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Abstract

The installed global solar panel capacity has rocketed since the last decade. After ratifying the Paris Agreement in April 2016, Norway agreed to fulfill their specific goal of 40% reduction of GHG emissions in 2030. Therefore, the electricity production from the Norwegian solar panel has been growing faster than ever before since 2018. However, the solar energy contribution to the Norwegian electricity production sector was still minimal. Therefore, the objectives of this study were to clarify the potential of solar PV installation market in Norway and to explore the role of Solar PV by the Multi-Level Perspective Framework.

A qualitative measure was conducted based on a research question to explain the installation of grid-connected PV capacity developed in Norway up to 2018. The findings indicated that Norwegian government played a key role in particular the financial aspect to facilitate solar PV installation market and respondents had positive outlook towards the market.

The salient point raised in this thesis is that despite the Norwegian policymakers have a very clear goal to maintain the security of supply in the Nordic region and to contribute to the European climate, any policies that is benefit to the environment should be put in top priority. Researchers should not underestimate the research value of solar PV in Norway together with storage technology. While power companies should cooperate with R&D institutions to gain knowledge and enrich the competence base of solar PV since power companies play a crucial role to promote solar PV installation especially to the private market.

Acknowledgment

The basis for this research originally stemmed from my passion for improving energy security by renewable sources. Energy security is something that catches my attention as I foresee this issue will only be more intense in the near future. I worked in the social responsibility department for international companies and saw factories trying to minimize the cost by using the most polluted source of energy. It is sad that human sacrificing the health of their future generations for present desires. I hope Norway can inspire me for feasible sustainable solutions as it is known for many years as Europe's "green power hub".

In truth, I could not have achieved my current level of success without a strong support group. First of all, I would like to express the deepest appreciation to my supervisor Mr. Tor Håkon Jackson Inderberg, who has continually provided academic support during my thesis as well as to give guidance for the preparation, development and completion throughout the study. Secondly, my family members, who supported me with love and understanding. And finally, to thank all the participants who had participated in the survey. It would have been impossible to write this thesis without their help. Thank you all for your unwavering support.

List of Abbreviations and Acronyms

CO_2	Carbon Dioxide
EU ETS	European Union Emissions Trading System
FIN	The Royal Norwegian Ministry of Finance
FIT	Feed-in tariffs
GHG	Greenhouse Gas
IEA	International Energy Agency
IETA	International Emissions Trading Association
IRENA	International Renewable Energy Agency
KLD	The Royal Norwegian Ministry of Climate and Environment
MLP	Multi-Level Perspective
MWp	Megawatts peak
NVE	The Norwegian Water Resources and Energy Directorate
OED	The Royal Norwegian Ministry of Petroleum and Energy
PET	Punctuated Equilibrium Theory
PV	Photovoltaic

1.0 Introduction

1.1 The Trend of Solar PV from a Global Context

Solar Photovoltaic (PV) is regarded as a decentralized source for producing electricity, with a number of benefits and challenges for developing and developed countries. The nature of decentralized electricity generation has several advantages. Solar PV electricity can be generated anywhere when solar radiation energy is available. Besides, there are less losses occurring due to shorter distance in transmission of electricity. Moreover, solar PV electricity generation has fewer constraints on the size of land needed for installation to generate similar amount of electricity compare with other renewable energy power plants. (Solanki, 2013, p. 35).

Solar PV performs a variety of functions such as heating, cooling, lighting, electrical power, transportation and even environmental clean-up (World Energy Council, 2019). Solar has the potential to fulfil such needs due to its abundance, infinity and accessibility. Solar, theoretically, represents a quantity of energy that far exceeds human needs. (Armaroli & Balzani, 2007, p. 56). The global average solar radiation, per m^2 and per year, can produce the same amount of energy as a barrel of oil, 200 kg of coal, or 140 m3 of natural gas (World Energy Council, 2019). Solar energy traditionally being considered as environmentally friendly because the converting solar radiation into electricity does not emit pollutants (Solanki, 2013, p. 35).

Until early 2016, numbers showed that the global installed capacity for solar-powered electricity reached 227 GWe which accounted for 1% of all electricity used globally (World Energy Council, 2019). China (43.1 GW), Germany (39.6 GW), Japan (33.3 GW) and the US (27.3 GW) were the top 4 countries with solar installed capacity in comparison to Norway was only 14MW. As per International Energy Agency (IEA) (2018, p.33), Norway has installed 17 MW of grid-connected solar PV power in 2017: installations were split between commercial (14 MW) and residential (3 MW) installations.

1.2 Intermittency Challenges the Load Duration Curve of Solar PV in General

Despite solar panel installation has more benefits than conventional power plants, the integration of solar PV is still slow in some geographical areas. This may be due to several reasons, including intermittency issues. Sivaneasan, Lim & Goh (2017, p.210) mentioned that negligence of intermittency to integrate large-scaled solar PV system will threaten the stability of a country's power system. Solar energy also has relatively low energy intensity, approximately 8 to $12m^2$/ kW. This is due to the diffuse nature of sunlight and the existing sunlight to electrical energy conversion efficiencies of PV devices that weaken the energy intensity (Florida Solar Energy Center, 2014). Unlike coal can be stockpiled for coal-based power plants and pumped hydro storage for hydropower solar radiation energy cannot be stored to provide energy for future use. For example, solar radiation is unavailable during the night but demand for electricity from the evening is high. Thus, the peak radiation availability during the day may not match with peak electricity demand. Location dependency is also critical to maximize the efficiency of the solar panel is installed where solar radiation is richer than other places that has less sunlight (Solanki, 2013, p. 35-36)

1.3 Norway as a Case Study for Solar PV Energy Policy from Technical, Political, Economic and Environmental Perspectives

To shed light over the dimensions and factors that increase PV uptake, this thesis adopted the case of Norway. This case was useful for illuminating these dimensions since Norway has lagged behind in the development of PV energy. This is in spite of the fact that solar PV activities in Norway has begun more than a century ago yet its contribution to the country's electricity generation sector is still insignificant (Elkem ASA, 2019. The case of Norway can bring important knowledge to address the research question. This will be presented as followed in particular from technical, political and economic perspectives in order to understand whether these perspectives can favour or hinder the increase of solar PV electricity production. Despite different parts of the world has been increasing solar panel installation significantly compared to Norway, the domestic market of solar PV in Norway contributes only about 0.1% of world markets (Klitkou & Coenen, 2013, p. 1796). It is often been told that the exploitation of solar energy in the Scandinavian region should be discouraged because of adverse weather conditions, false beliefs related to the exploitable solar potential a high latitude, logistical impediments and economic feasibility. These deep-rooted ideas just aroused my interest to research this topic.

From a technical perspective, the most noticeable assumptions of (1) cold climate, (2) long hours of darkness and (3) low inclination of solar rays have showed to be less relevant for explaining the usefulness and deployment of solar power (Lobaccaro, Carlucci, Croce, Paparella & Finocchiaro, 2017, p. 347). Several previous researches revealed that PV power plants are more efficient to cold outdoor temperature. Boström (2013) stated that it is incorrect to presume low temperature has a negative effect on solar systems. Norway has colder climate and higher latitudes which favours electricity production from PV power plants. The efficiency of solar cells increases when the ambient temperature drops (Dubey, Sarvaiya & Seshadri, 2013, p.311, 318. Performance begins to drop if the ambient temperature is higher than 25°c (Coley, 2011, p. 432). This means that if the solar cell's surface temperature increases by 20°C, the electric power produced will be reduced by about 8%. A study also showed that the solar radiation in southern Norway have a roughly similar level of resource base as Sweden, Denmark and central Germany (NVE, 2018a). Moreover, Lobaccaro et al. (2017, p. 348) discovered the low inclination of solar rays at high latitudes can utilize vertical harvesting surfaces to capture solar energy. Solar PV plants are most effective at low temperatures, and snow-covered landscapes brought more lights to the panels than otherwise to offset lower solar radiation (OED, 2016, p.164; Benjaminsen, 2019). Since some factors were positive to the solar PV market in Norway, such as this low temperature heat advantage attracted new actors to join the electricity production market. Nevertheless, Good, Lobaccaro & Hårklau (2014, p. 167) reminded that it should be careful with the complex and dynamic overshadowing effect on building surfaces. These complex urban environments are particularly challenging to the typical Scandinavian latitudes.

From a political perspective, the development of PV capacity installation, private households and large-scale commercial installations, has not been studied in large extent in Norway. A previous related study about Norwegian solar PV industry used the Triple Helix Approach to explain the low PV installation rate in Norway (Etzkowitz & Leydesdorff, 1995 1997 2000; Etzkowitz, 2003; Leydesdorff, 2012). The approach identifies systemic contradictions of its energy policy - unparallel development between the support of solar PV R&D and the national policy did not prioritize installation of solar PV facilities. Compare with only 14 MW cumulative solar installed capacity until 2016, 90 solar PV R&D projects were funded by the Research Council of Norway earlier between 1996 and 2009 (Klitkou & Godoe, 2013, p.1591). Most energy policy still targets hydropower and onshore windpower technologies because their installation costs are lower. Nevertheless, Norway is not the first-time facing goal conflicts when developing a policy. The national energy policy previously has also given priority to RD&D on offshore wind but no priority for demand-side policy instruments. The Ministry of Petroleum and Energy (OED) explained that the deployment of offshore wind facility in Norway is too expensive. In fact, the national policy provides strong incentives for further oil and gas extraction and existing renewable energy technology (Klitkou & Godoe, 2013, p. 1593). The study also suggested that solar PV can become price competitive over time if the policy had differentiated feed-in tariffs (FIT) in favour of PV. However, the study did not explain why the policy did not differentiate FIT.

From an economic perspective, a research also mentioned the difficulties faced by solar PV prosumers in Norway (Inderberg, Tews & Turner, 2016). They inducted factors according to two groups of actors: the government and prosumers (Inderberg, Tews and Turner, 2016, p. 74). The Norwegian electricity sector is very mature which almost fully renewables-based by hydropower (Statkraft, 2017). Thus, first, the technology development and installation of hydropower plants are mature. Second, energy that produced by hydropower is also environmental-friendly, green and clean. Therefore, these two favourable factors drive the government to pick the 'low-hanging fruits' rather than switching their investment plan on expensive solar PV power. Furthermore, Norway traditionally has cheap electricity compared to general European prices especially purchasing power is taken into consideration. Together with the less than attractive incentives such as only some installation support without feed-in-tariff which reduced the "needs" to become a prosumer (Inderberg, Tews and Turner, 2016, p. 53, 73, 76).

From an environmental perspective, Norway has been dedicated in mitigating climate change. It promised to achieve several climate goals. The EU's Renewable Energy Directive sets binding national targets to Norway to increase the national share of renewable energy to 67.5% by 2020. The primary solution is to establish an electricity certificate market with Sweden to increase renewable electricity production by 28.4 TWh by 2020 (NVE, 2018b). Besides, after ratifying the Paris Agreement in April 2016, Norway agreed to fulfill their specific goal of 40% reduction of greenhouse gas (GHG) emissions in 2030 compared with the 1990 level (KLD, 2016). In 2017, the Norwegian parliament decided to ban the sale of petrol and diesel-powered cars by 2025 (Independent, 2019). Norway also introduced the European Union Emissions Trading System (EU ETS) in 2005. Until 2018, over 80% of Norwegian emissions are subject to the carbon dioxide (CO_2) tax and/or are covered by the EU ETS. The carbon tax rate for petrol and diesel was corresponding to a tax rate of about NOK 500 per ton CO_2 (International Emissions Trading Association, 2015; UNFCCC, 2018, p. 2, 4).

1.4 Recent Trend of Solar PV Installation in a Norwegian Context from 2018

However, since 2018, Norwegian solar electricity production has been growing at an increased pace. The Norwegian solar PV sector is traditionally understood to be strong in R&D but weak in actual on-the-ground installation, leading to low electricity production by solar PV. A national cluster for the solar energy sector, Solar Energy Cluster (Solenergiklyngen), reported that 23.5 MW solar power was installed in Norway over 2018 and majority were grid-connected (enerWE, 2019a). Installing rooftop solar panel is not just limited to environmental activists but also ordinary people who wanted to save money. There was a significant growth in the private household market in 2018 due to a dry year with expensive electricity and plenty of sunshine which drove solar cells had their highest profitability ever Apart from private small households, larger energy companies and contractors are also examples of new participants in the cluster (Multiconsult, 2019a).

Enova played a critical role in boosting the solar PV installation. Back in Jan 2015, Enova was the only direct national support scheme to prosumers (Nilsen, 2014). However, the subsidization programme did not gain much success to trigger investments at the time despite the support can reach the level of a maximum of NOK 28,750 (about €3000) with basic and additional technical installation support (Inderberg, et al., 2016, p. 62). From 2017 to 2018, Enova has supported almost twice as many energy and climate measures in the private markets. The scheme has subsidized 164.8 million and paid out to 8123 measures in 2017 and 275.4 million for 14 486 measures in 2018 resulted in increased by nearly 80% in just a year included 837 measures for rooftop solar panels (enerWE, 2019b).

With the positive outlook of the Norwegian solar PV sector these recent years, it is optimistic that solar energy can become a more integrated part of the energy mix together with another dominating renewable energy in Norway, the hydropower. This is remarkable to the thesis because the situation accelerates the transition of energy mix by counting more on solar PV energy due to a little triumph of the demand-side policy. The latest development of solar PV capacity provides the prelude of the research question. This radical development provides more observations from the dynamic interactions between actors.

As mentioned in the significance of research, the story of Norwegian solar PV has started over a century ago about the production of solar cell materials. However, despite the growth of total cumulative installed capacity rose by 52% to 68 Megawatts peak (MWp) between 2017 and 2018 (Multiconsult, 2019b, p. 41-42), the share of solar PV in the electricity generation sector was still less than 1 GWh compare with hydropower was 144005 GWh until 2016 (IEA, 2019a; IEA, 2019b)Therefore, it is important to investigate the reasons behind the slow growth more deeply.

1.5 The Research Question

To address the slow growth of solar PV installation capacity in Norway, climate change naturally becomes a key factor. Since the Norwegian electricity price soars due to lack of melted snow to generate hydropower and simultaneously the government keep improving the existing prosumer support schemes and presence of prosumer installation companies, it is foreseeable to have a lower threshold to enter the prosuming market. This favours more urban electricity production, closer to where it is used.

Resting on the above basis, this thesis will investigate an overarching research question:

> ***How has the installation of grid-connected PV capacity developed in Norway up to 2018, and how can this be explained?***

1.6 Address the Problem Statement

In this regard, the focal point of the problem statement will be the recent trend of solar PV installation in Norway in terms of (1) private households who produce electricity from their rooftops and (2) large-scaled professional markets for companies that are involved in other businesses but at the same time also a power producer. To bring forward to future research, the following study will examine if climate awareness, fluctuating electricity price and improved supply-and-demand-side policy can trigger faster transition of the Norwegian electricity sector to solar PV. In particular, the effect of demand-side policy to integrate the solar PV system is also a main focus of this study. There are still only few actors involved in the market development of solar PV in Norway because of the supply-side policy has been outweighing the demand-side policy for decades. Several researches from previous section have also mentioned this imbalance of supply-and-demand-side policy problem. Thus, it is important to study of the Norwegian Solar PV integration can be accelerated with the effect of these internal (policies) and external (climate change) factors.

A Multi-Level Perspective (MLP) will be used as a theoretical framework to outline the landscape, regime and niche of the Norwegian energy policy in relation to the renewable solar PV energy. Since MLP is a holistic and heuristic framework to analyse the process of substitution of a technological paradigm. This paper aims to study the potential of solar PV to substitute the existing system and incumbents.

1.7 Objectives of the Research

This study was conducted to accomplish four research objectives: (1) explore the role of solar PV in a Norwegian context, (2) to understand what factors favour or deter the increase in solar PV capacity, (3) to discuss the transition of Norwegian solar PV market in a MLP context and (4) to provide implications to stakeholders which can facilitate the solar PV capacity.

The first step was to familiarize with the history and developments of solar PV and the electricity market in Norway. Then to position the status of solar PV across the three levels within the MLP. Finally, to investigate further the root cause from the findings and to propose ways for improvement.

1.8 Significance of the Research

The importance of the research is to present the potential and benefit of developing solar PV in Norway from different actors' perspective as well as to explain the trend of solar PV uptake until 2018. Nowadays, solar PV has gained recognition over the world and researches have proven the possibility of solar PV application in high latitude regions. The trajectory of solar PV in Norway can be traced back to more than a century ago in 1907 where Elkem was founded to produce the materials for solar PV cells (Elkem ASA, 2019). But why the share of solar PV in the Norwegian electricity production sector is still negligible until today and the researcher frontier is limited. Instead, the environmental controversial hydropower has become more and more important and even serve as the backbone of the sector. Therefore, there is the need to explore the root causes so as to tackle the problem and to provide sustainable solutions. This study will help market players to understand the barriers of solar PV development and to provide recommendations to policymakers to enhance the effectiveness of the electricity system so as to create window of opportunities for the solar PV market.

1.9 Structure of Thesis

This thesis consists of 7 chapters. Chapter 1 introduces the research question and addresses the aim of the study as well as to provide a list of literatures from different perspectives regarding the research topic. Chapter 2 demonstrates the theoretical framework that the operationalization of variables will be encountered throughout the whole thesis. This paves the way to explain the empirical information base on this framework. Chapter 3 presents the research design and methodology. Research timeline and limitations are also included. Chapter 4 analyses the collected data to present empirical findings thematically according to the framework. Chapter 5 discusses research limitations and empirical insights in light of debates in the research topic based on the literature. Chapter 6 concludes the researcher's thoughts and restates the research objectives. Chapter 7 is the last chapter that proposes recommendations, and implications for further research.

2.0 Theoretical Framework

2.1 Introduction

In this chapter, the theoretical framework that used in the thesis was presented and elaborated. The Multi-Level Perspective framework (MLP) has been chosen out of three feasible theories, to address the research question. The main structure of this chapter included functions of theories to serve the purpose of research, main options for theoretical strategy choice, groundings and general points of MLP, MLP in application, the 4 transition pathways and contribution of MLP to address this research.

2.2 Functions of Theories to Serve the Purpose of Research

The social science functions of a theoretical framework to be applied in the thesis is among other things to position the role of solar PV installation capacity in the Norwegian electricity generation market. The framework served as a guideline to discover the underlying causes of slow development of solar PV uptake from various perspective in order to address the research question. The framework also provided a decent structure to outline solutions for stakeholders and pave the way for future researches.

There were at least three theories that reasonably could be applied to address the research question of this study, i.e., Multi-Level Perspective (MLP), Triple Helix Model and punctuated equilibrium theory (PET). MLP can be used for the assessment of policy. MLP is developed to describe the dynamics of wider transitionary developments among configurations of technologies, infrastructures, social practices, institutions and markets in a long-term process (Kern, 2012, p. 298). Osunmuyiwa, Biermann and Kalfagianni (2018) analysed political dimensions of energy transitions in Nigeria by refining MLP. The Triple Helix approach investigates how innovations develop in line closely with the government, academia and industry in modern societies (Etzkowitz & Leydesdorff, 1997). Klitkou and Godoe (2013) adopted Triple Helix framework to explain the emergence of the Norwegian PV manufacturing industry. PET have been adopted in study transition concepts especially the diffusion of public policy innovations (Boushey, 2012). Kern and Rogge (2018, p. 107-108) characterized PET consists of path dependent phenomena and gave an example of Busch and Jörgens (2011) which was about the diffusion of solar PV technology closely coincided with the diffusion of the German style FIT across Europe.

2.3 Main Options for Theoretical Strategy Choice

MLP is the most suitable theory to address this study's research question. MLP focused on socio-technical system transition towards sustainability and resilience. It was an analytical framework to deal with complexity and resistance to change. Most importantly, the framework could be used to pinpoint the barriers and drivers to measure the effectiveness of a policy (Moradi & Vagnoni, 2018, p. 239). This was because the aim of this study is to investigate the slow development of solar PV uptake. Therefore, to identify the root barriers is essential so as to discover possible drivers that can accelerate the installation capacity.

Therefore, Triple Helix Model was not suitable because it tended to focus on manufacturing industry and the robustness among the government, academia and industry. Nevertheless, the focal point of this research was the influence of energy policies on the actual installation capacity. This kept Triple Helix less relevant compared to MLP. While PET emphasized on negative feedback leads to explosive change for a short period followed by establishment of a new policy (Geels & Penna, 2015, p. 70; Kern & Rogge, 2018, p. 107). This implied one of the four transition pathways from the MLP, e.g., de-alignment and re-alignment pathway (Geels & Schot, 2007, p. 413). However, this pathway was not adequate to describe the emergence of solar PV installation in Norway. Thus, PET would create prejudice on the judgment of choice of pathway which should not adopted in this study either.

2.4 Groundings and General Points of Multi-Level Perspective

MLP is a quite general theoretical framework and describes the relationship between theoretical principles and mechanisms. (Grin, Rotmans, Schot, Geels & Loorbach 2010, p. 18). Geels (2011) indicated that the MLP is a non-linear process to demonstrate overall dynamic patterns within the socio-technical transitions. Since there is no linear causality to drive the transition, it would be an interplay among three levels and dimensions at one time. In the nutshell, there are three interconnected levels, i.e., niches, socio-technical regime and socio-technical landscape, provide different kinds of coordination and structuration to activities. The following paragraphs explained landscape, regime and niches individually with the transition of Norwegian electricity production market as a concrete example.

The landscape developments – a broader and more complex backdrop structure which influences the niches and regime dynamics (Rip and Kemp, 1998). Landscape did not just only refer to the sustainable factors on technical and material aspects but also includes demographical trends, political ideologies, societal values, and macro-economic patterns (Geels, 2011). This referred to international agreement such as CO2 mitigation target ratified by the Paris agreement. External pressure that the government regime was not capable to resist and had to solve the problem. If not, the country might have bad reputation among the international.

The social-technical regime – it is more stable compare to niches because of larger networks and rules which has been established earlier. Regime actors are reluctant to major changes because they have already developed webs of independent relationship with their favourable stakeholders based on culture, norms and ideology (Grin et al., 2010, p. 20). Examples of regime rules are "cognitive routines and shared beliefs ….. and legally binding contracts" (Geels, 2011). Policy makers and economic actors who had the power to decide the type of energy source to be dominated in the electricity generation system.

Niches – "the social networks are small, unstable and precious" (Grin et al., 2010, p. 18). Niche actors are willing to support the in emerging novelties yet diverge from existing regimes. Their ultimate target is to let their innovations to be used in the regime or even as a substitute to the existing one. Examples to be associated with niches are R&D laboratories, subsidised demonstration projects and small market niches. Niche actors could be entrepreneurs, start-ups, spinoffs (Geels, 2011). Academic research institutions and start-up engineering consultancies played a role to modify the solar PV technology and to generalize the technology to the public by offering installation and consulting services.

2.5 Multi-Level Perspective in Application

MLP can be applied to explain for historic transitions to new socio-technical systems for variety of scenarios such as mobility, sanitation, entertainment, food, lighting and so on (Smith, Vob & Grin, 2010, p.436). MLP provides a framework to analyse different transition pathways. As pointed out by Grin et al. (2010, p. 54), some scholars referred to the MLP as a standardized representation of transitions. Sovacool (2016) proposed that different kinds of alignments result in different transition pathways. In an earlier research of Geels (2004), he mentioned that transitions based on the importance of alignments between developments at multiple levels. Grin et al. (2010, p. 51) suggested the operationalization of MLP is a "structuration theory thus provides a systemic socio-local explanation of (technological) trajectories". The essence of MLP is to investigate the interactions among various populations and how different trajectories evolve together. Therefore, Geels and Schot (2007) further consolidated the criteria to define pathways typology combined with two new dimensions, i.e., the timing and nature of the multi-level interactions. This created four types of transition pathways to differentiate the MLP.

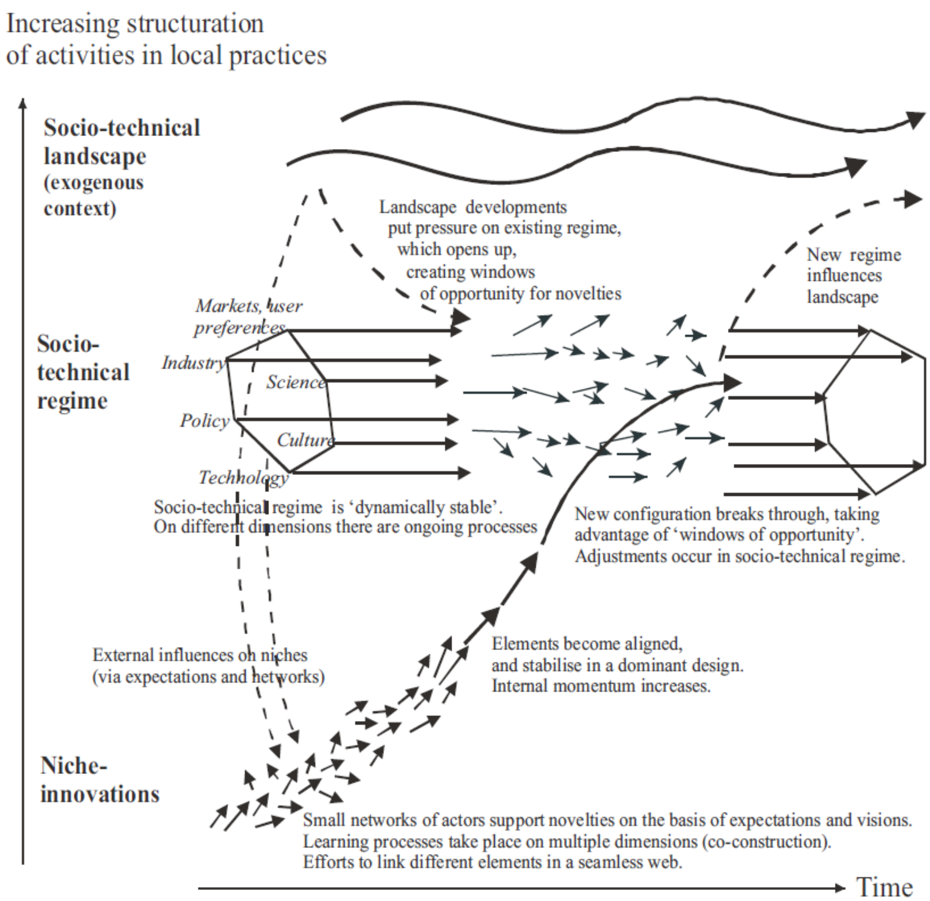

Figure 1: Multi-Level Perspective on Transformations (Geels, 2002: 1263)

As refer to the MLP on transformations (Figure 1), the interactions among these three levels lead to transitions. Rosenbloom, Berton and Meadowcroft (2016) suggested that socio-technical transitions occur from the "culmination of landscape pressures, problems within the regime, and the readiness of niche innovations". Once the niche development reaches a mature level, it seeks and waits for windows of opportunity and take over the place of incumbent socio-technical configuration. Grin et al. (2010, p. 18) also showed that niches and regime share common structure yet vary in size and stability. They are both surrounded by networks of actors that share certain rules and turn structuration to actions in local practices in different degrees.

2.6 The 4 Transition Pathways

This section seeks to connect the MLP in application to describe different transition pathways. This created four transition pathways to differentiate the MLP. The following paragraphs described each pathway typology and included an empirical example.

Transformation pathway – this occurs when the landscape pressure is moderate and niche-innovations have not been maturely developed. This regime actors can subsequently modify the direction of development paths and innovations activities with steady adjustments in regime rules. Thus, the niches still have too little power to displace as main drivers of the transition (Grin et al., 2010, p. 57). An empirical example is the hygienic reform of waste disposal in the Netherlands during the late 19th century. Despite there were graduation adjustment in regime rules, e.g., knowledge about disease, perceptions of waste and political rules of the game, new technologies' role was not significant enough to be the main driver of the transition. The regime changed rules incrementally to sewer systems (Geels, 2006a).

De-alignment and realignment pathway – due to substantial and extensive change in the landscape, the regime problems boost suddenly causes regime actors to lose faith. The regime will then be de-aligned and destroyed. If niche-innovations are not maturely developed, they are not capable to be substitutes. However, this creates room of development for of multiple niche-innovations who have been co-existing and competing for attention and resources. Finally, the strongest niche becomes dominant and become the main driver of a new regime. (Grin et al., 2010, p. 63). An empirical example is the American transition from horse-drawn carriages to automobiles. The existing horse-based regime was already unstable in the early process and simultaneously several technologies such as bicycles, automobiles and the electric tram emerged. The pathway was eventually dominated and substituted by electric tram then automobile. (Geels, 2005).

Substitution pathway – when there is a considerable amount of landscape pressure arise together with niche-innovations are maturely developed, the niches will present immediately and take over the existing regime. Nevertheless, the transition remains as a reproduction process without landscape pressure. Therefore, landscape pressure on the regime is critical to trigger specific shock for a technological substitution which this pathway has a built-in technology-push character. (Grin et al., 2010, p. 68)[6]. An empirical example is the transition from sailing ships to steamships in Britain. New technologies such as inland-water ways, ports and mail transport, emerged in small niches. Technologies substitution occurred because of major landscape changes such as mass emigration and Suez Canal. Therefore, this provided technology-push character to accelerate the breakthrough of steamships (Geels, 2002).

Reconfiguration pathway – they are symbiotic innovations that originally developed by in the niches and are adopted in the regime to solve local problems at the early stage. They are gradually able to influence the basic structure of the regime in the later stage. Niches can even be adopted as additional alternatives without difficulties if they have symbiotic relations with the regime. Economic considerations play a significant to get these innovations being adopted whilst without changing most of the regime rules (Grin et al., 2010, p. 72). An empirical example is the American transition from traditional factories to mass production. Several external landscape developments influenced this transition such as emergency of a national market, rising purchasing power and the Efficiency Movement. The transition to mass production was driven by multiple component innovations to solve particular problems (Geels, 2006b).

2.7 Contribution of Multi-Level Perspective to Address this Research

Why MLP is the most suitable framework to address the research question?

This study is to explore the potentials and limitations of solar PV installation in Norway. It addressed the research question by explaining the installation of grid-connected PV capacity development until 2018. It is essential to understand the history of the market so as to understand the transition process thoroughly. Therefore, MLP is a "popular framework to understand the dynamics of such socio-technical transitions". (Geels, 2002; Geels, 2012; Geels and Schot, 2007; Smith, Stirling, & Berkhout, 2005). MLP understands transitions to begin with the interplay between multi-dimensional developments across three analytical levels, i.e., niches (the locus of radical innovations), socio-technical regimes (the locus of established practices and associated rules that enable and constrain incumbent actors in relation to existing systems), and an exogenous socio-technical landscape. In the nutshell, the niche-innovations first build up internal momentum (through learning processes, price/performance improvements, and support from powerful groups). Then, changes at the landscape level created pressures on the regime. Afterwards, the regime destabilized and created windows of opportunity for the diffusion of niche-innovations. As a result, this interaction enabled the breakthrough of 'green' innovations where they struggle with the existing regime on multiple dimensions such as economic, technical, social and political (Geels, 2014, p. 23). This research aimed to look at how solar PV installation make use of the window of opportunities created by the landscape pressure to the regime in order to breakthrough to the mainstream Norwegian electricity market.

The dependent variable, PV installation capacity, is measured by the gigawatt that has been installed within Norway. The independent variables originating from the MLP framework are non-linear mechanisms to measure the overall dynamic patterns within the socio-technical transitions. Various types of agency from niche, regime and landscape are the three levels that measured different kinds of coordination and structuration to activities (Geels, 2011).

2.8 Limitations and Criticisms of MLP

Although MLP has been broadly applied on various researches on extensive topics, there are three main criticisms towards the framework. The following paragraphs has presented several limitations. Thus, these points have been brought to attention throughout the research so that the discrepancy between empirical explanation and theoretical assumption can be reduced as much as possible.

2.8.1 Operationalisation, Specification and Delineation of MLP

Several criticisms against the analysis of technological transitions has been outlines by scholars. Scholars have drawn a common problem regards drawing boundaries for the empirical categories of the framework. The scope of these categories determines operationalization of the regime concept (Geels, 2011, p.31). Genus and Coles (2008, p.1440) also criticized the problematic situation to define transitions. There is difficulty to determine when a transition is started and ended. Because of this problem, the case study could for example be perceived as having occurred on a different transition pathway depending on the perspective on transition. Different pathways can thus be identified by adjusting the focus of the regime and the time frame. This implies that radical transition might not be able to be demonstrated if the time cast is too short. Since MLP is a framework that help researchers to explain, predict, and understand phenomena from research theories, therefore, it is not a deterministic "truth machine" that produces correct answers automatically after the researcher has entered the data (Geels, 2011, p. 34). Hence, Geels (2011, p.31) advised researchers should decide their objectives of analysis at the very first beginning and then operationalise the analytical levels from the MLP. This can avoid being hasty to start analyzing the MLP levels. Since the regime does not have a designated scope for the research topics either because it is just an analytical concept, the scope of the research topic will eventually bring implications to operate the regime concept, for instance, the number of actors, their relationships and the rules and constitution (Geels et al., 2016).

2.8.2 Call for More Attention to Political Intentionality in the Regimes

Political factors have somehow been underestimated by its power on influencing transitions. The depth of the politics involved is frequently underplayed (Shove & Walker, 2007, p.766). The nature of political intentionally is problematic especially when interests are conflicted (Berkhout, Smith & Stirling, 2004, p. 32). As refer to the MLP diagram from Geels (2002), the political aspect was within the regime level. The most possible reason for leading to a transition is the top-down landscape pressure to the regime then followed by niche power. However, a number of examples demonstrated that political factor is the main driven power. Smith et al., (2005) and Geels (2011) also mentioned the same views concerning the political power over a transition. Smith et al. (2005) even argued "the role of power and politics" deserved to have more attention. Furthermore, an unpublished paper from Langhelle, Kern & Meadowcroft (2017, p.1,13) even proposed political factor should be "treated as separate and distinct from other landscape factors". They used an example of *Energiewende* in Germany to illustrate governments were the one who promote the niche in specific ways such as feed-in-tariff, other subsidies, cash grants and so on. Since regime naturally functions as selection and retention mechanism (Geels, 2002, p. 1260). As a result, they perceived state political institutions play a crucial and constitutive role in defining the *rules* and *policies* that surrounds regimes and niches at a national level. The absence of policies might lead to no transition. Therefore, Osunmuyiwa (et al., 2018, p. 153) introduced "politico-economic regime" to integrate with the existing socio-technical regime to remind researchers to pay more attention to the politics of energy transitions. This provides a political overview that reflects the influence of the political system on transition processes.

Norway's political institutions is also likely to have strong influences in the regime. The country may have less pressure from the landscape compare with other countries who are struggling with low-carbon transition, since its electricity sector is almost fully renewables-based Inderberg et al. (2016, p. 76). Besides, as mentioned previously in the introduction section, Inderberg et al. (2016, p. 54, 76) stated that Norwegian consumers in general have high level of trust towards the power companies. Traditionally low electricity prices also decrease the "need" to call for a change. This implies that Norwegian consumers tend to stay quiet and calm which further consolidate the stability of political institutions.

2.8.3 Criticism towards Bottom-Up Change Models

The MLP has been criticized for only limited to bottom-up changes, i.e., to begin from niche to landscape. Berkhout et al. (2004, p.32) suggest that MLP is "unilinear" since it over-emphasises on the regime change that should be start from niches to work-up which disregard the downward operation from a typical sociotechnical landscape. However, Geels (2011, p.32) disagreed with it as this is only limited to some earlier researches. He also suggested avoiding such bias by attention to persistence of change at the regime and landscape level. Many studies about sustainability transitions frame regimes as "barriers to be overcome" as their focus restrict to "green" niche-innovations only.

Therefore, multi-level interactions can happen in both bottom-up and top-down directions. Traditionally, radical innovation has to struggle to enter small market niches and subsequently diffuse into mainstream markets in order to compete with or replace existing regimes. However, the interactions between niche and regime can be symbiotic. This can be achieved if niche-innovations can be adopted as "competence-enhancing add-on" in the existing regime to solve problems and improve performance without disrupting the basic architecture. Geels and Schot (2007, p. 406)

Furthermore, horizontal interactions can also happen within the same level especially in the regime. Geels (2002, p. 1260) pointed out that regime accounts for stability of configurations. The interaction within regime is dynamic. Actors form the regime allow innovation but it has to be incremental. In Geels (2011, p. 31) later research, he, also emphasize regime has coherence, shared rules and but at the same time with certain variety, disagreement on specific issue, debate and internal conflict. Lack of homogeneity and internal alignment within a regime can lead to instability base on empirical explanation rather than just theoretical assumption. This indicates that regime will be at the expense of niche at all costs to maintain stability of status quo. These factors have the potential to drive electricity consumer to become solar PV prosumer. Thus, this may create top-down pressure for the regime from the landscape.

2.9 Anticipations for Norwegian Solar PV Installation Developments with MLP Framework

This section has anticipated some possible barriers that created by every single level to hinder the uptake of solar PV installations. As refer back to introduction chapter, solar PV create challenges to market actors most likely at the niche and regime levels from technical, political and economic perspectives.

Niche (technical) –the nature of solar PV has high intermittency. Provided that this problem was further magnified that latitude regions such as Norway where seasonal variations in the length of daytime are extreme. It is expected that PV panels have already stopped producing electricity before the peak demand period because the sun is set already especially during wintertime in particular actors from the households. If households cannot use the electricity that generated by the solar PV because they are away during the day, then their willingness to adopt solar panels will be low. While the barrier is lower to the actors from the business market if the commercial buildings are usually at work during the day with high solar production. Niche in this study focused on the solar PV installation companies.

Regime (political) – systematic contradictions of energy policies. The development was unparallel between the support of solar PV R&D and solar PV installation. Priority was given to solar PV R&D but not to any national policies about installation of solar PV facilities. Moreover, more than 98% of electricity produced in Norway was generated from renewable hydropower. There was no need to invest in other types of green energy source but way more expensive and immature technology. Therefore, if the perceived "political need" for solar PV system is low, then the motivation for launching solar PV policies is low.

Regime (economic) – the electricity price in Norway has always been lower compare with other European countries. There was also lack of economic incentive for those who install solar PV devices. If the electricity price is low and the incentive is negligible, then the motivation to install solar panels especially to the private market will be low also.

2.10 Priori Possibilities of 4 Transition Pathways

This paragraph anticipates the possibilities of solar PV installation development with hypothesis from 4 transition pathways so as to generate some expectations base on research frontier and literatures.

Transformation path – it is assumed that there is moderate landscape pressure, i.e., specific climate goals for Norway such as targets in the electricity certificate, carbon tax and Paris Agreement. However, if Norway has been "very green" in the electricity generation market, the regime actors do not have immediate landscape problems. Then, hydropower remained in the mainstream market while solar PV failed to move upward to the regime.

De-alignment and re-alignment path – this assume a divergent incident, significant and sudden, for example, hydropower dams collapse which lead to large causalities and economic loss. If all niche renewable technologies fight to get into the regime even though they are not mature developed. Then, at the time, this would depend on whether solar PV is the strong niche to become the new regime.

Technological Substitution – this also assumed that there is a specific shock that heavily damage the hydropower market. If by the time solar PV's intermittency problem was solved. Then, popularization of solar PV uptake among business and private markets due to climate change leads to soar in electricity price. Solar PV shall be mature enough to break through and replace the existing hydropower regime.

Reconfiguration pathway – the regime actors were open up to adopt other niche technologies from time to time to solve problems that cannot be solved within the regime. If solar PV can share the burden to produce electricity when the reservoir water level is low or to install solar PV devices at commercial buildings and rooftops to achieve more green buildings. Then, the local electricity production is beneficial for local consumption since grid is not needed to transfer electricity.

2.11 Measurement and Operationalization towards These Anticipations

Operationalization refers to making the variables observable or measurable, to enable an analysis to distinguish in what ways the empirical data may or may not confirm the theoretical expectation. There are several expectations when applying the framework to the research.

First, cross-sectional approach is confirmed which collect data and finds relationships between variables at one point in time due to time and financial constraints. This included one-time in-depth interviews to explore and to obtain insights about the recent situation and outlook about the Norwegian electricity market that did not mention in previous chapters. Methodology shall be discussed further in later chapters. Second, it is understood that the significance of political and economic factors has been playing a significant role in the regime. Therefore, extra attention is needed for data collection and analysis in order to allow the result to be able to reflect as closest to the real world as possible. Third, transition pathway will be adopted again in the discussion chapter. The empirical data will be analysed and sorted according to the framework of the three MLP levels. Findings will be used to decide one of the four pathways that suits the best to address the research question. The timeframe for the analysis part shall observe the aggregate pattern in long terms periods of more than 50 years since transition takes time.

The transition pathway shall be determined by main actors and main types of (inter)actions in the different pathways. With MLP's focus on interactions between niches, regimes and landscape, MLP provides narrative explanations. This explained in terms of patterns that result from interactions which is known as process theory. Process are understood as sequences of events that are enacted by situated actors. (Geels, 2007, p. 141 as cited in Abbott, 2001; Pettigrew, 1997; Poole et al., 2000).

3.0 Methodology

3.1 Introduction

Qualitative research has been undertaken to explore the Norwegian solar PV installation market with the application of the MLP framework. The aim of data collection was to further understand how the interactions between landscape and regime may uplift the solar panel installation capacity in Norway because solar energy is interpreted as niche in the Norwegian electricity generation sector. A primary approach was by the means of in-depth interview to gain inspirations and ideas from interviewees.

Feedbacks from interviewees were supported by secondary data. Most of the information from secondary data were official government publications from several departments such as the Ministry of Petroleum and Energy (OED), Ministry of Climate and Environment (KLD), Norwegian Water Resources and Energy Directorate (NVE), Enova SF and Energi21. Even though primary data helped to broaden the horizon of searcher and provided ideas to further researches, these documents served as cross-references to prove that these primary empirical data were valid and reliable. These official government publications that were written by different departments to represents secondary data because they are trustworthy which accurately reflect the real situation of Norway.

The information was organized base on the logic of theoretical framework, i.e., niche, regime and landscape levels. Research strategy and objectives, research design, data collection instruments, interview strategy, operationalization of the measures, limitations of the methodology, research ethics and data analysis strategy are presented and discussed below.

3.2 Research Strategy and Objectives

Qualitative research is a distinct methodological approach that provides an inquiry process to explore a social or human issue. The study is conducted in a natural setting by building a holistic picture, analysing words and reporting detailed views of participants (Creswell, 2013, p. 300).

Qualitative research is more suitable than quantitative research in this study. The reasons for this are: (1) to provide flexibility for the research design rather than a structured and sequenced linear process derived from an initial decision. (2) to explore and to gain insight of the market from different perspectives rather than to examine specific variables or relationships of the hypotheses mathematically. (3) to understand the phenomenon of the solar PV market in depth from a local to an international perspective rather than aiming to generalize and project result to a larger population (Maxwell, 2013, p.2 cited from Robson, 2011)

3.3 Research Design

According to Blaikie and Priest (2019, p. 80,81), exploratory research attempts to develop an initial, rough descriptive and understanding of some social context. This approach is necessary when very little is known about the topic being investigated, which is the case for Norwegian solar. The methods used to conduct exploratory research need to be flexible, so they may be adapted during the process of research, depending on the preliminary findings along the way. Therefore, this study wanted to understand the Norwegian PV solar market in a social context, for example, the opinions and expectations from different groups of market players.

Descriptive research seeks to present the patterns of relationships in some social phenomenon at a particular time and/ or changes over time (Blaikie, 2000, p.74 cited from Blumer 1986:66). These descriptive accounts can be expressed in qualitative and quantitative manner. Here was to justify the solar PV phenomenon based on the market players' perspectives with the MLP as a framework. Both types of researches require the use of concepts and theories (Blaikie, 2000, p.74).

3.4 Data Collection Instruments

In-depth interviews were chosen to collect primary data. The interviews were semi-structured, audiotaped and transcribed (Creswell, 2013, p. 160; Silverman, 2013, p. 199). For semi-structured interviews, an interview guide was developed, to serve as an orientation during the interviewees. The aim of the interview is to obtain the individual views of the interviewees on an issue. The interview did not present a list of possible answers. If interviewees' answers were not rich enough, the interviewer would probe further (Flick, 2011, p. 112). Therefore, interviewer should pay attention that these questions are open-minded, general and focused on understanding the central phenomenon in this study which is the development of Norwegian solar PV market (Creswell, 2013, p. 163). The interview guide was sent to all interviewees which contained a list of questions to be asked so that interviewees can prepare in advance.

Since the purpose of interview was to gain various individual's perspectives, unlike questionnaires, all questions were open-ended so that respondents were expected to reply free-flowingly and as extensively as they preferred. However, there were several questions which consisted of keywords which were highly relevant to the MLP, for example, the reasons for customers to adopt solar panels and the relationship between hydropower and solar PV energy.

3.5 Interview Strategy

The timing of data collection for this study was the cross-sectional approach. This approach (1) collects data from several groups and compare their positions and (2) collects data at a single point in time (Blaikie & Priest, 2019, p. 198)

Data collection proceeded with all participants in Norway at one single time. Participants contributed to various parts of the solar PV market value chain. Due to the time and financial constraints, data collection for this research could not go over a longer period of time. Therefore, even though longitudinal approach could have been useful, the cross-sectional approach was feasible in this case.

3.6 Selection of Interviewees

Judgmental sampling method was adopted to expect selected samples could give the most relevant information. For example, the unit of analysis are the respondents from electricity company, construction and building company, independent energy consulting unit, start-ups and the Norwegian government agency. The selection was based on the judgement by theoretical considerations to address the MLP framework. All interviewees contributed to different sectors of the Norwegian solar PV market. (Blaikie & Priest, 2019, p. 173)

Interviewees' job duties have currently related to the Norwegian renewable energy market in particular solar PV energy. The choice of these interviewees was due to their high relevance to the Solar PV installation market in Norway. They were all based in Norway and contributed to different value chains. It was essential according to the MLP framework to map the Norwegian solar PV installation development from various groups of actors because participants would have different perspectives from their work units. All the respondents has from 8 months to 10 years of experiences with the Norwegian solar PV market. Two out of 5 participants owned their personal solar devices, i.e., grid-connected solar panels and off-grid solar panels with inverter and batter storage.

3.7 Interview Procedure and Timeline

In depth individual interviews were conducted with 5 participants by 3 different media channels. Two participants by face-to-face, another two by internet skype interview and one by telephone interview. Interviews were held between 4 April and 23 April 2019 (Figure 2). The duration of the interviews ranged from 26 to 59 minutes. The mean of interview durations was 45 minutes. All interviews were taped recorded and transcribe in English with oral consensus from all participants. The main language of the interviews was English and supplemented with few Norwegian terminologies and all the Norwegian terminologies were clarified and interpreted in English during the interviews.

Activity	Timeline
Interview with Integrated Renewables AS	04 April 2019
Interview with Energy Consultant	05 April 2019
Interview with NVE	08 April 2019
Interview with Lyse	17 April 2019
Interview with Otovo	23 April 2019

Figure 2: The Interview Timeline

3.8 Operationalization of the Measures

The interview guide was divided into four topics: Personal background and general opinions to solar PV energy, respondents' view on their potential markets, role of solar PV compared with other renewable energies, and the effectiveness of the energy policies (Appendix 1).

Topic one consisted of five questions. This topic was getting to know more about the participants. It involved introduction questions for the respondents and their general opinions towards the Norwegian solar PV installation trend. For questions about owning solar PV devices, personal interests and contribution in the solar PV market were to obtain general knowledge background and personal experience of the respondents on solar PV.

Topic two consisted of six questions. The second topic was about respondents' perspective towards their target groups and work unit in relation to the Norwegian solar PV installation market. There were questions to gain insights on the driving motivations about why public, private and business sectors wanted to join the solar PV market. Besides, to investigate any changes for the reasons to adopt solar panels compare with the past and the present so as to understand the recent trend of installation capacity. Some tentative causes were provided in this question because these reasons were the factors that lie on each level of the MLP. Furthermore, the questions also addressed the major challenges of adopting solar panels in Norway from different sectors. Lastly, it tried to relate these challenges to the participants' work units and discuss solutions to overcome these challenges.

Topic three consisted of four questions. The third topic was to discuss the role of solar PV in relation to existing dominating renewable energy in Norway. The question began with to position whether solar PV was still considered to be niche technology in Norway until today. Then the growth of Norwegian solar PV market was compared with other European countries that had relatively outstanding performance on the solar PV industry. Questions also compared the development among solar PV, hydro and wind power to study whether the more dominating hydropower sector and the more noticeable offshore wind power would hinder the uptake of solar PV capacity, and if this is the case in what ways.

Topic four consisted of five questions. The fourth topic was to comment on the performance of government towards the Norwegian solar PV installation market. Participants were asked to measure the usefulness and limitations of the energy policies and incentives regarding the development trend of the PV market. This topic also tried to define the role of Norwegian government in promoting solar panel uptake.

3.9 Limitations of the Research Methodology

The transition pathways seek to access the importance of alignments between developments at multiple levels (Geels 2004). The observation of the transition pathways is an ongoing process. As mentioned earlier, it is challenging that radical transition might not be able to be demonstrated if the time cast is too short (Geels, 2011, p. 34). However, due to time and financial constraints, there was no opportunity to collect cumulative data. However, as there are some (but limited) research on the topic of small-scale solar in Norway, the findings were compared with this along the way.

Moreover, the solar PV market is relatively young compare with other major European markets. As a result, there might be difficult to obtain observable impact on the switch of pathway at a single point. This research had a solid value as it strived to be upfront to illuminate the emerging trends of solar PV installation in a Norwegian Context. Furthermore, language barrier regarded as a challenge to acquire information. Since the researcher is not native Norwegian speaker, therefore, there were constraints in particular collecting documents as they were only available in Norwegian. The research could miss some documents with research value due to not able to read the language nor to search with specific Norwegian keywords.

3.10 Validity and Reliability of Measurement

Validity refers to the "correctness or credibility" of interpretations and explanations to the research data (Maxwell, 2013, p. 123). Maxwell (2013, p. 123) also reminded qualitative researchers must try to address most validity threats after the research has begun as qualitative research is more challenging to avoid validity threats than quantitative research. (Campbell, 1988; Platt, 1964; Shadish, Cook & Campbell, 2002) Particularly, there are two main types of validity threats to this study: (1) researcher bias and (2) reactivity (Maxwell, 2013, p. 124 cited from Cook & Campbell, 1979).

Researcher Bias - The first possible threat could be subjectivity. This refers to the selection of data that only fit the research goal, existing theory and preconceptions or only select the data that can "stand out" to the researcher (Maxwell, 2013, p. 124 cited from Miles & Huberman, 1994, p. 263; Shweder, 1980). Reactivity refers to the influence of the researcher on the interviewee or interview setting to rule out unwanted cause of variability (Maxwell, 2013, p. 124). There was possibility that the researcher might have bias or control the interview effect in order to fit the result into one of the desired transition pathways. For example, this study mentioned earlier that the dominance of hydropower in the Norwegian electricity production sector and unfavourable factors that created hurdles for the development of solar PV market. Therefore, the researcher might try to influence the respondents to agree that hydropower was a key reason that hinder the development of solar PV.

Reliability refers to the extent to which results are consistent over time and an accurate representation of the total population and the results of a study can be reproduced under a similar methodology (Golafshani, 2003, p. 598 cited in Joppe, 2000, p.1). Since this study did not involve quantitative approach, reliability is not an appropriate criterion or even misleading to measure the quality of qualitative research. Therefore, it is suggested that reliability is a consequence of the validity (Stenbacka, 2001, p. 552; Patton, 2002 Lincoln & Guba, 1985, p. 316). Nevertheless, to ensure reliability in qualitative research, examination of trustworthiness is crucial. In order to test or maximize the validity and as a result the reliability in this study, multiple methods such as interviews, recordings and secondary data would lead to more valid, reliable and diverse construction of realities (Golafshani, 2003).

3.11 Managing Validity Threats

It is important to identify validity threats so as to understand them and to use them productivity. This is because eliminating the actual influence of the researcher is not possible (Maxwell, 2013, p. 125 cited from Hammersley & Atkinson, 2007). They also suggested the idea of reflexivity to constantly consider potential biases and to minimize their effects.

Respondent validation – this also known as member check. This is one of the most significant method to avoid the possibility of misinterpreting the meaning of interviewees' words and thoughts as well as to find out researcher's biases and misunderstanding of one's observation. (Maxwell, 2013, p. 126 cited from Bryman, 1988, p. 78-80; Lincoln & Guba, 1985). Respondent validation has been done during the interview and at the conclusion drawing process. For example, during the interview, it restated and summarized the answer and then questioned the interviewee to make sure accurate interpretations. Respondent validations were also done when discussing the research result with the interviewees. The researcher has agreed with participants to re-confirm with them if presenting quotes to the research result to reassure there was no misinterpretation of messages. While this method does not completely eliminate fault but decreased severely the occurrence of incorrect data in order to provide findings that are authentic, original and reliable (Maxwell, 2013, p. 126 cited from Miles and Huberman, 1994, p.242-243), it intends to reduce potential problems of validity.

Discrepant Evidence and Negative Cases – This attempted to locate and examine cases that disconfirm the researcher's expectations. To do this, the researcher has sought to test both supporting and discrepant data to evaluate whether it is more plausible to retain or modify the conclusions (Maxwell, 2013, p. 127-128). In this research, the expected conclusion was the matching or adapting the kind of transition pathway established for solar in Norway – if any. If I, for example, during the research expected the reconfiguration pathway will be the outlook of the Norwegian solar PV market, it also has to consider the data that support or undermine the choice of pathway.

3.12 Research Ethics

The research of this study perceived that ethics are equally important to all phases of the research process and in particular collecting and analysing data. This is because it is important to build rapport before and after the interview so that participants feel being respected and feel comfortable to give their open and honest responses during the interview as well as not to feel being exploited after the interview (Creswell, 2013, p. 56 cited from Lincoln, 2009; Mertens and Ginsberg, 2009). Therefore, to be clear about the premises for the study, an information guide was sent to all potential interviewees before interview. The main contents included the purpose of this research, to inform consent procedures, confidential toward participants and deletion of data after the research is completed (Creswell, 2013, p. 174 cited from Lipson, 1994. Therefore, there is always an irresolvable dimension between ethics and research transparency where protection of the research interviewees will have to take precedence over making all the information of the research as public as possible.

3.13 Privacy and Confidentiality

Researchers should always remember to respect the privacy and integrity of the interviewees. It is important to maintain confidentiality towards one person when necessary (Gomm, 2004, p. 303). In this research, specific information of the respondents and companies are omitted to fit the purpose of anonymity. (Creswell, 2013, p. 56 cited from Weis & Fine 2000; Hatch 2002) As participants were assign fictitious names of aliases as key respondents 1-5 (Figure 3).

Interview	Value Chain	Year of experience in PV industry
Key Respondent 1	Construction	8 months
Key Respondent 2	Consulting	5 years
Key Respondent 3	Policy Regulation	10 years
Key Respondent 4	Power Company	2.5 years
Key Respondent 5	Technology Start-up	17 years

Figure 3: Demographic Information of Respondents

3.14 Methodology for Analysing Qualitative Interview Result

Content analysis was used for the qualitative analysis. This approach aimed at classifying the content of texts by allocating statements, sentences or words to a system of categories. The reasons for choosing content analysis was due to it is (1) an empirical method description of substantial features of messages, (2) based on using category derived from theoretical models, i.e., MLP in this study and (3) applied such categories to texts rather than to develop them from the material itself (Flick, 2011, p. 133 cited from Fruh 1991, p. 25). This study would first define the material. For example, to select those parts of interview that are relevant for answering the research question which is the MLP in relation to the development of Norwegian solar PV market. Then, it defined the direction of the analysis for the selected texts which was necessary to be interpreted (Flick, 2011, p. 137).

The dependent variable, i.e., the development of grid-connected PV installation in Norway, was measured by the related factors of the independent variables, i.e., (1) niche innovations, (2) socio-technical regime and (3) socio-technical landscape. These 3 independent variables were also the levels that formed the MLP framework. The research question was defined based on this framework. The qualitative research data was decoded into themes and categorized according to the interview contents of 5 participants. The frequencies including the number of participants and the number of times were counted as well. The interview materials were paraphrased by the summarizing content analysis to skip less relevant passages and paraphrased with the same meaning. Then the materials were further bundled and summarized similar paraphrases (Flick, 2011, p. 137).

4.0 Findings

4.1 Introduction

This chapter recapped the research question and presented the results from both primary qualitative interview data and secondary data. Majority of points from primary data and secondary data were corresponded so as to serve as two types of sources to cross check and to proof the validity of the primary empirical data. The aim of this chapter was to map and describe the drivers and barriers to solar PV adoption and environmental conflicts with hydropower and wind favour solar PV uptake.

4.4 Sociotechnical Regime in Relation to the Trend Solar PV Uptake

4.4.1 Does Hydropower Hinder the Development of Solar PV Installation?

The earlier chapters introduced the dominance of hydropower in the Norwegian electricity generation sector and the Norwegian government did not prioritize solar PV R&D or installation of solar PV facilities. However, according to the interview result, all respondents did not perceive hydropower hinder the development solar PV installation market in Norway (Figure 7).

Hydro hinder PV Uptake	Explanation	Respondent	No. of times
No	Hydropower does not hinder the solar PV uptake	A, B, C, D, E	19
Yes	Hydropower hinder the solar PV uptake	/	0

Figure 4: To What Extent Hydropower Affect the Uptake of PV

Respondent A said hydropower and solar PV should co-exist. This is because it is becoming more difficult to meet the energy demands in Norway just by constructing more hydropower plants because of nature preservation concerns. Installing solar panels has far less harm and less geographical constraints due to its decentralized nature, according to the interviewees.

Respondent B said electricity market liberalization in Europe will have positive outlook for solar panel development in Norway. This is because if the Norwegian electricity grid have a stronger connection and network with the European market, the Norwegian electricity price in will be normalized, which results in increased prices. This is due to increased costs for system operation and increased grid tariff (NVE, 2016). According to Statistics Norway (2019), the price of electricity and grid rent include taxes between 2015 and 2019 Q2 have been increased for 37% from 81.9 to 112.6 øre/kWh. Therefore, solar PV does not compete with hydropower.

Respondent C perceived it to be important to achieve electricity efficiency economically. Thanks to the abundant of hydropower that helps to maintain a relatively low electricity price which is something that that solar PV cannot not fulfil because of its high costs. We should use the most cost-effective for electricity generation that available, according to interviewee C. If solar PV is much more expensive, you should build the hydropower instead of solar PV.

Respondent D did not agree that hydropower hinder the uptake of solar PV due to its renewable nature. Since the electricity market is connected tightly between Norway and Europe and will even be closer with connections under ongoing construction to the UK and Germany. Every unit of electricity produced by the Norwegian hydropower contributed to reduce coal use in Europe. Therefore, Norwegian hydropower has an important role to reduce carbon footprint.

Respondent E did not think hydropower hinder the update of solar PV at all. The respondent did not see any conflicts nor competition between different technologies. Different technologies serve different purposes, and hydropower provides centralized electricity while solar PV is decentralized and might be useful for other functions, like local grid stability and evening out peak demand. All forms of electricity generation are welcome as long as it is produced environmentally and economically, according to interviewee E.

Both interview with NVE and governmental documents said that they are committed to maintain the principle of technology neutrality where all renewable energy sources should have the equal opportunity to be supported (OED, 2012, p. 4).

4.4.2 Drivers for Sociotechnical Regime

Reasons	Summary factor and Explanation	Respondent	No of times
Investment return	Financial benefits from investing on the solar PV devices	A, B, E	15

Figure 5: Drivers to Adopt PV at Regime Level

Winther et al. (2018, p. 90) suggested the difference between the price of electricity delivered from solar PV panel to the grid and the cost of electricity purchased from the grid makes their interviewees considered self-consumption to be most profitable. They perceived their contribution to solar power could help stimulate further market developments.

Respondent A, B and E said solar PV devices to the private market serve as a pension plan that device owners expect to receive investment return and free electricity after the payback time (Figure 8). For the commercial market, free electricity generated by solar panels helps agricultural industry to lower the operation costs. Respondent B specifically mentioned the growing market of Build-in Integrated Photovoltaic facilitate to achieve energy efficiency and adding value to the buildings. Multiconsult (2019b, p. 44) suggested that it is more important to look at the return on investment than to focus on only one of several variables included in the calculation. Typical internal rate of return for a flat roof solar cell installation in Oslo is more than 6%.

According to Winther et al. (2018, p. 89), the investment cost might be paid off after 8–9 years. Few interviewees thought that the installation of PV panels would be financially profitable in the short run, even though the possibly would be higher in the long run. The panels are intended to last for about 25 years.

Respondent A was the only person who was optimistic to the cost of solar PV systems. This is because the main customer group is the business market. He stressed that prosuming electricity by solar panels achieved peak-load reduction in order to stand against high charges by big power companies.

Role of Government in Promoting Solar PV Installation Uptake

Participants suggest that these are the barriers to adopt PV. Participants suggested several roles that the Norwegian government could have done to increase motivation for solar PV installation, such as (1) to update of energy policy and regulation, (2) more financial support mechanisms, (3) provide comprehensive information about the PV market to the public, (4) facilitate off-grid technology. "Financial support mechanisms" regarded as the most influential role as it was mentioned by all participants and have been mentioned 87 times.

4.4.3 Barriers for Sociotechnical Regime

Reasons	Summary factor and Explanation	Respondent	No of times
Lack of financial support mechanisms	Need more incentives, subsidy and financial aid for both business and private markets / cost reduction	A, B, C, D, E	87
Energy policy and regulation are not up-to-date	Need more recognition by the government about the role of solar PV	A, B, C, E	21
Long payback time for private markets	The waiting time before receiving investment returns	A, B, C	11
Low electricity price	Electricity price is considerably lower compare with other EU countries	B, C, D, E	13
Lack of information exchange platform - Provide comprehensive information about the PV market to the public	Consumer failed to receive comprehensive information to analyze thoroughly for the most suitable decision	C, E	9

Figure 6: Barriers to Adopt PV at Regime Level

Lack of Financial Support Mechanisms

Winther et al. (2018, p. 90) as cited in Henden et al., (2017) the government continued to roll-out smart metres in respond to the Demand Side Response initiatives (e.g. capacity pricing to achieve flexible electricity use). However, it was unclear how such developments would favour the private market. All respondents stressed the importance of financial incentives can advocate the development of solar PV installation market especially to the private consumer market (Figure 9). They perceived that low economic motivations fail to advocate solar PV systems, but they gave different explanations for how. Respondent D and E considered the uncertainty regulations and lack of incentives by the government to be important, as it has not attracted the private market sufficiently. Respondent A and D suggested the government should support the development of solar PV market as much as electric vehicles (EV). Respondent B clearly explained the extent of the Enova support is less than satisfactory (there is no support for the electricity produced, only for reducing the costs of the installation itself), he suggested it would rather be more important for the government and parliament to recognize and promote the solar PV technology so as to form a top-down movement instead of the current bottom-up situation. The current incentive for installation of solar PV devices was only from Enova. Even though Enova was founded already back in 2001, its Subsidy Scheme was launched in 2015 and just see a considerable growth in 2018 (Enova, 2017; Enova, 2018, p. 5)

Energy Policy and Regulation not Up-To-Date

The Norwegian Water Resources and Energy Directorate (NVE) and other governmental institutions should promote prosuming practices and inform about relevant support schemes, assist in application and regulatory processes, and spread general knowledge about solar PV adoption opportunities (Inderberg et al., 2018, p. 266; NVE, 2018c). It was their responsibility to make sure the public can access the relevant information. This is because it took more efforts for local access to this technology for potential market than to the global market for technology (Inderberg et al., 2018, p. 229, 260). Respondent C and E said government failed to serve as a channel of communication to create a platform to exchange information so that the public were being well-informed with the solar PV related knowledge (Figure 9). For example, respondent C said there is lack of information about which power companies were allowed to buy self-generated electricity by prosumers and how this works, so that they know where to sell their surplus. Respondent E said the government did not make solar PV adoption easier and more reachable to help the public make the right decision. Multiconsult (2019b, p. 44) also emphasized potential buyers are not aware that prices have gone down significantly in recent times. In practice, the district power companies and third-party company provide contact point and technical solutions and installations, instead of the government.

Respondent A, B, C and E admitted the power of government and regulations can facilitate or fail an emerging market (Figure 9). They also claimed that the energy policies are not up-to-date. Respondent A and C urged the government to pass the law so that sharing self-generated electricity among different homeowners would become legal. Respondent B suggest the topic of developing solar PV installation should be brought up to a parliament level to gain broader awareness. Respondent E even said "The technology is newer than the legislation!". Inderberg et al. (2018, p. 266) further stressed that despite the increasing activities from the DSOs around 2013 and 2014, the available information about prosuming market was still very limited at the time. It waited until 2015 to launch the Enova Subsidy (Enovatilskuddet) (Enova, 2017). A climate agreement that signed by major aluminum producers with the Royal Norwegian Ministry of Climate and Environment (KLD) to reduce emissions of GHG between 2005 and 2007 (KLD, 2018, p. 127). Despite the success of the agreement, it expired in 2007. A new emission trading system was resumed in 2008. This left the industry was not included in the trading system without any regulation between 2007 and 2008. Therefore, about 20% of Norway's GHG which emitted within this gap period were not monitored by a valid policy instrument (SusNordic Gateaway, 2008). This showed the Norwegian policy vulnerability with outdated policy to cope with the changes in the wider landscape level.

Low Electricity Price

Norway have traditionally had considerably lower electricity price compare with most of the countries in the Europe. The electricity made it even lower compare with the country's level of income. According to the European Commission (2019a), the household and industrial electricity prices of Norway in 2017 were the 4th and 2nd lowest out of 32 countries within Europe. Respondent B and C emphasized the electricity in Norway was cheaper than a lot of places in the world which all thanks to the hydropower. Therefore, respondents B, C, D and E said consumers did not have the urge to adopt solar PV systems because the electricity price in Norway is still relatively low (Figure 9).

Long Payback Time for Private Markets

Otovo (2019) published Solar Payback Trends 2019 about payback times for solar PV power for consumers. Norway was the country that had the longest payback time from 9 to longer than 12 years compared with most of Western Europe sees payback times well below 10 years. The Respondent A, B and C said the long payback time deterred the private households to consider solar panels. They considered 15 years of payback time is too long to the homeowners compared with the commercial sector (Figure 9). The payback time is suitable for business investment yet challenging especially to old homeowners. However, respondent B emphasized the payback time is shorter than building wind parks in terms of full cycle cost and time.

4.2 Mapping the Trend of Solar PV Capacity Development

To recap from the introduction chapter, the growth of total cumulative installed capacity rose by 52% to 68 (MWp) between 2017 and 2018 (Multiconsult, 2019b, p. 41-42). However, the share of solar PV in the electricity generation sector was still less than 1 GWh, worth comparison with hydropower which was 144005 GWh until 2016 (IEA, 2019a and IEA, 2019b). Nevertheless, the neighbouring country, Sweden who has been working closely with for the electricity certificate market, already had 143 GWh of solar PV contributed to the electricity production market in the same year (IEA, 2019c).

The qualitative research data was decoded into themes and categorized according to the interview contents of 5 participants. The frequencies including the number of participants and the number of times were being counted. Key findings for the factors that favour or deter the development of solar PV capacity were sorted across three levels in the MLP accordingly.

4.3 Niche Innovations in Relation to the Trend Solar PV Uptake

This section presented respondents views about whether solar PV considered to be niche technology in Norway nowadays as well as some drivers and barriers concerning the development of Solar PV installation capacity. Figure 4 showed participants defined Norwegian PV as a or not. Four participants did not completely agree solar PV is niche. Only respondent E explicitly define solar PV is a niche technology in Norway.

4.3.1 Respondents Said PV is not a Niche in Norway Anymore

Is PV a niche?	Coding and Explanation	Respondent	No. of times
PV is not a niche	Already part of the regime or finished entering the regime	A, B, C, D	21
PV is still a niche	The social networks are small, unstable and precious	E	4

Figure 7: To the Extent that Norwegian PV Defines as Niche

The Norwegian White Paper (OED, 2016, p. 154) stressed the potential of the solar PV technology in the Norwegian electricity market. The paper also further implies that solar PV is not a niche technology anymore. The paper (OED, 2016, p. 154) further expressed that this renewable energy technology is mature enough to discuss potential and costs. The falling prices of battery are likely to open for new applications such as balancing of larger solar. Moreover, due to the fast pace of technological change, the cost of solar cells has fallen by 80 % since 2009 (KLD, 2017 p.9 in IEA & IRENA, 2017). The number of employees in solar energy was equivalent to 770 full-time equivalents in 2013 who were mainly from the supplier industry (OED, 2016, p.80).

Respondents had two main different interpretations towards “niche”. They defined niche according to the technological level and installation capacity. Respondent B said the installation capacity is growing rapidly especially in the commercial sector, e.g., farming industry and office buildings. Both respondent B and A said solar PV is also growing among public sector. Respondent A gave an example of Utsira Island Project (2004-2008). Respondent B mentioned lighthouses (1992-2001) and Kjøladal Tunnel (2016) where these places have difficulties connecting to the grid due to geographical constraints (OED, 2016, p.163). Respondent C perceived solar PV is still a niche regarding the contribution of electricity production but not a niche from a technological popularity perspective . Respondent D said solar PV is walking away from the niche into a more established industry slowly but surely. He is foreseeing that the solar PV market soon will have a bigger share every year despite the dominance of hydropower. Respondent E defined solar PV is still a niche technology in Norway because less than 0.2% of homeowners have installed solar PV systems.

4.3.2 Drivers for Niches

Reasons	Summary factor and Explanation	Respondent	No of times
Technological interest	Interest in technological development	A, B, E	26
Electricity storage	Energy storage system, e.g., battery, electric vehicles, water body	A, B, C, D	61

Figure 8: Drivers to Adopt PV at Niche Level

Technological interests along with environmental contribution formed the underlying motivations to adopt solar panels (Figure 5). A study from Winther, Westskog and Sæle (2018, p. 89) reported that majority of research targets who were interested in the technology had a job related to energy and expected that their experiences with the technology would be useful to their work. These individual prosumers were prepared for the relatively high transaction costs with limited expectations for financial profitability. Respondent A, B, E also said a group of technology savvy customers are particularly adopting new technology. Many of them already adopted solar PV devices before the technology is aware by the public.

Battery storage technology

Although this is not the focus of this study, the majority of respondents mentioned this point as a driving factor to adopt solar PV devices. Respondents A, B, C and D said solar PV systems become more attractive when combining it with storage technology (Figure 5). They introduced storage for electricity surplus can be with various methods such as batteries, electric vehicles, water bodies or transfer back to the grid. Respondent C suggested the government could use “flexibility” as selling point to promote solar PV with battery storage. Respondent A and D said electric vehicles facilitate the uptake of solar PV devices in the not too distant future because they can transfer the electricity surplus to their car in the evening and avoid expensive electricity during critical peaks. Besides, some old houses also lack charging infrastructure for electric vehicles. Respondent D predicted battery storage would be crucial in the future to in favour solar PV uptake.

4.3.3 Barriers for Niches

Challenges	Summary factor and Explanation	Respondent	No. of times
High installation cost	The cost of installing solar PV devices, e.g., labour costs	B, C, D, E	37
Shortage of sunlight in the winter	Large seasonal variation in hours of daylight in Scandinavia	B, C	7

Figure 9: Barriers to Adopt PV at Niche Level

High Solar PV Installation Costs

Even though the prices of solar panels have fallen, solar power was still an expensive energy technology in Norway. With Norwegian sun conditions, NVE (2019) has calculated an energy cost for solar power of around 140 øre / kWh in the most favourable cases. Solar PV plants were the most expensive if constructed up north or in the smallest scale. Although retrofitting of small solar power plants to buildings today has been the most expensive form of solar power production, building materials had the same characteristics as solar panels. If solar panels could replace other building materials, such as roof panels, the additional cost of installing solar cells could be significantly lower (NVE, 2019). Respondents B, C, D, E expressed clearly that high installation cost of solar panel is a big challenge (Figure 6). Respondent B said the cost of labour in Norway is obviously higher than other European countries such as Belgium or Netherlands. Respondent C and D said small solar PV market struggles to bring down the costs.

Moreover, a large part of the costs contributed to installation costs, which were affected by the installers' salary level, experience and competition in the market. This explained a large part of the difference in costs between Norway and the neighbouring countries, according to the interviewees. Solar power was not profitable today compared with today's electricity prices. Therefore, as mentioned earlier concerning price signals, the Royal Norwegian Ministry of Petroleum and Energy (OED) (2016, p. 162) expected that the cost of solar power in Norway to decrease further in the upcoming years. This was again also spoken by respondent B, C, D and E.

Intermittency challenges decreased electricity production flexibility

Norwegian energy system was determined by whether the technologies had properties that support the electricity system during periods of greatest need. Such value was reflected in the power price. The opportunities to create value from various types of electricity generation depended on market developments in the Nordic and European electricity market and technological developments (OED, 2016, p.164). Nevertheless, the production profile was only positive in the summer when the solar radiation was strongest at the same time when energy demand at the same time the electricity prices were low which also mentioned by respondent B and C (Figure 6). The flexibility to produce when needed is also low. Thus, the Norwegian solar PV has always been struggling to become an important role to support the electricity system to satisfy the "greatest need".

4.5 Sociotechnical Landscape in Relation to the Trend Solar PV Uptake

4.5.1 Drivers for Sociotechnical Landscape

Reasons	Summary factor and Explanation	Respondent	No of times
Climate awareness	Dedicate to renewable energy to reduce carbon emission to mitigate climate change	A, B, C, D, E	38
Electricity price uncertainty	Unpredictable increase in electricity price in future due to climate change which lead to low rainfall for hydropower	A, E	8
Environmental costs from constructions	Environmental problem caused by hydro and wind	A, B	7

Figure 10: Drivers to Adopt PV at Landscape Level

Climate Awareness

As mentioned earlier, Norway agreed to fulfil the binding targets which set by the EU's Renewable Energy Directive to increase the national share of renewable energy to 67.5% by 2020. (NVE, 2018b). Besides, Norway have signed the Paris Agreement in 2016 which agreed to reduce 40% of GHG emissions in 2030 compared with the 1990 level (KLD, 2016). This has also raised a lot of attention in the country about climate change. In this study, all respondents clearly expressed that climate awareness is a reason to adopt solar PV devices (Figure 10). They said people do not mind installing expensive solar PV devices so as to contribute to a better environment and more sustainable. Respondent A and B stressed that the climate issue is more present with the younger generation. Respondent D suggested customers from business sector who install solar PV devices is to build a green image while customers from private sector who truly want to save the planet. Winther et al. (2018, p. 90) explained some private prosumers perceive solar PV panels is a way to improve the environment. For example, electricity delivered from the solar panel helped reduce the stress on the electricity system and the natural environment (avoid exploiting more rivers in Norway) and avoid importing electricity produced by fossil or nuclear sources.

Climate Change Caused Electricity Price Uncertainty

Low rainfall led to increase energy trade with its neighbouring countries which led to significantly high electricity price especially during 2018 to early 2019 (Otovo, 2019a; Taylor, 2019a; Taylor, 2019b). As mentioned earlier, research suggested that it is more profitable to consume electricity generated from solar PV panel than obtain electricity purchased from the grid. Therefore, respondent A and E said electricity price uncertainty accelerated the adoption of solar PV devices (Figure 10). Respondent E regarded the technology as an insurance against high electricity prices to avoid suffer from getting expensive electricity bill in the future. Norway has traditionally had low electricity price until second semester 2018, the price for household consumers went up to 12^{th} most expensive (€0.1907 per KWh) out of 41 European countries which is only slightly cheaper than Sweden who ranked the 11^{th} (€0.199 per KWh)(Eurostat, 2019). Furthermore, Inderberg (2015, p. 100) mentioned that the direction of setting electricity policies in Norway based on precipitation levels (dry or wet years) and temperatures (warm or cold winters).

Environmental costs by hydropower in Norway

The Norwegian White Paper repeated several times that emphasis must be placed on environmental costs (OED, 2016, p.159). Back to 1970s, there was “Alta Affair” which massive protests when the state decided damming a gigantic hydro-electric power project in the Sami core areas at the Alta-Kautokeino River (Jentoft, Minde & Nilsen, 2003, p. 75-78; Ween, 2012, p. 260). Hydroelectric power stations with reservoirs could store energy and produce power during the highest electricity demand. This was important to maintain the security of supply in the Norwegian and Nordic power system. The restructuring of the energy markets in Europe and rapid development of renewable energy in the Nordic region have intensified the focus on the role of Norwegian hydropower reservoirs in balancing unregulated renewable power production. However, extensions would often result in environmental problems along with entirely new development projects. Although the increase in utilization of hydropower regulation capacity involved more power driving, the accompanying rapid changes in water flow and water level could have negative consequences for birds, fish and bottom animals as well as emit large amount of GHG due to rotting vegetation in the water (Deemer et al., 2016, p. 956). It would therefore be important to balance the benefits of power driving with the disadvantages of the environment and other user interests (OED, 2016, p.159, 160). In 2012, research from Bakken, Sundt, Ruud & Harby (2012) and later followed up by Opperman (2018) discovered the unexpectedly large accumulated impacts of small-scaled hydropower plants while Norway was a culprit because the country had more small than large-scaled plants due to its natural terrain.

Solar PV installation and integration compensates the Environmental degradation caused by wind energy

The Norwegian energy policies also designed for deployment of energy technology give priority to onshore wind apart from small hydropower (Klitkou & Godoe, 2013, p. 1593). Wind power plants were space-consuming and reasonable trade-offs are important for important environmental and social concerns especially installation and integration. The environmental challenges associated with wind power have largely related to valuable natural habitats, bird life and landscape. It also involved challenges related to settlement, outdoor life, defence of interests, cultural monuments, Sami interests and biodiversity (OED, 2016, p.192). Rydell et al., (2012, p. 29-30) conducted a research about the number of birds killed annually at wind power facilities in Europe including Norway. Researches between 2010 and 2011 by Bevanger et al. (2010) and Bevanger et al. (2011) revealed that wind farm in Smøla, an island off the coast of Norway showed a particularly high fatality rate for sea eagles especially during the during nesting season from March to June. This point corresponded to respondent A and B about nature preservation trade-offs when constructing new power plants (Figure 10). However, solar panel installation has considerably less environmental impact. Miller and Keith (2018, p. 2, 3) mentioned that for the same generation rate, the climatic impacts from solar PV systems are about ten times smaller than wind systems. Besides solar panel did not have moving parts. Solar panels also had considerably less limitations to location which panels could be mounted nearly anywhere (Lavric, Pattison, Richardson & Wood, 2019). This showed solar PV was capable than other niche renewable technology to solve regime problem when necessary.

4.6 Timeline of Highlighted Events of Norway's Electricity History in Relation to Solar PV Technologies

The timeline (Figure 11) for the transition began from 1945 when Norway has experience periods of both power deficits and surplus. Due to frequent periods of load shedding, the socio-economic costs of a power shortage were significantly higher than the costs of a power surplus until 1960s (NVE, 2017, p. 7).

During 1950 to 1985, there was massive national expansion of the hydropower sector with installed capacity of 33000 MW until 2013 (NVE, 2017, p. 7). In 1963, the first cross border electricity cooperation with Sweden were commissioned which subsequently formed the Nordic electricity market and expanded the electricity trade among other EU countries (NVE, 2017, p. 9). In 1991, NVE decided to deregulate its electricity sector to improve the performance of the economic efficiency in resource utilization (Bye & Hope, 2005, p. 4, 14). In 1979, the Alta Issue triggered large-scaled demonstration for the first time in the Norwegian hydropower history.

Later from 1980 to 1992, the 1st solar PV wave emerged rapidly to the electricity production for the leisure market. Large demand for solar panel installation in remote cabins in the forests and mountains of Norway. The high density of cabins resulted in one of the largest markets in the world for solar cells and the cabin market accounts for 80-90% of the Norwegian market (Luud & Larsen, 2005, p. 24; Bugge, 2012, p. 8). Between 1992 and 2001/2002, there were approximately 2350 installations in the Coastal Guard programme. These projects were powered by PV and were provided with a NiCd batterybank with storage capacity is 120 days without power from the PV system Bugge, 2013, p. 4). In the same year, Enova SF was founded by OED to increase innovation in energy and climate technology adapted to the transition to the low-emission society (Enova, 2019). In late summer 2003, Norwegian reservoirs were still not being replenished and were nearly depleted. The water level of reservoirs directly affected the availability of electricity of the country. Fortunately, the crisis was offset by the electricity transmission between the Nordic Power Market from Sweden and Finland (Aarhus, 2004, p. 5-7; Inderberg, 2015, p. 102). In 2005, European Union Emissions Trading System (EU ETS) was introduced for CO2 tax (European Commission, 2019b).

During 2004 to 2008, the Utsira Island Project with battery storage technology which mentioned previously was started up (NCE Maritime CleanTech, 2018). Again, in spring 2011, water reservoirs that fed Norway's hydro-plants are only 20.6% compared with an average of 44.3% same time of the year (Fouche, 2011). In 2012, Bakken et al., (2012) and Opperman (2018) discovered the unexpectedly large accumulated impacts of small-scaled hydropower plants where Norway had numbers of small-scaled plants. Between 2015 and 2016, Norway had built several technology milestones. For example, the world's first electric ferry – Ampere, new ENOVA housing subsidy scheme to boost smarting housing technologies and Kjøladal Tunnel Lighting Project which featured solar panel and battery storage technologies.

In 2016, Norway ratified the Paris Agreement. The country agreed to reduce 40% of GHG emissions in 2030 compared with the 1990 level (KLD, 2016). In 2018, once again a serious drought made Norway turned to power importer (Karagiannopoulos, 2018). Until the of same year, Enova granted 837 measures about roof-top solar panels (EnerWE, 2019b). The electricity price also hit the highest for 8 years in Jan 2019 (Taylor, 2019a).

The following table summarized a list of highlighted events of Norway's electricity history in relation to solar PV related new technologies in sequence. This table is significant to discuss and explain the transition pathway of installation of grid-connected PV capacity developed in Norway until 2018 in the discussion chapter.

Year	Event
1945-1960	Power deficit with frequent periods of load shedding
1950-1985	Massive national expansion of the hydropower sector
1963	First cross-border power exchange with Sweden
1979	Alta Issue - against construction of hydroelectric power plant
1991	Deregulation of the Norwegian electricity sector
1980s-1992	Hugh demand from Norway's cabins made one of the largest markets in the world for solar cells
After 1992	Emerging significant market for PV powered coastal lighthouses with a NiCd batterybank
1992-2002	Coastal Guard Programme completed with approx. 2,350 installations
2001	Founded Enova SF
2002-2003	Extreme weather fluctuated water level for reservoirs
2003-2004	Dramatic shortfall resulted Norwegian reservoirs were nearly depleted
2004 - 2008	Started up the Utsira Island project
2005	Introduced the EU ETS for CO2 tax
2011	Electricity disruption alert due to unprecedented low hydro-power reservoir levels with only 20.6% full
2012	Research discovered environmental impacts of small hydropower in Norway
2015	The world's first electric ferry Ampere operated between Lavik and Oppedal
2015 Jan	New ENOVA housing subsidy scheme
2016	Norway ratified the Paris Agreement
2016	Kjøladal Tunnel Lighting Project by solar panels and battery storage systems
2018	Norway turns to power imports after dry spring hits hydropower reserves
2018	Enova paid out nearly 837 support measures for rooftop solar panels
2019	Recorded highest January electricity price in Norway for 8 years

Figure 11: Highlighted Events of Norway's Electricity History in Relation to Solar PV Related New Technologies

4.7 Summary

The above has included a content analysis in related to the research objectives. It presented the findings of the qualitative interviews that most of the key ideas were echoing the secondary data. The Norwegian government played a key role to especially in the financial aspect to facilitate solar PV installation market. Respondents had positive outlook towards the market.

Furthermore, government's niche technology neutrality commitment, solar PV projects and environmental problems caused by hydropower derived symbiotic innovations as additional alternatives to solve local problems while hydropower still survived in the regime. These empirical examples provided implications and characteristics that the transition was in line with reconfiguration pathway. In next discussion chapter, the reconfiguration pathway was discussed thoroughly empirically and theoretically as points of departure.

5.0 Discussions

5.1 Introduction

This chapter is devoted to providing a critical discussion of the initial analysis based on the empirical findings, which set against the existing literature as discussed previously in the theoretical framework chapter. MLP theoretical conceptual framework was adopted as an organizing principle to address the research question. The overall aim of this thesis is to examine the Norwegian solar PV market context along with the dynamic interaction of three levels within the MLP framework. This chapter had discussed empirical findings and the timeline from previous chapter in relation to the characteristics of reconfiguration pathway and its theoretical implication to the MLP framework.

5.2 Address the Research Question

Below is a recap of the research question which correspond to the interview design.

> ***How has the installation of grid-connected PV capacity developed in Norway up to 2018, and how can this be explained?***

Despite the nature of qualitative analysis, this study contained factors for dependent and independent variables. The dependent variable, PV installation capacity measured by the gigawatt that has been installed within Norway. The independent variables, the MLP framework is defined as a non-linear mechanism to measure the overall dynamic patterns within the socio-technical transitions. Actors from niche, regime and landscape are the three levels that measured different kinds of coordination and structuration to activities (Geels, 2011).

5.2.1 Niche Innovations in Relation to the Development of PV Capacity in Norway

Today, almost everyone in Norway know what solar PV is. Therefore, the Norwegian solar PV market whether or not regarded as niche technologies depends on one defining from which angle. There are several features about niches from Grin et al. (2010, p.22-23) that matches with the Norwegian context. First, niche technology was exposed to actors from the selection environment under relatively protected circumstances. The share of electricity generation sector resulted solar

PV to be a very niche market compare with the hydropower. However, the government designated solar PV technology as the main and the only source of electricity supply for the Kjøladal Tunnel Project in Rogaland to provide lighting system. Therefore, compared with the dominant hydropower, solar PV technology was well protected by the government to be engaged with the project because solar power plants are flexible in terms of location which solved the problem of electricity transfer to this remote tunnel.

Second, technological niches are carried by experimental projects (Grin et al., 2010, p.22). The Utsira Island Project, for example, it has been working on electricity self-sufficient by a hybrid energy system. Therefore, the project emphasised on storage that included new technology, electric vessels, to balance and support the power line onshore (NCE Maritime CleanTech, 2018).

Third, protection comes from networks of dedicated actors who are willing to invest resources in the new technology. Thus, these actors have high expectations and public subsidies contribution. Here implied that the rather than using traditional cheaper electricity generation and transmission by hydropower plants and grid connections, the government would rather to pay a higher price on niche solar PV technology and battery storage systems. This is because the actors believed that their investment will gain, from different dimensions not only limited to financial gains, in the long run. For example, the Kjøladal Project costs about 20% of the connection to the conventional network would cost with replace to solar cells, batteries and smart power consumption management. Besides, this could avoid damages that cannot be measured in money such as impact on natural landscapes by overground power lines or digging and blasting of ditches affects hydrology and vegetation by underground cables (NVE, 2007, p. 66; OED, 2016, p.153). Furthermore, larger projects like Utsira can demonstrate of sustainable energy solutions as an energy carrier. This further facilitates the project goal by helping to improve public awareness and acceptance, to improve cost competitiveness of renewable energy and to reduce market barriers for new energy and technology solutions in general. In order to allow "more high cost niche applications may also emerge" (Nakken, Frantzen, Hagen, & Strøm , 2006, p. 2-3).

To summarize the above ideas, there were only a few cases that solar PV was the main source of electricity. Although majority of interviewees did not perceive solar PV as niche, their points of departure were the awareness of the such PV technology in the general public. Therefore, it was based on personal assumption and respondents' feeling which created subjectivity. However, this thesis focusses on the installation and the market share of the electricity generation sector. Thus, it could state that solar PV in Norway is a niche.

5.2.2 Socio-Technical Regime in Relation to the Development of PV Capacity in Norway

Hydropower is undoubtedly the dominant source of energy for the Norwegian electricity generation sector. To stabilize such social-technical regime systems, this involved various groups, including the policy makers, users and special-interest groups. Policy makers from the government institutions, e.g., OED and NVE, played key roles to compile energy policies. OED is responsible for energy policy by managing energy resources and NVE is to ensure an efficient electricity system by achieving correct price signals and to decide reasonable prices for the energy market. Users referred to stakeholders who consume electricity that provided by the power grid. This involved from the general public to private individuals. Special-interest groups were the stakeholder who are benefited from the energy security within the Nordic power system. This point will be explained further.

These incumbent actors were reluctant to major changes because they develop "webs of interdependent relationships" (Grin et al., 2010, p.20 in Tushman and Romanelli, 1985: 177). Since hydropower forms the basis of the electricity generation regime in Norway, as declared by OED (2016, p. 8) earlier, the large-scale flexible hydropower will still be the backbone of the country's energy system. Hydropower production was important from a European climate perspective. The OED believed that they have the responsibility to maintain the security of supply of the Norwegian and Nordic power system. Moreover, the NVE who is responsible for expanding the licensing policy for new hydropower after 2020. This attempt was to emphasize the ability to produce sufficient electricity during peak demand period. This can lighten the effect of intermittency with the growing share of electricity source that are not flexible, e.g., solar and wind energy (Lia, Jensen, Stensby, Midttømme, & Ruud, 2015, p. 38). This example demonstrated these social groups interact and form networks with mutual independencies. Innovation, e.g., small hydro plants, still occurs but is of an incremental nature (Grin et al., 2010, p.21; Lia, et al., 2015, p. 38-39).

Existing socio-technical systems can be stabilized in several ways. Findings revealed that there were too little financial support mechanisms to lower the threshold for potential new (niche) market players. There was only Enova subsidy for private market and no incentive schemes for business market. This obstructed potential actors to enter the market due to financial constraints. Sometimes cognitive routines blind dominant actors to developments outside their focus (Geels, 2007, p. 400 cited in Nelson & Winter, 1982). However, according to the interview with NVE and governmental documents defended that they would like to comply with the principle of technology neutrality which means all energy sources defined as renewable energy sources qualifies for the right to be supported (OED, 2012, p. 4). Moreover, the findings indicated that Norwegian energy policy was not up-to-date. For example, the Enova Subsidy (Enovatilskuddet) was launched 15 years after Enova was founded. The expired climate agreement which led to 20% of Norway's GHG emissions without being measured between 2007 and 2008. Such practices demonstrated that organizations were resistance to major changes. However, as showed by Langhelle, Kern & Meadowcroft (2017, p.1,13), the Norwegian government had sufficient power to promote the niche in specific ways and this relied on political willingness.

5.2.3 Socio-Technical Landscape in Relation to the Development of PV Capacity in Norway

Thanks to those dedicated actors who have developed the lock-in social technical regime, however, they are still directly and indirectly influenced by the broad exogenous environment and complex backdrop from the socio-technical landscape. First, landscape are the factors that do not change or that change only slowly in the long-term (Van Driel & Schot, 2005, p.54). For example, due to climate change. After signing the Paris Agreement in 2016, all participated nations have to contribute to mitigate the emission of $CO2$ for 40% by 2030 compared with 1990 level (European Commission, 2019c). Even if GHG emissions are reduced in line with the Paris Agreement, Norway will still have to manage the effects of gradual climate change for a long time (FIN, 2018, p. 8). Climate awareness was also explicitly mentioned earlier by all the interviewees as a highlighted motivation in response to the growth of Norwegian solar PV installation market.

Second, landscape pressure was also caused by long-term changes. For example, the environmental costs caused by construction of hydroelectric power plants. That can already be traced by to late 1970s about the "Alta Issue". The immediate effect of these constructions was visible such as affected the lives of Sami inhabitant as the power plant located at core areas at the Alta-Kautokeino River. However, the construction of hydroelectric power plants has also caused long-term environmental changes and problems. For example, changing in water flow altered the river ecosystem and also emit GHG due to rotting vegetation in the water even though the emission amount varies significantly from power plant to power plant. These problems took time to get to the surface but the consequences can be severe because of the industry's growing demand. Thus, this landscape development occurred initially with human agency whom the Norwegian government planned and decided to build the hydropower plants. As a result, the environmental costs caused by building hydro power plants trigger environmental degradation which gradually accounted for a negative contribution to the climate change. Moreover, it was very important to remember that the biggest landscape challenge was to reduce GHG emission as agreed internationally. Nevertheless, GHG emission caused by rotting vegetation weakened or might even counteract the effort of low carbon energy created by these hydropower plants.

Third, landscape factors also refer to rapid external shocks. The shock in this study refers to the unpredictable drought (leading to high electricity prices) during the first half of 2018. Norway came across significant drought in summer 2018 and lack of snow fall in winter 2019 to fill up the water capacity and it is known that hydropower is the backbone of the Norwegian electricity system. Fortunately, Norway is still far away from "electricity blackout" due to the collaboration with neighbouring country, Sweden (Taylor, 2019a; Taylor, 2019b). Norway had also come across several drought before, the most serious drought was happened between 2003 and 2004 where Norwegian reservoirs were nearly depleted (Aarhus, 2004, p. 5-7; Inderberg, 2015, p. 102). Although the government can decide whether or not to increase electricity price to adjust market efficiency, it was a fact that the amount of electricity production is decreased due to unexpected weather shock. Therefore, "electricity policy in Norway swings with precipitation levels and temperatures" (Inderberg, 2015, p. 100). Van Driel and Schot (2005, p. 54) explained these two points combined in a single landscape category as they form an external context that actors cannot influence in the short run. The external shocks were the result from the outbreak of the incremental evolution.

5.2.4 Transition Pathway of the Trend of Solar PV Installation Capacity in Norway up to 2018

In this research, the reconfiguration pathway is the best fit of the pathways to explain the emerging Solar PV market in relation to the transition of the Norwegian electricity production market (Figure 12). To recall the definition of reconfiguration pathway, it involved symbiotic innovations. Technologies that developed in niches were originally adopted in the regime to solve local problems. The trajectories later changed the regime's basic architecture.

The trajectory of the transition began from the 1st shock from the landscape in 1945 to 1960 when Norway has experience periods of both power deficits and surplus (Figure 12). However, due to frequent periods of load shedding, the socio-economic costs of a power shortage were significantly higher than the costs of a power surplus (NVE, 2017, p. 7). Therefore, the government proposed three solution in respond to the instability electricity supply in a time sequence.

First, during 1950 to 1985, there was massive national expansion of the hydropower sector with installed capacity of 33000 MW until 2013 to secure the socio-technical regime of the electricity market (NVE, 2017, p. 7). Second, the first cross border electricity cooperation with Sweden were commissioned in the early 1960s which subsequently formed the Nordic electricity market and expanded the electricity trade among other EU countries (NVE, 2017, p. 9). The NVE decided to deregulate its electricity sector in 1991 to improve the performance of the economic efficiency in resource utilization (Bye & Hope, 2005, p. 4, 14). This determined hydropower as the basic architecture of the Norwegian electricity market regime. Thirdly, in late 1970s, the Alta Issue which triggered large-scaled demonstration for the first time in the Norwegian hydropower history. Thus, this simultaneously created window of opportunity for different electricity production innovations to solve the regime problems.

Later from 1980 to 1992, the 1st solar PV wave emerged rapidly to the electricity production for the leisure market. Large demand for solar panel installation in remote cabins in the forests and mountains of Norway. The high density of cabins resulted in one of the largest markets in the world for solar cells and the cabin market accounts for 80-90% of the Norwegian market (Ruud & Larsen, 2005, p. 24; Bugge, 2012, p. 8). After the cabin market was saturated in 1992, the trend of solar PV uptake was immediately compensated by the of new markets - PV powered coastal lighthouses. A milestone was the Coastal Guard programme development which completed in

2000-2001. Approximately 2350 installations were powered by PV and were provided with a NiCd batterybank with storage capacity is 120 days without power from the PV system (Bugge, 2013, p. 4). The uptake of solar PV and battery storage technology formed smaller and larger component that add-on to existing electricity market component while hydropower was still heavily responsible for the providing electricity to the whole country. In the same year, Enova SF was founded by OED to increase innovation in energy and climate technology adapted to the transition to the low-emission society (Enova, 2019).

Nevertheless, the 2nd shock from landscape of extreme depletion approached between 2002/2003 winter. Even until the late summer of 2003, Norwegian reservoirs were still not being replenished and were nearly depleted. The water level of reservoirs directly affected the availability of electricity of the country. Fortunately, the crisis was offset by the electricity transmission between the Nordic Power Market from Sweden and Finland (Aarhus, 2004, p. 5-7; Inderberg, 2015, p. 102). Thanks to the socio-technical aid from the neighbouring countries, this helped to block the avalanche change and stabilize the regime. Niche-innovations such as solar PV were not very sufficiently developed to substitute hydropower at the time either. The electricity transmission saved the regime from erosion and eventually prevented de-alignment. After the critical drought challenge in 2003, the regime was maintained calm for several years. During 2004 to 2008, the Utsira Island Project with battery storage technology which mentioned previously was started up (NCE Maritime CleanTech, 2018).

The regime faced the 3rd shock with double pressures in 2011. Norway had the potential electricity disruption with an unprecedented low in hydro-power reservoir levels according to NVE. Water reservoirs that fed Norway's hydro-plants are only 20.6% full in spring 2011, compared with an average of 44.3% same time of the year (Fouche, 2011). Moreover, a year later, Bakken et al., (2012) and Opperman (2018) discovered the unexpectedly large accumulated impacts of small-scaled hydropower plants. Norway had more small than large-scaled plants due to its natural terrain. Between 2015 and 2016, the government also supported several niche technologies to add-on to the electricity market. For example, the world's first electric ferry – Ampere, new ENOVA housing subsidy scheme to boost smarting housing technologies and Kjøladal Tunnel Lighting Project which featured solar panel and battery storage technologies.

The 4th shock happened in 2016 where Norway ratified the Paris Agreement. Norway agreed to reduce 40% of GHG emissions in 2030 compared with the 1990 level (KLD, 2016). Even though this shock was regular and incremental, this caused pressure to Norway to accelerate the mitigation of GHG emissions in order to meet the target within two decades. In 2018, Norway once again faced the same external pressure from the landscape. A serious drought made Norway turned to power importer (Karagiannopoulos, 2018). The electricity price also hit the highest for 8 years in Jan 2019 (Taylor, 2019a). This time the government and the public had built up higher resilience due to previous experiences. Together with the Enova incentive support and more mature of the niche solar PV and battery storage technology that triggered a record of 837 Enova measures in total of roof-top solar panels until the end of 2018 (EnerWE, 2019b).

Several external landscape developments influenced the transition. For example, several drought alerts led to critically low in hydro-power reservoir levels and discovery of high environmental impact of hydropower plants. While these landscape pressures created pressure but also opportunities, e.g., deregulation and liberation of the electricity sector, cross-border electricity cooperation, emergence of the solar PV and battery storage market, electricity market efficiency improvement and improved resilience of the electricity system. The main characteristics of this reconfiguration pathway was the interaction between multiple component innovations and the regime. The transition of the solar PV market uptake was driven by sequences of multiple component innovations, e.g., solar PV, electricity storage technology, new energy policies that favour niches. The innovations were initially developed to solve particular problems, i.e., electricity shortage, and progressively enabled adjustments in the basic architecture of the electricity production market (Geels & Schot, 2007, p. 413). Besides, another important point was the hydropower regime and its actors survived in this reconfiguration pathway from these several shocks and further facilitated more new elements and novelties.

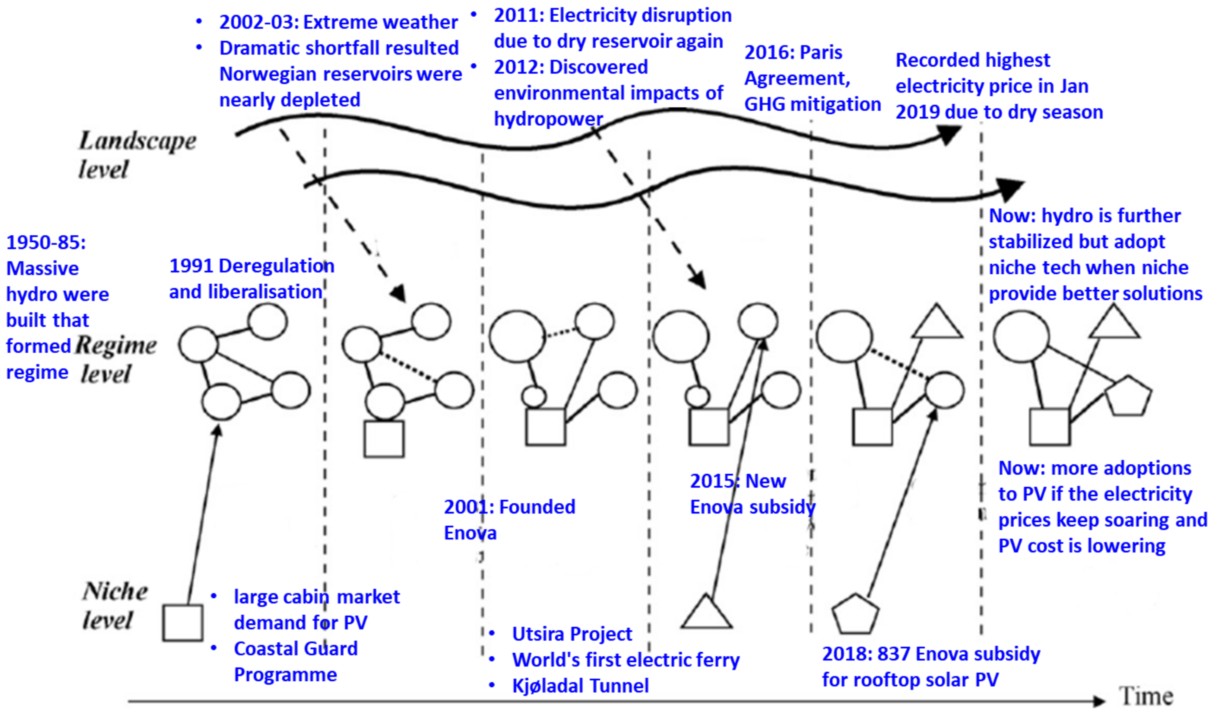

Figure 12: The Norwegian Solar PV Industry in Reconfiguration Pathway (adapted from Grin et al., 2010)

5.3 Implications of PV in Norway Being on the Reconfiguration Pathway

5.3.1 From Theoretical Perspectives

The scope of the empirical topic implies the operationalization of the regime concept. Given that political intentionality is one of the most important that determine the trajectory of a pathway. Economic consider is always the main concern for political decision making. We can expect that the focal point of this thesis is to explore the potential and challenge of Norwegian solar PV installation in particular from political and economic perspectives. This implies that transition theory needs to accommodate various types of agency (Geels & Schot, 2011, p. 415). Actors who have been contributing to the transition were mainly policy makers, power suppliers, PV installation companies and electricity consumers rather than R&D related personnel nor academic research institutions. Therefore, the scope of the empirical topics at the regime level was mainly around the political willingness to adopt solar PV throughout while continue to consolidate hydropower as a factor to determine which level solar PV belong to within the MLP.

5.3.2 From Empirical Perspectives

The hydropower regime and its actors survived well in the reconfiguration pathway. Although the Norwegian hydropower experienced several noticeable pressures, e.g., low reservoir levels and protest again plant constructions, it was still able to remain as a backbone of the Norwegian electricity generation regime. Furthermore, given that the feedback from OED which hydropower would bear a more significant responsibility to secure the electricity supply of both Norwegian and Nordic power systems. We can expect that the solar PV installation capacity nor other niche renewable technologies will not be increased dramatically in a foreseeable future as long as the capacity of hydropower remains steady. However, the government will open up to other niche technologies if such symbiotic innovations can easily be adopted to solve small problems and to improve performance without affecting the status of hydropower in the electricity generation regime.

Solar PV has to compete with other "fellow" niche renewable technologies especially offshore wind power. The NVE's inspiration of technology neutrality implied that solar PV needs its own unique feature that can stand alone form other niche renewable energy sources in order to "queue up at the front of the waiting list" in order to be chosen by the regime when it noticed PV could provide better solution to solve local problem that caused by exert pressure from the landscape. Given from the previous empirical examples, solar PV was capable to be adopted more frequently because it was more suitable to achieve most of the regime's targets than other niche renewable energy technologies. For example, solar PV was the best solutions among other niche renewable energies to the Kjøladal Tunnel Project and could not be solved by the hydropower regime either. We can expect that this added more symbiotic values to solar PV within the transition of the Norwegian electricity generation structure framework.

5.4 Respond to the Criticisms of MLP to Meet Research Expectations

5.4.1 Overestimation on the Influence of Socio-technical Regime

The transition pathway is considered to be different before and after data analysis. The Norwegian solar PV market was positioned as transformation pathway in the theoretical section but now considered reconfiguration pathway fitted better with the research result. The key reason was due to overestimate the influence of the socio-technical regime in the interactions with three levels.

This is because as mentioned earlier that quite a number of studies reminded researchers to call for more attentions to political intentionality in the regimes. Besides, above it was mentioned that the "regime will be at the expense of niche at all costs to maintain stability of status quo". Therefore, it was believed that at the beginning of the research, the Norwegian hydropower market players would make their most effort to put obstacles on the uptake of the emerging solar PV market. Thus, this study initially tended to focus on the barriers of solar PV that mainly were related to political interests since it would make it more valid to seem conflicted with the regime's interests. However, this research provided different points of view and new insights after interviewing with different groups of solar PV actors in particular NVE. It is realised that the importance of hydropower in Norway was due to the cooperation from neighbouring countries to maintain an efficient electricity market. The loss to the Norwegian electricity market and also the economy could be gigantic if the hydropower system fails. In this regard, paying too much attention on political aspects may create unnecessary bias.

5.4.2 Limited Power of the Socio-Technical Regime against the Landscape

This study suggests that the socio-technical regime always faces dilemmas. The most explicit source is the pressure from landscape that challenges the stability of the regime, for example, the adverse effect caused by climate change. In this study, the result showed that the Norwegian government bear a key responsibility to maintain and secure the energy sector in several aspects, i.e., (1) the sufficient supply of electricity, (2) the efficiency of electricity system by obtaining correct price signal (3) export electricity as national revenue and (4) the close electricity market connections with neighbouring countries . Therefore, they must prioritize their tasks in order to achieve these goals. Fortunately, the Norwegian government in general is relatively open-minded. They are willing to function the electricity market through the interplay of different old and new renewable energy sources, e.g., hydropower, wind and solar PV. NVE have also been promoting different emerging niche renewable energy sources since their objective was to give equal opportunities to the niches by maintaining technology neutral. As recapped from the interview with NVE and related government publications revealed that they supported the idea to prioritize the stability and effectiveness of the Norwegian electricity market in the long run.

However, to maintain the electricity market efficiency is a great challenge particularly in the long run. If the speed of transformation of hydropower to other sources of renewable is too fast, the electricity market has a risk of collapsing when it comes to external shocks because of the absence of a solid foundation, e.g., *Energiewende* in Germany. Germany has further accelerating the transition to phase-out nuclear due to the Fukushima accident in 2011. The *Energiewende* resulted in consuming more coal to fill the back-up capacity caused by phasing out nuclear. This aggressive attempt has meant that Germany even moved further away from the road to renewable future (Buchan, 2012, p. 24; Beveridge & Kern, 2013, p. 8; Dohmen, Jung, Schultz & Traufetter, 2019). Therefore, actors from the electricity market have to adopt the renewable source of energy that has lowest environment costs without undermining the electricity system.

5.4.3 Limited Research on Solar in a Norwegian Context

The social science research about solar PV in particular Norway is somewhat limited. This is because there is substantial underestimation for the potential of solar PV in Norway (Statkraft, 2019). Besides, compared to another niche technology, offshore wind, was financially back up by large-scaled energy companies and government funding while solar PV only supported by small power grid companies, therefore, the former is more capable for technology R&D and market development (Equinor, 2019). Since there are only few previous studies on the topic, this narrowed the scope of literature review. To tackle the problem, exploratory research was adopted in this research instead of casual research. By conducting interviews with different group of actors from the solar PV market, this helped to broaden the horizon of searcher and provided ideas to further researches. Casual research was less suitable because its purpose was to prove hypothesis and assumptions which might result in too conclusive base on imperfect information. Therefore, exploratory research is suggested in the current phrase to avoid research bias caused by limited research perspective.

Moreover, there is high research value on the Norwegian solar PV market. This study has demonstrated solid potentials of solar PV in Norway from environmental, social, economic and technological aspects. One reason for limited previous researches on this topic was because researchers are not confident with the research result since both time and financial cost of a research is high. It is suggested to have more similar researches in future as the cost of research failure is low.

5.5 Conclusion

This chapter has discussed the roles of actors from different levels of the MLP who contributed to increasing the Norwegian solar PV capacity. It highlighted the importance of political regime in promoting a technology in specific ways. The financial support in increasing solar PV capacity was minimal which was in line with the policy principle of technology neutrality. However, there was possibility for the regime to become vulnerable if the landscape pressure was too robust. Multiple landscape pressures created various windows of opportunity to increase solar PV capacity from the recent trend.

6.0 Conclusion

6.1 Introduction

The result provided evidence that Reconfiguration pathway is the most suitable to describe the transition of the Norwegian solar PV market. Since solar PV which strengthened by battery storage was developed in niche and adopted in the regime to solve problems for several times. This helped the government to save a considerable amount of expenses of infrastructure that could not be solved by the dominating hydropower.

6.2 Restate the Research Objectives

To address the research question: "*How has the installation of grid-connected PV capacity developed in Norway up to 2018, and how can this be explained*?" This research analysed the transition of solar PV installation market in the Norwegian electricity generation sector. Reconfiguration pathway demonstrated how the regime adopted niches to solve their own problem derived from the landscape but leaving regime actors survive in the path. Therefore, de-alignment and realignment pathway and substitution pathway are noticeably not suitable to describe this study. These two pathways require a collapse in the regime and eventually need a niche in order to form a new regime so that the transition will be able to continue. However, in this research, hydropower remained as the regime for the Norwegian electricity production market regardless of the shock magnitude. Furthermore, transformation pathway is not suitable either due to the absence of specific shocks with regime actors modify the direction of development path itself. Nevertheless, in this study, hydropower has struggled with several shocks from landscape in order to survive in the regime and sometimes to combine with other niches, i.e., PV and storage technology, as novelties to solve problems that could not be solved be the regime alone. Thus, reconfiguration pathway is suggested to be the most suitable to describe the research result.

The first research objective was to explore the role of Solar PV in a Norwegian context. The researcher obtained insights from stakeholders so as to discuss what favour the development. The value of solar PV to policymakers is to improve the power market efficiency while to business and private markets are due to environmental awareness and the extra credits given by battery storage.

Furthermore, both primary and secondary findings have clarified the potential of solar PV installation market in Norway. They emphasized the solar PV is strong enough to move away from niche to increase market share. However, we should not neglect barriers since they have heavy influences. The high installation cost was still remained to be a key barrier and would be difficult to be solved in the short-run due to the labour cost in Norway is remarkably higher than majority of countries. Moreover, solar PV's natural intermittency problem should be faced properly and can be offset when battery storage is becoming popular. If solar PV can serve the high demand periods, it will provide attractive price signal to the electricity system. Thus, policymakers will allocate more resources to facilitate solar PV.

The second research objective was to understand what factors favour or deter the increase in solar PV capacity. The research presented the significance of bias for data collection. This study had paid too much attention to the influence of regime because several research frontiers stressed the importance of regime that affects the interaction within the MLP. Before data collection, it was believed that the biggest barrier of solar PV development was due to dominance of hydropower. However, both primary and secondary findings revealed that the challenge faced by the regime was the difficulty to maintain the electricity market effectiveness as well as pressure from the landscape which mainly unpredictable weather that derived from climate change.

The third research objective was to discuss the transition of Norwegian solar PV market in an MLP context. Reconfiguration transition pathway explained the transition trajectory of Norwegian solar PV from the past half-century until today. The result of this research echoed with the priori possibilities of reconfiguration pathway. The solar PV technology has natural advantage to reduce the environmental costs caused by hydropower. Solar panel installation has considerably less environmental impact and less geographical constraints compare with other renewable plants such as hydro and wind power plants. Nevertheless, solar PV was still not able to share the burden to produce electricity when the reservoir water level is low from the regime perspective. The government would rather offset the crisis by the electricity transmission from neighbouring Nordic countries to prevent de-alignment of regime. One main external yet determining reason for unstable reservoir level was due to climate change which led to unstable rainfall.

7.0 Recommendations and Implications

This section will propose a list of suggestions to different stakeholders from the Norwegian solar PV market. This will also respond to the fourth research objective to provide implications so as to facilitate the solar PV capacity. There are recommendations and implications for future work to (1) Norway's R&D institutions for directions future research, (2) to the policy makers in achieving electricity market effectiveness in relation to solar PV and (3) power companies who involve in solar PV activities with their business strategies.

7.1 Recommendations for Norway's R&D Institutions for Future Research

7.1.1 Data Collection

The sampling size for qualitative approach was small. It is suggested that a larger scale of interview should be adopted because research about solar PV in Norway is still limited. Future researches can also interview solar PV market customers from business, private and public sectors. It should particularly focus on asking their opinions before and after installing of solar PV devices as well as their expectations. Besides, this study only asked the market players which are actors who offer services and making energy policies. Therefore, the data will be more comprehensive/ less biased if end-users are also interviewed. Besides, despite cross-sectional was designed for this study, longitudinal design would have been more suitable especially on research about transition pathways because transition takes time to change. Longitudinal design satisfies the research purpose of observing a phenomenon to change over a period of time from looking back and forward if time is sufficient (Blaikie, 2010, p. 229).

7.1.2 Regime-Driven Bias

Researchers should pay more attention to the challenges faced by regime created by landscape. This point also mentioned in previous chapter about the criticisms of MLP. Many studies had over focused on bottom-up movement where niche takes every window of opportunity to grow the replace the existing regime. This study re-stated the pressure from landscape (climate change) to regime (hydropower) that creates top-down change so that regime needed help from the niche (solar PV) to maintain stability. Although regime has power to promote the niche in specific ways, it is always in a weaker position against changes from landscape. Therefore, the power of landscape should not be neglected. Just as Geels (2011, p.32) mentioned that to avoid research bias by attention to persistence of change at the landscape level.

7.1.3 Attention to Norwegian Solar PV Market with Storage Technology

Solar PV studies can be linked up with electricity storage. This point is particular important to researchers targeting high latitude locations due to extreme light variation between seasons, e.g., Norway. The idea of electricity storage accelerates the integration of solar PV to the Norwegian electricity sector especially to the off-grid market by offsetting the intermittency problem. Besides, the rising popularity of electric car where its battery can combine with the PV technology to maximize the functionality solar PV energy. Therefore, to include electricity storage can increase the value and attractiveness of solar PV researches.

7.2 Implication for the Policy Makers

If the Norwegian authorities would like to increase solar capacity in Norway, they should persistently diverse the share of electricity generation sector so as to maintain a stable and effective electricity market. Unfortunately, the adoption rate of solar PV and battery storage grows slow because they both still considerably more expensive than hydropower. Nevertheless, the technological level of solar PV and batter storage system has been mature enough to recognize their potential and to discuss costs (OED, 2016, p. 154). Furthermore, previously have demonstrated that hydropower and emerging wind power have been facing different uncertain externalities and environmental challenges. Fortunately, solar PV naturally have less conflicts with the landscape. It can solve a lot of environmental problems that cased by these two renewable energy sources and also save high expenses caused by building electricity grid and cables to rural locations.

There is a three-step suggestion for the government to achieve electricity market effectiveness. First, the government could figure out a correct price signal for the electricity as soon as possible so as to calculate the optimal amount of electricity generated by solar PV that can be digested by the grids. Second, the government should then try different means to lower the costs of solar PV and storage technologies so as to attract more players to contribute to the market. Long-term vision is critical to regard solar PV and storage technology as long-term investment. Although the start-up costs are high and the payback time is long, the return on investment is higher as it enhances the resilience on economic losses caused by climate change. Third, to promote solar PV technologies to the business and private markets. There are several methods such as to provide the importance of raising awareness of prosuming options and knowledge of accessible economic support (Inderberg et al., 2016, p. 65). This does not mean to reduce the importance of hydropower as it is indispensable to provide national income and to bridge the electricity market of neighbouring countries. The government should just utilize the solar PV technology to improve performance and to solve small problems while letting hydropower to maintain a strong status in the regime (Grin et al., 2010, p. 72).

7.3 Implication for the Power Companies

Power companies play a crucial role to promote solar PV installation especially to the private market. These power companies serve as third-party entrepreneur who are responsible for providing technical solutions and dealing with the technical installation aspects, e.g., Otovo and Lyse (Otovo, 2019b; Lyse AS, 2019). District system operators with larger scale are more active supporters than the smaller ones. This is because larger grid companies have greater capacity for incorporating new business-models into their routines than the smaller companies who have limited organizational capacity for managing change (Inderberg et al., 2016, p. 57). This will create snowball effect if potential customers find it accessible to join the prosuming market.

Besides, power companies should cooperate with R&D institutions to gain knowledge and enrich the competence base of solar PV in order to be more competitive in the industry. Thus, they can promote innovation and knowledge to their target customers. Power companies can also have more communications with other peers. By sharing information to obtain latest trend from the market for better planning for their business strategies.

7.4 Further Implications

For future research, it is suggested that researchers should not underestimate the research value of solar PV in Norway. The environmental problems caused of hydropower further accelerate the emerging of solar PV market. Together with the combination of battery storage escalated the research potential. Besides, this research was limited to time constraints. Researchers can also interview end-users of solar PV devices in a longitudinal manner to monitor and compare the user reviews at different periods of time.

Implications to the solar PV power companies should devote to providing technical solutions and dealing with the technical solar PV installation aspects especially to the private market. They should also consolidate base by collaborating with R&D institutions to be more competitive within the market. The Norwegian policymakers have a very clear goal to maintain the security of supply in the Norwegian and Nordic power system and to contribute to the European climate. Therefore, they strive to security the role of hydropower as the backbone of Norway's energy system. They had also learned from the German Energiewende example that the over-acceleration of mass adoption of solar PV does not appear to be an appropriate option to the electricity market to loading of the power grids. Therefore, it is assumed that PV installation will not soar in a foreseeable future as long as the role of hydropower remains unchanged. However, the government should always have back-up electricity production plans even though there are electricity transmission agreements with neighboring countries this means there will be externalities. Externality creates uncertainty and is always difficult to control.

On the whole, it is suggested that in spite of any circumstances, any policies that is benefit to the environment should be put in top priority regardless the intention of the actors. Policymakers should put more weight on sustainability and less on economic growth. Dependence on economic growth and on scarce natural resources generates pollution, such as are severe and pervasive. Policymakers should bear in mind just like Higgins (2013) says: "What can I do to help our world rely less on a level of economic growth that harms the environment and society, and encourage a path toward sustainability?"

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Appendix

Appendix 1: Interview Guide

Topic 1 – Introduction to the interview

1. How long have you been working with solar PV market?
2. How did you come to contribute to the solar PV industry?
3. Could you tell me more about your interest in solar PV?
4. What makes you feel interesting working with solar PV?
5. Do you own any solar PV devices?

Topic 2 – About the Target Market

1. Who are your target markets?
2. What were the main reasons that customers want to adopt solar panels?
3. Have you been observing any changes for the reasons to install solar panels these recent years?
4. What are the major challenges to increase Norway's solar PV capacity?
5. How would you relate these challenges to your company?
6. If so, how does your company overcome the challenges?

Topic 3 – About Norwegian Electricity Generation Market

1. What do you think Solar PV is as a niche technology in Norway until today?
2. How would you compare Norway's solar capacity with other European countries?
3. How would you describe the role of hydro and wind power in the Norwegian electricity generation market?
4. How would you describe the relationship between hydro or wind power and the development of solar PV installation?

Topic 4 – About the Government

1. What are the targets for solar installation capacity for Norway and the recent status?
2. How would you describe the relationship between PV service providers and the government?
3. How does the energy policies help to increase the customer base / sales?
4. How would you predict if the government remove these incentives which acted as a boost for solar adoption and sale?
5. What is the role of Norwegian government in promoting solar panel installation?