegian roads by 2040 as a path to sustainability is neither likely nor reasonable policy (I4), as great financial flows would be required at the expense of Norwegian taxpayers.

Though the unfavourable preconditions of Norway's on-road transport market in terms of economies of scale is worth emphasis, fruitful endeavours may still be reaped in this sector. It is important to note that the value chains of hydrogen technology are highly international. As such, Pilots with hydrogen vehicles should not be neglected. To niches, pilots are important to the degree that they enable innovations to be tested in practice. Hydrogen ventures in Norway, are already enjoying support for this purpose.

The Pilot-E project for instance, sat aside 120 million NOK to calls for hydrogen proposal, with the objective of promoting more rapid development and deployment of environmentally friendly energy technology (Enova, 2020; Innovasjon Norge, 2019). Grants to hydrogen related projects are further provided by support from the Klimasats fund (Miljødirektoratet, 2020a). By developing competence and experience among Norwegian firms through testing, Norway may circumvent the barrier of technology supply to an arguable limited Norwegian transport market by redirecting distribution to larger markets (I4), such as that of Europe's. Oslo for example, have been used as a test arena, to demonstrate the technology, and to advance competencies and technological progress (Regjeringen, 2015). Together, these support schemes represent concrete support from the top, which enables lower levels of government to initiate pilot-projects and testing.

However, following the insights from (I6), it was found that call for bids from regional governments, that included zero-emission requirements on ferries for example, conflicts with the support guidelines of Enova that triggers financial aid to come about. Meaning that, fund scheme from Enova are not adequately rigged in relation to hydrogen projects. Enova, who has the monetary muscles to aid diffusion of hydrogen, was further exposed to have played a somewhat reluctant role in relation to hydrogen support (I3). While, support from the klimasats scheme is found to be more appropriate for hydrogen, the financial size of these grants is said to be limited for the realisation of new technology (I6).

4.9 Exploiting the Windows of Opportunity

Despite receiving notice in Norway's new transport plan, the window of opportunity for large scale commercialization of hydrogen appears to be less open compared to that in the maritime sphere. According to Frode Seland, the battery was able to break through into the Norwegian market as the infrastructure was already there (Ursin, 2018). As the government initiated a strong policy for EV diffusion through favourable economic incentives, a market was subsequently successfully created (Regjeringen, 2019a). Battery technology was also recently deemed the most suitable solution for replacing diesel driven trains according to the Minister of Transport Knut Aril Hareide when confronted on the prospect of a 'green' hydrogen-based railway (Stortinget, 2020).

For aquatic highways on the other hand, do hydrogen appears to have the upper hand, given its range, where batteries are found to fall short. Promising developments in Norway seems to indicate a somewhat traction, for example with projects in Rogaland and Finnmark. However, in the awaiting absence of clearer governmental support repeatedly highlighted during the interviews, such as with a hydrogen strategy, a general reluctance remains in the atmosphere among key actors, both within sub-governmental domains and private spheres. In contrast to foreign nations such as Japan, Korea and China where their governments play an active role in technology promotion, Norway has performed more passive approach (I4). Yet, actors concerned with hydrogen requires a certain degree of assurance and predictability given innated risks of investments.

Further support to the claims made on the residing reluctance can be found on the Norwegian Hydrogen Forum's websites[14] and regional government's application letters for Klimasats grants[15], which underscores the importance of state involvement and broader coordination among relevant actors in order to overcome the financial and structural risks (Hordaland Fylkeskommune, 2019, p. 1).

In overcoming these barriers, actors concerned with hydrogen diffusion, such as, industry, clusters, forums and NGOs, are found to mobilize pressure on central authorities. Overall, the

[14] (NHF, 2020b)
[15] Application to Klimsats support regarding coordination of vessel purchases (Hordaland Fylkeskommune, 2019)

hydrogen community has worked actively to promote the opportunities of hydrogen in the transport sector (NHF, 2017). The birth of the yet to come national hydrogen strategy is one example of an outcome that might have been initiated due to such pressure, especially the work done by Norwegian Hydrogen Forum has been salient in this regard (I1). Networks are also built transnationally, which includes participation and demonstration projects in Europe, as well as collaboration with Asian and North American Countries (NHF, 2017, p. 10).

More subtle however, is work undertaken more at the grassroot level, through the form of communicating the benefits of hydrogen. For example, Ocean Hywind Cluster notes that a significant amount of attention is directed towards the aspect of social acceptance, for example by holding lectures at middle- and high schools (I2). "...it is of crucial importance to establish a sense of assurance among politicians, the administration and regular consumers regarding the matter of safety" (I2). Indeed, hydrogen may explode, and this concern is of key interest to the public eye. Similar trends of scepticism were also prominent during the emergence of LNG but faded following its incorporation to society (I3).

Additionally, it has been important that certain individuals in the state apparatus has been active in placing hydrogen on the agenda (I3), such as former Minister of the Environment, Ola Elvestuen and his state secretary Atle Hamar.

What's important to take into the equation, is that power is not only wielded by actors in the regime in the format that power is understood here. Actors at the niche level build up power as they test, learn and acquire competence, to which to further convey to additional actors, for example through workshops or in clusters. As they do so, their power becomes amplified, heightening their aggregate of resources at disposal when they place pressure on actors in the regime.

5.0 Discussion

RQ1:

"*How does power and politics enable and constrain the diffusion of hydrogen in Norway in respect of its' [Norway's] proclaimed transition to a low carbon society*?"

RQ2:

"*What barriers and opportunities are presently of blocking or enabling the diffusion of hydrogen in Norway*?"

To answer these questions, this thesis has employed Geels' MLP as its guiding theoretical framework. Based on the findings mapped out in the sections above, several opportunities exist for the diffusion of hydrogen. Likewise, do the findings give life to the variety of barriers negating its' ascendancy. To understand the relevance of power and politics more clearly, this section aims to align the findings more explicitly in the MLP, so that a conclusion may take form.

First, let us return to the particularities of Norway's deep grammar. Theoretically speaking, the syntax of Norway's regimes is made up by the following particularities: Policy, technology, culture, science, industry and, markets and user preferences. Each of these nodes, convey important clues to the current practices and rules in socio-technical regimes, such as transport- and energy systems. Furthermore, it is argued that these nodes require to be viewed in relation to the situational context of Norway in to acquire a fully-fledged comprehension. As pinned down, Norway, is a leading maritime nation. Since the early 1900s, it has maintained a strong record of resource nationalist policies, seen in its dealing with hydroelectric energy production and subsoil wealth.

Technological development has followed this trajectory, to which Norway has been able to build up a strong hydroelectric and offshore industry owed to by its accumulation of competence over the years, accompanied by the co-evolution of technological and safety standards. Of the energy consumed in Norway, an incredibly high percentage stems from its well-established hydroelectric industry, which now increasingly penetrates the automobile market. True, the popularity of EV and hybrid vehicles is surging, but their overall share still remain asymmetric compared to traditional combustion engines (SSB, 2019). While Norway subscribes to a rationality of technological neutrality, the State performs a powerful role in shaping the direction of the national economy, along with its' coalition of incumbent supporters, such as Equinor.

Now, from our borrowed theories on power, we know that this regime is inherently stable. Deep system changes do not come easily. Yet, the direction of Norway's socio-technical systems is not carved in stone, and we should further be careful in treating regime actors automatically as the 'antagonists' in transitions. Due to increasing concern of global warming and climate change, the State has made ambitious commitments to alter its strain on the environment. Though stability is prescribed as a key characteristic of regimes, the power and politics that underpin the development and implementation of specific policies are highly affected by internal and external factors. For instance, there is a reason why the popularity of EV is surging. Likewise, there is a reason why niche actors have taken upon them the risky task of hydrogen experimentation, to which they have pushed central authorities to announce a hydrogen strategy. Belonging to a highly globalised world, the potency of landscape changes, such as the rising acceptance and concern of climate change is not to be underestimated, as it has prompted a global recognition of the current predicament that nation-states find themselves (in, McGrew, 2017. p. 17), and to subsequent action. Though the plunging prices on oil and the spread of Covid-19 are treated as exogenous shocks if importance, it remains too early to make firm claims about their true impacts on hydrogen diffusion.

Hydrogen is however an odd case. While humanity's unfortunate strain on the environment has been a vital co-existing force in possibly opening hydrogen's window of opportunity, there are important considerations that requires attention. The prospective picture of opportunity to hydrogen is large. But hydrogen is not necessarily the best option for every domain in Norway, and eventual policy development may come to reflect this fact. First, it is haunted by significant barriers such as modest energy efficiency, level of matureness, and high investment cost. Secondly, electricity in Norway is already produced on sustainable practices. As accounted for, electricity manifests the best option from a sustainability perspective, provided that it is suitable for the given application. These are all important consideration to take into account when assessing how power and politics either enable or constrain the diffusion of hydrogen and to what degree it is desirable.

Norway may very well be committed to tackle climate change but pursuing options that are less suitable just for the sake of integrating hydrogen is unlikely to gain traction. Therefore, it must be stressed that in some instances, hydrogen is not necessarily constrained by powerful actors, but also by its own shortcomings relative to other low-carbon solutions. While it may very well be fair to claim that the established position of hydroelectric power in Norway reduces the stimulation of hydrogen diffusion, but whether that is a result of power exercise against hydrogen diffusion is less clear from this thesis' point of view. Nevertheless, if one is to create a market for hydrogen, it is important to scale up the infrastructure on the production and supply side, coupled with incentives at both ends. Accordingly, the relevance of power and politics cannot be ruled out. However, this requires central authorities to coordinate its' politics on the production side with that of the consumer side, as was failed to see in the flawed roll-out of the HyNor project.

As noted, transition studies have frequently identified ways in which regime actors actively resists socio-technical transitions. But in terms of opposition, the analysis of this thesis' data did not manage extract any explicit opposition to hydrogen development in Norway. While we should be cautious in explaining why without any hard evidence, it is worthwhile to note that hydrogen diffusion is still in an early stage of development, meaning that it may not be viewed as significant threat to other incumbents at the time of writing. Regime actors are found to play supporting roles, meaning that they also contribute to the development of hydrogen, for example through piloting schemes. Also, even though it is said to be in the wind, hydrogen's share is barely visible in domestic energy statistics, and even less so on Norwegian roads. But, if more incidences like the one in Sandvika were to happen, there is a chance that future opposition may emerge, especially at local levels, but at the time of writing, these claims remain speculations. Similar conclusions may be drawn in the event of faraway incidents.

Either way, based on theoretical perspectives employed in this thesis, power is viewed as a significant component in alleviating hydrogen upwards on the political agenda. While there may be an explicit lack of opposition from actors in the regime, barriers of institutional nature are very much maintained by the State when following Avelino's (2017) interpretation of power, even though it shows support to hydrogen with some financial or regulatory incentives, and pilot projects. Indeed, the state do possess the resources required to integrate hydrogen more firmly into its sustainable agenda, but as sustainability transitions implies, there are multiple pathways to achieve more sustainable modes of production and consumption, hydrogen is just one out of many. As such, pressure from other agents of sustainability is also worth to keep in mind, such as proponents of wind power, solar and EV. These also represent solutions that have proved their potency, and hydrogen is still relatively in its test phase.

Integrating hydrogen to existing renewables is an option, but also here, there needs to be a discussion on how beneficial this is for society as whole.

Indeed, there are good reasons to why hydrogen is advocated in Norway. Several gaps on the path to sustainability is far from filled. Norway's footprints are still not compatible with the pledges it has made. These gaps can be saturated with the help of hydrogen. Norway belongs to a highly globalised world, where it among else play an active role in supplying energy outside its borders. To policymakers, being situated in a world of tight interconnectedness means that they have to take notice of developments occurring outside of their respective borders. Great opportunities exist especially for the maritime transport sector, the offshore industry and to export. Both hydrogen itself and hydrogen related technology may be exported to markets abroad. As accounted for, hydrogen does not only receive notice in Norway. Promising developments are presently taking place in Norway's closest trading partner, the EU. Japan, China and Korea too, are important players here. Though the latter three are geographically distant, their experiments with hydrogen may prove highly beneficial from an export perspective if Norway decides to become a leading pioneer in the upcoming hydrogen economy, given the interconnectedness of the present world.

Powerful actors, such as Equinor may further absorb hydrogen into their energy portfolio as part of meeting their envisioned emission reduction of 50 per cent. If that pathway is embarked upon, Norway can supply foreign markets, such as the EU, with blue hydrogen, conditioned that CCS technology is incorporated into the production process. Though absorption of niches are argued (in, Geels, 2014, p. 560) as method which regime actors may utilize to resist transitions, the aforementioned instance can be viewed as beneficial from a sustainability transition perspective, as long as sustainable preconditions are met. The export argument may also prove further insights to why central opposition to hydrogen has not been identified, as hydrogen may compensate for a future decline in oil and gas (NHF, 2017, p. 20). Conversely, it may also be argued that canalising substantial support to blue hydrogen production will put green hydrogen in the shade, as fewer resource may flow in this direction.

Explicitly, power and politics are vital elements to hydrogen diffusion, because as the findings have sought to illustrate, hydrogen requires a significant degree of collaboration and coordination in order to become commercially realised by virtue of the pre-existing barriers it faces, especially in the transport sector, including maritime. As the understanding of power in this thesis pointed out, the resources that underpins actors' power are interrelated. Meaning that if hydrogen is to transform regimes such as transport or energy, mobilisation of one resource alone is not sufficient. Recent developments in hydrogen technology may very be able to reconfigure modes of production and consumption, based on what improvement have been made in the technologies, but the innovative capacity of the actor's technology also rests on their ability to exploit the windows of opportunities, enabled by developments in the landscape, and subsequently reinforce the reconfigured structures, as well as to reproduce them. To this end, the hydrogen niche requires willingness and support from the state and powerful incumbents such as Equinor and Enova. But that largely depends on whether the authorities are politically willing to do so. Conclusively, power either enable or constrain the diffusion on hydrogen based the degree of resources mobilised for that purpose. While politics can be said to enable or constrain the diffusion of hydrogen based on whether it is, in fact, desirable among policymakers.

6.0 Conclusion

By name, *The Power of Power*, has sought to demonstrate the important role power and politics play in influencing what kind of power is produced and consumed. In doing so, this thesis has payed loyalty to the methods belonging to the traditions of qualitative research, by interviewing experts and analysing existing documents. Within the methodological box of tools, the aim of understanding power and politics, was further enabled by the guidance of a multilevel framework, enriched by theoretical insights on power and politics. Specialised with these tools, this inquiry was armed with an appropriate set of tools, both to illuminate what barriers and opportunities that currently confronts hydrogen diffusion, but also how power and politics may constrain or overcome challenges of a negating nature.

The key findings paint a picture where hydrogen is confronted by high-costs, level of matureness, inadequate regulatory framework, such as gaps in standards, and a somewhat safety misconception among possible users and markets. Favouring factors on the other hand, are closely associated with the grand challenge of climate change, the increasing convergence of climate awareness and willingness to change from fossil options to low-carbon sources of energy. These are all underlying drivers used to explain why hydrogen are being pushed for, both domestically and globally.

Though power has not been mobilised in an organised manner to inhibit the diffusion of hydrogen in the examined sectors, lack of mobilisation and clearer policies are found to constrain the momentum of hydrogen in Norway at the time of writing. To achieve the end were hydrogen eventually replace fossil fuels within a given sector, different types of resources requires mobilisation, as well as different forms of power exercise, including innovative, transformative and reinforcive power. Presently however, in the absence of hydrogen strategy, a clear direction to where hydrogen is envisioned to head in the future, explicitly, is lacking from central authorities, which largely stands to the disadvantage of hydrogen proponents, who depends on a certain degree of assurances and predictability.

While this paper points to different instances of power and political influence, further research is believed to be required for a more comprehensive view, possibly by extending the scope to other socio-technical systems.

7.0 Policy recommendations

To scale up hydrogen in Norway, there needs to a more reciprocal understanding among the political authorities and actors with interest in hydrogen, so that the risky business of investing in hydrogen can be mitigated. In addition, it is deemed beneficial to review the current regulatory framework in respect of hydrogen, considering that some part is not necessarily up to date with the most recent technology developments. The matter of technology, safety, and environmental standards is also recommended to be addressed in coordination with the EU.

8.0 Bibliography

Acar, C., & Dincer, I. (2020). The potential role of hydrogen as a sustainable transportation fuel to combat global warming. *International Journal of Hydrogen Energy, 45*(5), 3396-3406. doi:https://doi.org/10.1016/j.ijhydene.2018.10.149

Avelino, F. (2017). Power in Sustainability Transitions: Analysing power and (dis)empowerment in transformative change towards sustainability. *Environmental Policy and Governance*. doi:10.1002/eet.1777

Avelino, F., & Rotmans, J. (2009). Power in Transition: An Interdisciplinary Framework to Study Power in Relation to Structural Change. *European Journal of Social Theory - EUR J SOC THEORY, 12*, 543-569. doi:10.1177/1368431009349830

Bakker, S. (2014). Actor rationales in sustainability transitions – Interests and expectations regarding electric vehicle recharging. *Environmental Innovation and Societal Transitions, 13*. doi:10.1016/j.eist.2014.08.002

Baxter, P., & Jack, S. (2010). Qualitative Case Study Methodology: Study Design and Implementation for Novice Researchers. *Qualitative Report, 13*.

Beck, U. (1992). On the Logic of Wealth Distribution and Risk Distribution. . In *Towards a New Modernity* (pp. 1-19). London: Sage.

Bhatasara, S. (2011). From Globalization to Global Sustainability: Perspectives on Transitions. *Journal of Global Citizenship & Equity Education, Volume 1* (1). Retrieved from https://pdfs.semanticscholar.org/6c07/64bab59e30ff5793a051ed49bafa57b1bb9e.pdf?_ga=2.253130253.587834128.1579519585-325342234.1564996471

Burke, M. J., & Stephens, J. C. (2018). Political power and renewable energy futures: A critical review. *Energy Research & Social Science, 35*, 78-93. doi:https://doi.org/10.1016/j.erss.2017.10.018

Chesteny, N., & Abnett, K. (2020). Green hydrogen's time has come, say advocates eying post-pandemic world. *Reuters*. Retrieved from https://www.reuters.com/article/us-health-coronarivus-hydrogen-analysis/green-hydrogens-time-has-come-say-advocates-eying-post-pandemic-world-idUSKBN22K0MJ

D'Allegro, J. (2019, 23.02.2019). Elon Musk says the tech is 'mind-bogglingly stupid,' but hydrogen cars may yet threaten Tesla. *CNBC*. Retrieved from https://www.cnbc.com/2019/02/21/musk-calls-hydrogen-fuel-cells-stupid-but-tech-may-threaten-tesla.html

Damman, S., & Gjerløw, J. C. (2019). *National Policy Paper - Norway*. Retrieved from https://www.hylaw.eu/sites/default/files/2019-03/National%20Policy%20Paper%20-%20Norway%20%2810.03.2019%29.pdf

Dicken, P. (2015). *Global Shift Mapping the Changing Contours of the World Economy* London: Sage Publications

DNV-GL. (2019). *PRODUKSJON OG BRUK AV HYDROGEN I NORGE* (2019-0039, Rev. 1).

Eames, M., & McDowall, W. (2010). Sustainability, foresight and contested futures: exploring visions and pathways in the transition to a hydrogen economy. *Technology Analysis & Strategic Management, 22*(6), 671-692. doi:10.1080/09537325.2010.497255

Elbilgrossisten. (2020). Ladeguiden: tpye 1 og type 2 Retrieved from https://www.elbilgrossisten.no/pages/ladeguiden-type1-type2

Elvestuen, O. (2018). Hydrogen - kan Norge bli verdensledende? Retrieved from https://www.regjeringen.no/no/aktuelt/hydrogen---kan-norge-bli-verdensledende/id2600955/

Energifakta-Norge. (2019a). ENERGIBRUKEN I ULIKE SEKTORER. Retrieved from https://energifaktanorge.no/norsk-energibruk/energibruken-i-ulike-sektorer/

Energifakta-Norge. (2019b). Kraftproduksjon. Retrieved from https://energifaktanorge.no/norsk-energiforsyning/kraftforsyningen/

Enova. (2020). Pilot-E. Retrieved from https://www.enova.no/pilot-e/information-in-english/

Equinor. (2005). "Hydrogen highway" between Oslo and Stavanger. Retrieved from https://www.equinor.com/en/news/archive/2005/05/20/HydrogenHighwayBetweenOsloAndStavanger.html
Equinor. (2020a). Equinor lanserer ambisjon om å redusere netto karbonintensitet med minst 50 % innen 2050. Retrieved from https://www.equinor.com/no/how-and-why/climate.html
Equinor. (2020b). Leting. Retrieved from https://www.equinor.com/no/what-we-do/exploration.html
European Commission. (2019). *The European Green Deal* (COM(2019) 640). Retrieved from https://g8fip1kplyr33r3krz5b97d1-wpengine.netdna-ssl.com/wp-content/uploads/2019/12/The-European-Green-Deal-Communication.pdf
Fenstad, A. (2018). Fiskerne får subsidiert diesel i 2019, men i 2020 må de kutte utslipp. *Teknisk Ukeblad*. Retrieved from https://www.tu.no/artikler/fiskerne-far-subsidiert-diesel-i-2019-men-i-2020-ma-de-kutte-utslipp/447781
Findlay, R., & O'Rourke, K. H. (2007). *Power and Plenty Trade, War, and the World Economy in the Second Millennium*. New Jersey: Princeton University Press.
Forskningsrådet. (2019). Pilot-E: Helhetlig leveransekjede for hydrogen eller innovative løsninger for utslippsfri bygg- og anleggsvirksomhet. Retrieved from https://www.forskningsradet.no/utlysninger/2019/pilot-e-helhetlig-leveransekjede-for-hydrogen-eller-innovative-losninger-for-utslippsfri-bygg--og-anleggsvirksomhet/
Frafjord, E., Lydersen, T., & Skodje, M. (2020). Tror på mer gull i havet: Regjeringen øker med 70 mill. til mineralutvinning. *NRK*. Retrieved from https://www.nrk.no/rogaland/sp-vedum-krever-bedre-oljetiltak-na _-erna-vil-kartlegge-mineraler-1.15012639
Frattaroli, S. (2012). Qualitative Methods. In G. Li & S. P. Baker (Eds.), *Injury Research: Theories, Methods, and Approaches* (pp. 221-233). Boston, MA: Springer US.
Frydenlund, S. (2017). Hvor bærekraftig er hydrogen som drivstoff? Retrieved from https://elbil.no/hvor-baerekraftig-er-hydrogen-som-drivstoff/
Fuel Cells and Hydrogen Europea (FCH). (2019). *Hydrogen Roadmap Europe*

A Sustainable Pathway for the European Energy Transition. (EG-06-18-327-EN-N). Retrieved from https://www.fch.europa.eu/sites/default/files/Hydrogen%20Roadmap%20Europe_Report.pdf
Fuenfschilling, L., & Binz, C. (2018). Global socio-technical regimes. *Research Policy, 47*(4), 735-749. doi:https://doi.org/10.1016/j.respol.2018.02.003
Fylkeskommune, H. (2019). *Koordinering av nasjonal hydrogenflåtebestilling*. Retrieved from https://www.miljodirektoratet.no/myndigheter/klimaarbeid/kutte-utslipp-av-klimagasser/klimasats/2019/koordinering-av-nasjonal-hydrogenflatebestilling/
Gamal, R. E., Lawler, A., & Astakhova, O. (2020). OPEC's pact with Russia falls apart, sending oil into tailspin. *Reuters*. Retrieved from https://www.reuters.com/article/us-opec-meeting/opecs-pact-with-russia-falls-apart-sending-oil-into-tailspin-idUSKBN20T0Y2
Garud, R., & Gehman, J. (2012). Metatheoretical Perspectives on Sustainability Journeys: Evolutionary, Relational and Durational. *Research Policy, 41*, 980–995. doi:10.1016/j.respol.2011.07.009
Garud, R., Gehman, J., & Karnøe, P. (2010). Categorization by association: Nuclear technology and emission-free electricity. In D. S. Wesley & J. D. Robert (Eds.), *Institutions and Entrepreneurship* (Vol. 21, pp. 51-93): Emerald Group Publishing Limited.
Geels, F. (2002). Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. *Research Policy, 31*(8), 1257-1274. doi:https://doi.org/10.1016/S0048-7333(02)00062-8
Geels, F. (2010). Ontologies, socio-technical transitions (to sustainability), and the multi-level perspective. *Research Policy, 39*(4), 495-510. doi:https://doi.org/10.1016/j.respol.2010.01.022

Geels, F. (2011). The multi-level perspective on sustainability transitions: Responses to seven criticisms. *Environmental Innovation and Societal Transitions, 1*(1), 24-40. doi:https://doi.org/10.1016/j.eist.2011.02.002

Geels, F. (2014). Regime Resistance against Low-Carbon Transitions: Introducing Politics and Power into the Multi-Level Perspective. *Theory, Culture & Society, 31*(5), 21-40. doi:10.1177/0263276414531627

Geels, F., & Schot, J. (2010). The Dynamics of Transitions: A Socio-Technical Perspective. In (pp. 11–104).

Geels, F., Sovacool, B., Schwanen, T., & Sorrell, S. (2017). Sociotechnical transitions for deep decarbonization. *Science, 357*, 1242-1244. doi:10.1126/science.aao3760

Genus, A., & Coles, A.-M. (2008). Rethinking the multi-level perspective of technological transitions. *Research Policy, 37*, 1436-1445. doi:10.1016/j.respol.2008.05.006

Gilpin, R. (2001). *Global Political Economy*. Princeton: Princeton University Press.

Gjerstad, S. (2019). 10.000 elever skulker skolen for klimaet. *TV2* Retrieved from https://www.tv2.no/a/10627428/

Goering, L. (2019). Climate-change protesters poised to kick off global wave of street marches. *Reuters*. Retrieved from https://www.reuters.com/article/us-climate-change-march/climate-change-protesters-poised-to-kick-off-global-wave-of-street-marches-idUSKBN1W4365

Golafshani, N. (2003). Understanding Reliability and Validity in Qualitative Research. *The Qualitative Report, 8*(4), 597-606. Retrieved from https://core.ac.uk/download/pdf/51087041.pdf

Healy, N., & Barry, J. (2017). Politicizing energy justice and energy system transitions: Fossil fuel divestment and a "just transition". *Energy Policy, 108*, 451-459. doi:https://doi.org/10.1016/j.enpol.2017.06.014

Hiller, J., & Hampton, L. (2020). Oil in the age of coronavirus: a U.S. shale bust like no other. *Reuters*. Retrieved from https://www.reuters.com/article/us-global-oil-shale-bust-insight/oil-in-the-age-of-coronavirus-a-u-s-shale-bust-like-no-other-idUSKCN21X0HC

Hulst, N. v. (2019). Three reasons why the IEA report on hydrogen is a game-changer. Retrieved from https://www.iea.org/commentaries/three-reasons-why-the-iea-report-on-hydrogen-is-a-game-changer

IEA. (2019a). The Future of Hydrogen Retrieved from https://www.iea.org/reports/the-future-of-hydrogen

IEA. (2019b). Global demand for pure hydrogen, 1975-2018. Retrieved from https://www.iea.org/data-and-statistics/charts/global-demand-for-pure-hydrogen-1975-2018

IEA. (2019c). Korea Hydrogen Economy Roadmap 2040. Retrieved from https://www.iea.org/policies/6566-korea-hydrogen-economy-roadmap-2040

IEA. (2020). Oil. Retrieved from https://www.iea.org/reports/world-energy-outlook-2019/oil#abstract

IMF. (2020). *World Economic Outlook*. Retrieved from https://www.imf.org/en/Publications/WEO/Issues/2020/04/14/weo-april-2020

Innovasjon Norge. (2019). PILOT-E - Energiprosjekter fra ide til marked. Retrieved from https://www.innovasjonnorge.no/no/tjenester/utlysninger/pilot-e-2019/

Innovation, S. (2017). SocioTechnical Systems. Retrieved from https://systemsinnovation.io/sociotechnical-systems-articles/

IPCC. (2018a). *Summary for Policymakers. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*. Retrieved from https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_SPM_version_report_LR.pdf

IPCC. (2018b). *Sustainable Development, Poverty Eradication and Reducing Inequalities. In: Global Warming of 1.5°C.* . Retrieved from https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_Chapter5_Low_Res.pdf

IPCC. (2020). Reports. Retrieved from https://www.ipcc.ch/reports/

Jacobsson, S., & Bergek, A. (2004). Transforming the energy sector: The evolution of technological systems in renewable energy technology. *Industrial and Corporate Change, 13*, 815-849. doi:10.1093/icc/dth032

Jenkins, K., Sovacool, B. K., & McCauley, D. (2018). Humanizing sociotechnical transitions through energy justice: An ethical framework for global transformative change. *Energy Policy, 117*, 66-74. doi:https://doi.org/10.1016/j.enpol.2018.02.036

Jensen, A. B. (2019). Årsaken bak Sandvika-eksplosjonen: To bolter ble skrudd til for svakt. *Teknisk Ukeblad*. Retrieved from https://www.tu.no/artikler/slik-startet-lekkasjen-som-forte-til-hydrogen-eksplosjonen-i-sandvika/468765

Jensen, S. (2018). *Svar på spm. 346 fra stortingsrepresentant Else-May Botten*. (18/4336). Retrieved from https://www.regjeringen.no/no/aktuelt/svar-pa-spm.-346-fra-stortingsrepresentant-else-may-botten/id2619224/

Jin, H., & Chung, J. (2019). Hydrogen hurdles: a deadly blast hampers South Korea's big fuel cell car bet. *Reuters* Retrieved from https://www.reuters.com/article/us-autos-hydrogen-southkorea-insight/hydrogen-hurdles-a-deadly-blast-hampers-south-koreas-big-fuel-cell-car-bet-idUSKBN1W936A

Johnstone, P., & Newell, P. (2018). Sustainability transitions and the state. *Environmental Innovation and Societal Transitions, 27*, 72-82. doi:https://doi.org/10.1016/j.eist.2017.10.006

Kemp, R., Schot, J., & Hoogma, R. (1998). Regime shifts to sustainability through processes of niche formation: The approach of strategic niche management. *Technology Analysis & Strategic Management, 10*(2), 175-198. doi:10.1080/09537329808524310

Kerber, R., Green, M., & Jessop, S. (2020). For richer or poorer: coronavirus, cheap oil test climate vows. *Reuters*. Retrieved from https://www.reuters.com/article/us-health-coronavirus-climate-analysis/for-richer-or-poorer-coronavirus-cheap-oil-test-climate-vows-idUSKBN20Z0PD

King, N., & Horrocks, C. (2010). *Interviews in Qualitative Research*. London: SAGE Publication Ltd

Knutsen, R. G. (2019). Regjeringens hydrogenstrategi Retrieved from https://www.regjeringen.no/no/aktuelt/regjeringens-hydrogenstrategi/id2678082/

Köhler, J., Geels, F., Kern, F., Markard, J., Wieczorek, A., Alkemade, F., . . . Wells, P. (2019). An agenda for sustainability transitions research: State of the art and future directions. *Environmental Innovation and Societal Transitions*. doi:10.1016/j.eist.2019.01.004

Koistinen, K. (2019). *Actors in Sustainability Transitions.* (Doctoral). Lappeenranta-Lahti University of Technology LUT, Lappeenranta. Retrieved from https://lutpub.lut.fi/bitstream/handle/10024/159322/Katariina%20Koistinen%20A4.pdf?sequence=1&isAllowed=y

Lawhon, M., & Murphy, J. T. (2011). Socio-technical regimes and sustainability transitions: Insights from political ecology. *Progress in Human Geography, 36*(3), 354-378. doi:10.1177/0309132511427960

Markard, J. (2017). Sustainability Transitions: Introduction to newcomers [June 17]. IST Conference, Gothenburg.

Markard, J., Raven, R., & Truffer, B. (2012). Sustainability transitions: An emerging field of research and its prospects. *Research Policy, 41*(6), 955-967. doi:https://doi.org/10.1016/j.respol.2012.02.013

McCauley, D., & Heffron, R. (2018). Just transition: Integrating climate, energy and environmental justice. *Energy Policy, 119*, 1-7. doi:https://doi.org/10.1016/j.enpol.2018.04.014

McDowall, W. (2012). Technology roadmaps for transition management: The case of hydrogen energy. *Technological Forecasting and Social Change - TECHNOL FORECAST SOC CHANGE, 79*. doi:10.1016/j.techfore.2011.10.002

McGrew, A. (2017). In J. Baylis, S. Smith, & P. Owens (Eds.), *The Globalization of World Politics An Introduction to International Relations* (7th ed., pp. 15-30). Oxford: Oxford University Press.

Milfont, T. L., & Markowitz, E. (2016). Sustainable consumer behavior: a multilevel perspective. *Current Opinion In Psychology*(10), 112-117. doi:10. 10.1016/j.copsyc.2015.12.016

Miljødirektoratet. (2020a). Klimasats-prosjekter. Retrieved from https://www.miljodirektoratet.no/myndigheter/klimaarbeid/kutte-utslipp-av-klimagasser/klimasats/klimasatsprosjekter/?type=63901

Miljødirektoratet. (2020b). Klimasats – støtte til klimatiltak. Retrieved from https://www.miljodirektoratet.no/klimasats

Moses, J. W., & Knutsen, T. L. (2012). *Ways of Knowing*. London: Palgrave Macmillan.

Moses, J. W., & Letnes, B. (2017). *Managing Resource Abundance and Wealth*

The Norwegian Experience Oxford: Oxford University Press

Nagashima, M. (2018). Japan's Hydrogen Strategy and Its Economic and Geopolitical Implications. Retrieved from https://www.ifri.org/en/publications/etudes-de-lifri/japans-hydrogen-strategy-and-its-economic-and-geopolitical-implications

Newell, P., & Mulvaney, D. (2013). The Political Economy of the Just Transition. *The Geographical Journal, 179*, 132–140. doi:10.1111/geoj.12008

Newell, P., & Paterson, M. (1998). A climate for business: Global warming, the state and capital. *Review of International Political Economy, 5*, 679-703. doi:10.1080/096922998347426

Norge, I. (2019). Arena. Retrieved from https://www.innovasjonnorge.no/no/subsites/forside/om_klyngeprogrammet/arena/

Normann, H. (2015). The role of politics in sustainable transitions: The rise and decline of offshore wind in Norway. *Environmental Innovation and Societal Transitions, 15*, 180-193. doi:10.1016/j.eist.2014.11.002

Norsk Hydrogen Forum (NHF). (2020). Hydrogenbiler. Retrieved from https://www.hydrogen.no/kjoretoy/hydrogenbiler/

Norsk Hydrogenforum (NHF). (2017). *The Norwegian Hydrogen Guide*. Retrieved from https://www.hydrogen.no/assets/files/files/hydrogenguide/nhf-hydrogenguiden-2017.pdf

Norsk Hydrogenforum (NHF). (2020a). Her finner du hydrogenstasjonene i Norge. Retrieved from https://www.hydrogen.no/stasjoner/kart-over-stasjoner

Norsk Hydrogenforum (NHF). (2020b). Hydrogendrevet ferge i Geiranger - Hellesylt Hydrogen Hub. Retrieved from https://www.hydrogen.no/maritimt/hydrogendrevet-ferge-i-geiranger-hellesylt-hydrogen-hub

Norsk Hydrogenforum (NHF). (2020c). Medlemmer & sponsorer. Retrieved from https://www.hydrogen.no/norsk-hydrogenforum/medlemmer/

Norsk Petroleum. (2019). Grunnleggende Forvaltningsprinsipper. Retrieved from https://www.norskpetroleum.no/rammeverk/rammeverkgrunnleggende-forvaltningsprinsipper/

Norsk Petroleum. (2020a). EKSPORT AV OLJE OG GASS. Retrieved from https://www.norskpetroleum.no/produksjon-og-eksport/eksport-av-olje-og-gass/

Norsk Petroleum. (2020b). Utslipp til Luft. Retrieved from https://www.norskpetroleum.no/miljo-og-teknologi/utslipp-til-luft/

Osterhammel, J., & Petersson, N. P. (2003). *Globalization a short history*. New Jersey: Princeton Universty Press.

Øvrebekk, H. (2019). Vi trenger en ny norsk olje- og gassfortelling. *Stavanger Aftenblad*. Retrieved from https://www.aftenbladet.no/meninger/kommentar/i/4ql57g/vi-trenger-en-ny-norsk-olje-og-gassfortelling

Øvrebekk, H. (2020). Equinors klimaflørt. *Stavanger Aftenblad*. Retrieved from https://www.aftenbladet.no/meninger/kommentar/i/VbB0er/equinors-klimaflrt
Owens, P., Baylis, J., & Smith, S. (2017). From International Politics to World Politics. In J. Baylis (Ed.), *The Globalization of World Politics: an Introduction to International Relations* (pp. 1-13). Oxford: Oxford University Press.
Planete Energies. (2015). Hydrogen Production. Retrieved from https://www.planete-energies.com/en/medias/close/hydrogen-production
Regjeringen. (2015). *Kraft til endring — Energipolitikken mot 2030*. (Meld. St. 25 (2015–2016)). Retrieved from https://www.regjeringen.no/no/dokumenter/meld.-st.-25-20152016/id2482952/?ch=4#kap17-9
Regjeringen. (2019a). Norge er elektrisk. Retrieved from https://www.regjeringen.no/no/tema/transport-og-kommunikasjon/veg_og_vegtrafikk/faktaartikler-vei-og-ts/norge-er-elektrisk/id2677481/
Regjeringen. (2019b). *Regjeringens handlingsplan for grønn skipsfart*. (T-1567 B). Retrieved from https://www.regjeringen.no/no/dokumenter/handlingsplan-for-gronn-skipsfart/id2660877/
Ren, J., Gao, S., Liang, H., Tan, S., & Dong, L. (2017). Chapter 1 - The Role of Hydrogen Energy: Strengths, Weaknesses, Opportunities, and Threats. In A. Scipioni, A. Manzardo, & J. Ren (Eds.), *Hydrogen Economy* (pp. 1-33): Academic Press.
Reuters. (2019). Reuters ranked as second most trusted news brand in GlobalWebIndex report. *Reuters*. Retrieved from https://www.reuters.com/article/rpb-globalwebindex2019/reuters-ranked-as-second-most-trusted-news-brand-in-globalwebindex-report-idUSKCN1U62E2
Ritchie, H., & Roser, M. (2018). Energy. Retrieved from https://ourworldindata.org/energy
Roberts, C., Geels, F., Lockwood, M., Newell, P., Schmitz, H., Turnheim, B., & Jordan, A. (2018). The politics of accelerating low-carbon transitions: Towards a new research agenda. *Energy Research & Social Science, 44*, 304-311. doi:https://doi.org/10.1016/j.erss.2018.06.001
Robertson Munro, F., & Cairney, P. (2020). A systematic review of energy systems: The role of policymaking in sustainable transitions. *Renewable and Sustainable Energy Reviews, 119*, 109598. doi:https://doi.org/10.1016/j.rser.2019.109598
Saeedmanesh, A., Mac Kinnon, M. A., & Brouwer, J. (2018). Hydrogen is essential for sustainability. *Current Opinion in Electrochemistry, 12*, 166-181. doi:https://doi.org/10.1016/j.coelec.2018.11.009
Samferdseldepartmentet. (2017). *Nasjonal transportplan 2018–2029*. (Meld. St. 33). Retrieved from https://www.regjeringen.no/contentassets/7c52fd2938ca42209e4286fe86bb28bd/no/pdfs/stm201620170033000dddpdfs.pdf
Sanders, Sandvik, P. T., & Storli, E. (2019). Regulation of Natural Resources in the Nordic Countries 1880-1940. In P. T. S. Andreas R.D. Sanders, and Espen Storli. (Ed.). University of British Columbia press: Vancouver (B.C.).
Simons, H. (2014). The Oxford Handbook of Qualitative Research. In P. Leavy (Ed.), *Oxford Library of Psychology* (pp. 455-470). Oxford: Oxford University Press.
Skarsaune, E. (2018). Ny oljeminister vil ha full gass for «ren norsk olje». *E24*. Retrieved from https://e24.no/olje-og-energi/i/QokvOV/ny-oljeminister-vil-ha-full-gass-for-ren-norsk-olje
SSB. (2019). Bil og transport. Retrieved from https://www.ssb.no/transport-og-reiseliv/faktaside/bil-og-transport
SSB. (2020). Bilparken. Retrieved from https://www.ssb.no/bilreg
Steen, M., Bach, H., Bjørgum, Ø., Hansen, T., & Kenzhegaliyeva, A. (2019). *Greening the fleet: A technological innovation system (TIS) analysis of hydrogen, battery electric, liquefied biogas, and biodiesel in the maritime sector*.
Stortinget. (2020). *Skriftlig spørsmål fra Siv Mossleth (Sp) til samferdselsministeren*. (Dokument nr. 15:867 (2019-2020)). Retrieved from https://www.stortinget.no/no/Saker-og-publikasjoner/Sporsmal/Skriftlige-sporsmal-og-svar/Skriftlig-sporsmal/?qid=78702

Taylor, A. (2019). Photos: Climate-Change Protests Around the World. *The Atlantic*. Retrieved from https://www.theatlantic.com/photo/2019/04/photos-climate-change-protests-around-world/588016/
Tjora, A. (2013). *Kvalitative Forskningsmetoder* (2 ed.). Oslo: Gyldendal Norsk Forlag AS.
Tomasgaard, A., Berstad, D. O., Burheim, O. S., Blekkan, E. A., Dawson, J., Espegren, K. A., . . . Ulleberg, Ø. (2019). *Hydrogen i fremtidens lavkarbonsamfunn*. Center for Sustainable Energy Research (CenSES), NTNU Retrieved from https://www.ntnu.no/documents/7414984/0/Hydrogen+i+framtiden_rapport_A4_web_LR+28-03-2019.pdf/cbcf5251-7a61-41ac-88ea-faef5daf558c
Tracker, C. A. (2019). Norway. Retrieved from https://climateactiontracker.org/countries/norway/pledges-and-targets/
Tülüce, N. S., & Yurtkur, A. K. (2015). Term of Strategic Entrepreneurship and Schumpeter's Creative Destruction Theory. *Procedia - Social and Behavioral Sciences, 207*, 720-728. doi:https://doi.org/10.1016/j.sbspro.2015.10.146
Unruh, G. C. (2000). Understanding carbon lock-in. *Energy Policy, 28*(12), 817-830. doi:https://doi.org/10.1016/S0301-4215(00)00070-7
Ursin, L. (2018). Ekspertintervjuet: Ren energi fra vann. Retrieved from https://energiogklima.no/to-grader/ekspertintervjuet-ren-energi-fra-vann/
Vogler, J. (2017). Environmental Issues. In J. Baylis, S. Smith, & P. Owens (Eds.), *The Globalization of World Politics: An Introduction to International Relations* (pp. 385-401). Oxford: Oxford University Press.
Williams, S. (2020). Study suggests civil action is increasing public awareness of climate change. Retrieved from https://www.ceh.ac.uk/news-and-media/news/study-suggests-civil-action-increasing-public-awareness-climate-change
World Commision on Environment and Development. (1987). *Our Common Future: The Wrold Commission on Environment and Development*. Oxford: Oxford University Press.

Appendix

Interview guide – the Power of Power (Translated into English)

Consent:

- Is it okay for you that the interview is to be recorded, transcribed, and subsequently utilised within the frameworks of this project? Data emerging during the interview will only be utilised for this particular investigation and are not be shared with external parties.

- At any given time, you have the right to withdraw your consent, even after the interview. In terms of citing and paraphrasing, data deriving from this interview and utilised in the text will be sent back in advance of the submission date, so that you may verify the citations prior to publication. Your personal data will not come forth in the thesis.

Brief analysis of the myself, the project, and its aim.

Introductory questions

1. How would you explain your (or your institution's) role in hydrogen related work, and how extensive is your experience on the matter?
2. What areas of interest would you say is most prominent in your business (in relation to hydrogen)? For example, what sector is your primary focus?

Theme 1: Hydrogen and Norway

1. How would you describe the Norwegian context in light of blue and green hydrogen?

- Why is Norway advantageous country for hydrogen propulsion? For example in terms of the country's geography, maritime and historical experience or in light of its climate policies.

2. How have the development of hydrogen played out over the years?

- Can you explain this development in more detail?

3. In what ways have the present sustainability challenges played a role in changing actors' hydrogen strategies in Norway?

Theme 2: Resource Mobilisation

4. What kind of developments to you deem are required in order to achieve the diffusion of hydrogen in Norway, contingent on the fact that it is produced, stored, and distributed on sustainable practices?

5. As hydrogen is an energy carrier that may contribute in several applications across different sectors. What kind of resources is mobilised/ do you mobilise in order to stimulate the diffusion of hydrogen in Norway? Can you think of any examples on specific things you do, or is done in general?

- Do your strategies differentiate substantially from other actors with interest in hydrogen?
- Which actors do you deem essential to the diffusion of hydrogen in Norway? International actors are also relevant here.

6. The Norwegian government has announced that a new hydrogen strategy is on the way. Have you played a role in its construction or inception? For example through close dialogue with politicians or lobbying.
7. Can you think of any examples to how you approach central or regional authorities in regards of hydrogen?

Theme 3: Politics and Regulatory Framework

8. How would describe the present political measurement and financial support in respect of hydrogen? Is the government playing an active or passive role? How is hydrogen viewed along the different political parties?
9. Would you say that municipal and regional governments, and private actors, are disposed with an adequate support from central authorities? If yes, please explain why. If no, please explain why not. Example here, may be incentives, type of support, and possible rewards.
10. Can you think of any examples of regulatory barriers that stands in the way of diffusion of hydrogen in Norway?

Theme 4: Opposition, conflict or lack of support.

11. Is there any opposition to hydrogen in Norway today? If yes, please explain why. If no, please explain why not.
12. Can you think of any examples of incumbents that may feel threatened by the diffusion of hydrogen in Norway?

13. Are you familiar with any projects, or planned hydrogen projects that failed? If yes, can you explain what caused it/them to fail?

Theme 5: Visibility and Legitimacy

14. How would you describe the visibility of hydrogens opportunities in Norway? Do many people know about its low-carbon advantages?
15. How would you describe the present legitimacy of hydrogen in Norway? If answered low, what do you do to enhance its legitimacy?

Theme 6: Value creation

16. How may hydrogen generate revenue and job creation if further diffused?

Theme 7: External shocks from the Landscape

17. In what ways influence the ongoing effects of Covid-19 and the slumping prices of oil the diffusion of hydrogen in Norway? How does these developments affect current ventures in hydrogen and the momentum of the climate cause?

Wrapping up:

- Are there any additional perspectives and aspects that you think is necessary to include in my project?
- Do you have any suggestions of reports, regulations, or laws that you think is necessary to include in the analysis?
- Do you have any suggestions to other informants that would be valuable to contact?

Thank you very much for your participation!

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