Michael Leander Dale Riisøen

The Development and Expansion of the Norwegian Solar Photovoltaic Industry

Master's thesis in Globalisation and Sustainable Development
Supervisor: Markus Steen
May 2023

Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Social and Educational Sciences
Department of Geography

NTNU
Norwegian University of Science and Technology

Michael Leander Dale Riisøen

The Development and Expansion of the Norwegian Solar Photovoltaic Industry

Master’s thesis in Globalisation and Sustainable Development
Supervisor: Markus Steen
May 2023

Norwegian University of Science and Technology
Faculty of Social and Educational Sciences
Department of Geography

NTNU
Norwegian University of
Science and Technology

Abstract

The solar PV industry is seen as one of the viable solutions to the energy transition happening in the world. However, large parts of the value chain on solar PV are in China, and regions like the US and Europe wants to bring back the manufacturing value chain to their respective countries. Norway has a long history of solar PV and can be beneficial when Europe wants to expand and develop the solar PV industry in Europe. However, there are some issues regarding the conditions for growth of the solar PV sector in Norway. The thesis will study the key conditions for influencing and expanding the solar PV industry in Norway.

This thesis aims to examine the conditions for growth. The key conditions for further influencing and expanding the Norwegian PV industry are the knowledge base in Norway, the cost development in Norway, and the Norwegian regulatory frameworks. The secondary objective is to look at the drivers and barriers to the development of the industry in Norway. The thesis is using perspectives from the theoretical approaches of EEG and GVC to examine this further. It has examined this through conducting semi-structures interviews and triangulated data in the form reports and news articles.

Acknowledgements

I must first thank my supervisor, Markus Steen, for all the support and advice during the writing of this thesis. Thank you for all the input, comments and the nice conversations we had during this process.

Much appreciation is directed towards the informants who have supplied valuable input to this study. Although not mentioned by name, I wish to thank each one of you for taking your time for a conversation and sharing your knowledge. It was insightful to hear your knowledge on the area.

A big thank you to my family (Sienna, you are included) for always believing in me and providing much needed support.

I also wish to thank my classmates for all the good times throughout the study programme. No matter if it was academically related or not, I have appreciated all our good conversations and support.

I also want to thank my landlord, that provided me with the opportunity to travel and work in Svalbard, which led to an increased interest in sustainable development and renewable energy, especially solar photovoltaics.

Table of Contents

List of figures

List of tables

List of abbreviations

EEG	Evolutionary Economic Geography
EPD	Environmental Product Declaration
EU	European Union
FiT	Feed-in-Tariff
GCC	Global Commodity Chains
GDIP	Green Deal Industrial Plan
GPN	Global Production Network
GVC	Global Value Chain
GW	Gigawatt
IEA	International Energy Agency
PVPS	Photovoltaic Power System Programme
IRA	Inflation Reduction Act
IPCEI	Important Projects of Common European Interest
MW	Megawatt
NTNU	Norwegian University of Science and Technology
NVE	Norwegian Water Resources and Energy Directorate
PV	Photovoltaic
R&D	Research and Development
RCN	Research Council of Norway
REC	Renewable Energy Corporation
RES	Renewable Energy System
TIS	Technological Innovation System
TSO	Transmission System Operator
US	United States
USD	United States Dollar

Chapter 1 - Introduction

Through the last decades, the negative effects of climate change have received growing attention, and new solutions have contributed to an upcoming energy transition. As a result, the development and deployment of renewable energy systems (RES) is experiencing a boom worldwide. Europe is one of the regions that recognises solar photovoltaics (PV) as one of the most viable RES likely to succeed in the future energy transition. Solar PV systems are getting implemented widely and at an increasing pace. Solar PV is one of the cheaper and more efficient RES making it an attractive solution in the European market. The EU has recently launched an ambition to be a climate-neutral society by 2050. Introducing different renewable energies fuels this ambition, one of them being solar PV (McKinsey & Co, 2022).

The history of solar PV has changed on a global scale. Whereas the developmental phase of solar PV systems mainly commenced in Japan, the United States (US) and Europe, it has changed throughout the years to China being the leading country today. In the late 1990s and early 2000s, when solar PV emerged fully as a viable alternative for energy production, Europe was one of the leading regions in the world. Among other countries, Norway and Germany were the most influential in the solar PV energy sector. However, Asia and China have become the last decade's top regions. While other countries in Europe that were traditionally big in solar PV, China grew and enhanced its production in every part of the value chain. China remains currently the largest producer in the solar PV industry (Zhang & Gallagher, 2016).

In the current geopolitical climate, China, as the leading actor in industrial development and market deployment, is seen as problematic. The European Union (EU), the US, India and the rest of the world do not want to depend on China in the future on solar PV. The EU has implemented strategies to expand and develop the manufacturing chain in Europe to prevent this risk. The United States (US) and India are doing the same, as both of them are implementing national policies and schemes to boost manufacturing in their region.

The Global Landscape of Renewable Energy Finance 2023 report claims that solar investments reached US Dollar (USD) 308 billion in 2022, increasing from USD 226 billion in 2021 to USD 162 billion in 2020. 83% of these investments in solar PV came from private finance (IRENA, 2023, p. 18, 47). The number of investments shows that solar PV is developing and expanding quickly in Europe. According to the International Energy

Agency's (IRA) report, *Renewables 2022*, global renewable capacity expects to increase by almost 2 400 gigawatt (GW), nearly 75%, between 2022 and 2027, equal to China's total installed power capacity of today. The IRA claim the following based on two factors; 1. high fossil fuels and electricity prices from the global energy crisis have made renewable power technologies more attractive, and 2. Russia's invasion of Ukraine has caused fossil fuel importers, especially in Europe, to increasingly value the energy security benefits of renewable energy (Renewables, 2022, p. 17).

Norway has traditionally had a strong presence in the solar PV industry in Europe. Norway has a large silicon industry and through this involved in solar PV both from the manufacturing side and research and development (R&D). However, Norway only has a small amount of solar PV installed, even though it is strongly present in the manufacturing value chain. Thanks to the country's knowledge development, Norway is one of the few countries leading globally in the production of ingots and wafers in the value chain. However, the deployment of solar PV needs to be improved in Norway.

This thesis aims to explain the manufacturing value chain of the solar PV industry, followed by an assessment of Norway's position in the value chain. Then, the thesis will use primary data in the form of interviews with firms in the Norwegian solar PV industry and secondary data in the form of reports and articles to explain the key factors that will influence further development in the Norwegian solar PV industry and examine the growth conditions.

In this thesis, I want to answer the following research question:

What are the key factors influencing the further development and expansion of the Norwegian solar PV industry?

The primary objective is to examine the conditions for growth, that being the key factors influencing further development and expansion in the Norwegian solar PV industry. The secondary objective is to look at the drivers and barriers to the development of the industry in Norway.

The thesis will explore market deployment and industrial development to get a broader understanding of the possible development and expansion of the Norwegian PV industry and the possible conditions for growth. Market deployment refers to the implementation of technology, in this case, the deployment of solar PV. Industrial development entails developing, manufacturing, and delivering goods and services.

The remainder of this thesis is organised in these chapters. The second chapter is the empirical background. The empirical background introduces the main drivers behind the continuing growth of solar, both from a Norwegian and European perspective. The third chapter examines the theoretical approaches for this thesis. The theoretical part draws on different approaches. The two main theoretical approaches are global value chains and evolutionary economic geography, supported by specific segments in global production networks, technological innovation systems and path creation theories. The fourth chapter presents the methodological part. The methodology includes, among other things, the research design, data sampling, and reflections. The fifth chapter analyses the results. The analysis consists of both results from interviews as the primary data and reports and articles as secondary data. The sixth chapter will discuss the key factors to further develop and expand the Norwegian solar PV industry and detail the drivers and barriers to the development of the industry in Norway. Lastly, I will conclude with the following conclusion, that to further develop and expand the Norwegian PV industry, Norway needs to value the existing knowledge base, examine the cost development, and improve the regulatory frameworks.

Chapter 2 - Empirical background

There are three main drivers behind the continuing growth of solar today. First, the economics of energy. Second, the energy crisis was driven by the war in Ukraine. Third, a growing global focus on green and net zero initiatives (PV Magazine, 2022).

According to (“Solenergiklyngen”), The Norwegian National Solar Energy Cluster’s Roadmap argues for three different drivers for increased growth in the development of solar PV. First, the cost of solar panels for buildings in Norway is dropping fast, making solar PV an increasingly attractive option for customers. In addition, the awareness around solar, especially in buildings, increases the demand. Technological development and increased activity in the installation market will press prices down. Second, the installation rate, competence, and capacity have improved significantly. Therefore, the solar PV industry has enormous potential for further growth. Third, environmental declarations are expected to be stricter in the future, making them more desirable. In addition, research shows that solar PV is fundamental for establishing zero-emission buildings- and areas (Solenergiklyngen, 2020, p. 28).

2.1. The economics of energy

Historically, solar PV has been a significant industry in Europe, but after China’s entrance into the industry, the rest of the world has lagged in both the industrial development and the market deployment of solar PV. Therefore, when the EU decided that solar PV is one of the most important RES, they started implementing policies and forwarded solutions to increase the volume of solar PV back to Europe (EU Solar Energy Strategy). Only a little over a year ago, Kadri Simson became famous for saying, “We need to bring manufacturing back to Europe, and the Commission is willing to do whatever it takes to make it happen” (Kadri Simson, 2022). She mentioned the three C’s of solar in her speech: challenges, citizens, and competitiveness.

Challenges, the solar industry has to operate in a market with some barriers. In market deployment, the barriers include issuing permits and power purchase agreements and the availability of people who can process the requests. More skills are also needed, and the installation sector needs help finding people. In industrial development, the barriers include financing and finding the money to help EU manufacturing scale up.

Citizens, the solar industry should be easily accessible, and citizens can engage with it and drive its deployment in a way that is impossible for other renewables. From a market deployment perspective, all citizens have the right to be prosumers. From an industrial development perspective, it can utilise existing infrastructure, boost energy independence, and shield consumers from volatile energy prices.

Competitiveness, the solar industry is deploying rapidly. Regarding market deployment, 26 GW were installed in 2021 and will continue to grow. Regarding industrial development, the EU has a large and strong single market as well as being a former "manufacturing powerhouse" (Kadri Simson, 2022).

2.2. Energy crisis driven by the war in Ukraine

Among those instruments to bring back the value chain, the EU introduced the REPowerEU plan. The REPowerEU plan is about "rapidly reducing our dependence on Russian fossil fuels by fast-forwarding the clean transition and joining forces to achieve a more resilient energy system and true Energy Union". This plan is one of the most important policies for solar PV. In addition, just as important is the EU's solar energy strategy. The latter and the REPowerEU plan emphasise the need for solar energy as a contributor and way of ending Europe's dependency on Russian fossil fuels, as mentioned in REPowerEU. The strategy aims to deploy more than 320 GW of solar PV by 2025 and almost 600 GW by 2030.

According to NVE *("Norges- vassdrag og energidirektorat")*, the Norwegian Water Resources and Energy Directorate, 299 megawatt (MW) of solar PV was installed in 2022 (NVE, 2023). According to the Roadmap, the conditions for growth in Norway are highly vulnerable because of volatile regulatory measures. Therefore, estimating Norway's total solar PV capacity towards 2030 will be difficult. The change will depend on cost, financing, subsidies, and regulatory measures. Nevertheless, based on trends for industrial development and actors' expectations, it is estimated that it will be installed between 2 and 4 GW of new capacity in Norway by 2030 (Solenergiklyngen, 2020, p. 29).

2.3. Growing global focus on green and net zero initiatives

In addition, one of the most central plans by the EU to bring back the manufacturing value chain is the Green Deal Investment Plan (GDIP), which aims to increase technical development, manufacturing production and installation of net-zero products and energy supply. Introduced at the same time, the Net-Zero Industry Act is highly synchronised with the pillars of the GDIP, aiming at "simplifying the regulatory framework and improving the investment environment for the Union's manufacturing capacity of technologies that are key to meet the Union's climate neutrality goals" (GDIP, 2023, p. 1).

In Norway, the Government, the Norwegian government claims that Norwegian companies need consistent and predictable conditions that offer private investments and further growth to reach the GDIP. According to the Roadmap for Green Industry Growth ("*Veikart for grønt industriløft"),* the following six proposals are some of the initiatives the government promised to do to enable greener industrial development.

First, an ambition that strengthens the electricity grid and shortens the application process time. Second, introducing a national strategy for green industrial areas of interest and parks with a competitive advantage. Three, prepare a mineral strategy to develop a sustainable mineral industry in Norway. Fourth, activate access to private capital for the green shift through international support schemes. Fifth, increase efforts to build up green industrial growth further. Sixth, complete a broad reform on competence regarding employment (Nærings- og fiskeridepartmentet, 2022, p. 25)

Chapter 3 - Theoretical part

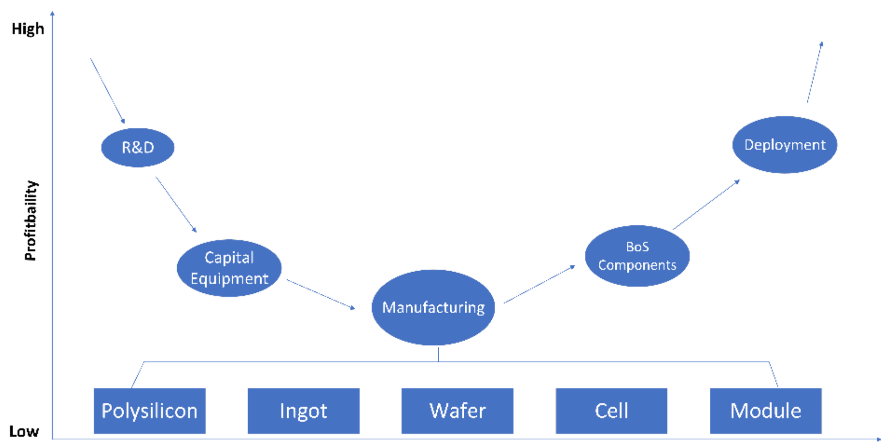
This chapter, the theoretical part of the thesis, will draw on the theoretical approaches of GVC and EEG to look at the emergence of the industry and industry formation. Even though the two theories employ different concepts, they are also highly similar when connecting them. In addition to these two theoretical approaches, the chapter will contain concepts from theories on global production networks (GPN), technological innovation systems (TIS) and path creation. In addition, the chapter will examine the solar PV value chain,

3.1. The solar PV value chain

The framework of GVC is often used in case studies and qualitative firm-based research since it aims to explain how and why certain countries participate in an industry. Moreover, also it determines how successful a country has been in the industry and provides recommendations on how this can be sustained or increased in the future (Frederick, 2019, p. 30). “The value chain describes the full range of activities that firms and workers perform to bring a product from its conception to end use and beyond” (Gereffi & Fernandez-Stark, 2019, p. 55).

This thesis describes two definitions of the value chain (*Figure 1)* for the solar PV industry based on the definitions from Hipp and Binz (2020) and Zhang and Gallagher (2016). The thesis utilises definitions that focus mainly on the manufacturing part of the value chain.

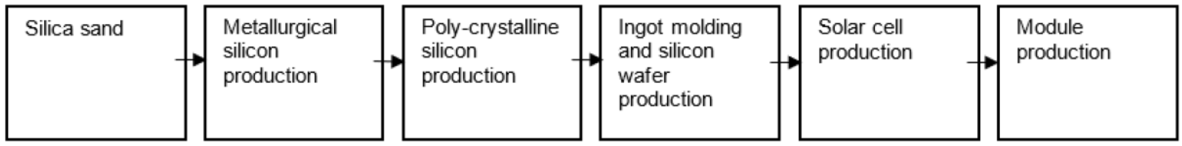
Figure 1 - The definitions of the value chain



Made based on the figure from (Zhang & Gallagher, 2016, p. 195).

Defining an entire value chain for solar PV is too extensive. Therefore, the value chain definition by Hipp and Binz, employed here, only defines the producing part of the value chain. The definition explains that the solar PV industry’s value chain consists of three main parts. The upstream part includes the production of silicon and manufacturing equipment. The core part involves processes related to ingot, wafer, cell and module manufacturing. Third and last, the downstream part entails the balance of system (BoS) components and grid integration (Hipp & Binz, 2020, p. 6).

Figure 2 - Manufacturing process for silicon PV modules



(Franco & Groesser, 2021, p. 15).

First, in more detail, the upstream part relies on both knowledge-intensive R&D, the development of basic cell materials and technologies, and the development of automated production lines used to manufacture ingots, wafers, cells, and modules. The next step in the value chain is the core activities. These are recognised as etching and polishing wafers to create PV cells, adding anti-reflective coating, and combining them into the final product, PV modules. Lastly, the downstream, includes all elements beyond the PV module that are needed to connect a PV system to the electricity grid and operate it. This is comprised of electrical wires, charge controllers, mounting equipment, etc. (Hipp & Binz, 2020, p. 6)

The second definition by Zhang and Gallagher extends the first definition and breaks it down into six main separate value segments in the form of a smile curve.

First, R&D, where the aim is developing basic, general, or specific technologies related to the PV technology. However, this is seen as knowledge-intensive, un-predictable and financially risky. Second, capital equipment production. This entails what is required to produce polysilicon, cells, and modules and also includes the furnace for polysilicon purification, chemical and gas suppliers, abrasives, and equipment for cutting wafers, pastes and inks for cells, encapsulation materials for modules, and specialised measurement equipment for use in production (Zhang & Gallagher, 2016, pp. 194-195).

Third, is the production of polysilicon. In this process, one converts metallurgical-grade silicon to the polysilicon appropriate for solar cells. This production is both capital and energy intensive, and therefore, it requires high-tech equipment and know-how. Fourth, module manufacturing encompasses four steps. It starts with casting silicon into ingots. Then, slicing the wafer from the ingot block. After the wafer is turned into a cell through etching and polishing, cleaning, the cells turn into modules (Zhang & Gallagher, 2016, p. 195).

Fifth, the balance of system components includes the mounting equipment, charge controllers, monitoring devices, inverters among other things. Sixth, the PV deployment is the integration of the PV system and the delivering it to customers (Zhang & Gallagher, 2016, p. 195).

Table 1 - Key PV manufacturing process by segment

Segment	**Key processes**
Polysilicon	Silicon purification
Ingots	Crystalline ingot growing; material property analysis; ingot cutting
Wafers	Wiring; pre-washing; wafer separation; main-washing; wafer inspection and sorting
Cells	Wet station; diffusion; chemical vapour desposition/sputtering; screen printing; baking; cell transfer; inspection
Modules	Cell wiring (string); layup (module assembly); laminating and sealing; curing; frame and terminal assembly; module transfer; inspection

(IEA, Special Report p. 35)

3.2. Global Value Chains (GVC) Approach

One of the key questions in global value chain literature is researching which countries/regions can develop or participate in new value chains or upgrade existing value chains (Boschma, 2022, p. 130). This question is often asked regarding GPNs. In short detail, the difference between global value chains (GVCs) and the global production networks (GPNs) are mainly two-fold. First, it looks at the strategy of a lead firm's home market in more detail. Second, it looks at other regions, overseas markets, and the desire to locate the production of goods and services to that market because of localization and time-to-market (Coe, 2021, p. 29).

3.2.1. Origin of GVC Framework

The global value chain framework originates from the global commodity chains (GCC). Global commodity chains were first introduced by Hopkins and Wallerstein (1977, 1986) "as a heuristic to study the operation of global capitalism and reproduction of a stratified and hierarchical world-system beyond the territorial confines of nation-state". However, the perspective that laid the foundations of the framework 'global commodity chains' was created by Gereffi and Korzeniewicz, tying "the concept of value-added chain directly to the global organisation" (as cited in Gereffi, Humphrey & Sturgeon, 2005, p. 82). The concept gained popularity mostly for its analysis of contemporary industries, and it can analyse upgrading/downgrading trajectories of countries and firms within them [the industries] and became a foundation for the elaboration of the GVC framework (Ponte, Gereffi & Raj-Reichert, 2019, p. 8).

The GVC framework's relation to the global commodity chain (GCC) is its nuanced understanding of governance dynamics and its more thorough incorporation of multiple scales of analysis beyond the global and national (Coe, 2021, p. 9). The GVC framework is based today on the notion of globalisation of production and trade. In essence, the framework of GVC is useful for understanding how both global industries are organised by examining the structure and dynamics of the different actors involved in the industry (Gereffi & Fernandez-Stark, 2019, p. 54).

The thesis will explain GVCs governance dynamics that stem from the paper of Gereffi, Humphrey and Sturgeon (2005). They theorise GVCs from inter-firm governance dimensions, and the theoretical framework aims to explain a "better understanding of the shifting governance structures in sectors producing for global markets, structures we refer to as 'GVCs'" (2005, p. 79).

3.2.2. Value chain analysis

The value chain analysis will identify the firms, products, activities, stakeholders, and geographic locations involved in taking a good or service from concept through production to the final consumer (Frederick, 2019, p. 30). The theory on GVC can be essential to explain the solar PV industry. The GVC analysis focus on the organization of the industry in the global economy across an international and geographic scale. Additionally, it focuses on the way firms in developing countries can gain access to global markets, what the benefits from such access might be, and how these benefits might be increased. The GVC approach analyses the global economy from two viewpoints, top down and bottom up. The first, the top-down view is the "governance" of global value chains, which focuses mainly on lead firms and the organization of international industries. The second, the bottom-up view is "upgrading", which focuses on the strategies used by countries, regions, and other economic stakeholders to maintain or improve their positions in the global economy (Gereffi, 2011, pp. 39-40).

According to Davy, Hansen and Nygaard (2022), the GVCs perspective operates with three main analytical dimensions, which are used to characterise a given value chain and to identify the opportunities for the insertion, the strategic coupling, of local developing-country firms at various points in the value chain.

The input-output structure dimension of GVCs includes the flow of materials, goods, and services across various segments along the value chain. The governance dimension is an analysis of the lead firm and the decisions and activities of that lead firm that create the governance structure. The geographical dimension analyses the localisation of the specific segments of the value chain and includes production and processing activities and end-markets and ranges from local to national or regional depending on the value chain (Davy, Hansen & Nygaard 2022, pp. 3-4).

The theory of value chain governance is based on three patterns. First, the complexity of information and knowledge transfer required to sustain a particular transaction, particularly with respect to product and process specifications. Second, the extent to which this information can be codified and, therefore, transmitted efficiently and without transaction-specific investments between the parties to the transaction. Third, the capabilities of actual and potential suppliers in relation to the requirements of the transaction. These three types generate five types of governance (Gereffi, Humphrey & Sturgeon, 2005, p. 79).

First, market governance, which involves simple transactions and where suppliers can make products with minimal input and little coordination with buyers. In this type of governance, price is the central mechanism (Gereffi & Lee, 2012, p. 25). Second, modular governance, recognized as when suppliers make products to a customer's specification that are complex but relatively easy to organize. The exchange of information through standards, the buyers and suppliers reduce coordination costs (Gereffi & Lee, 2012, p. 25).

Third, relational governance, exists "when buyers and suppliers rely on complex information that is not easily transmitted. Frequent interactions and knowledge sharing based on mutual trust and social ties between parties are critical in coordination relational chains" (Gereffi & Lee, 2012, p. 25).

Fourth, captive governance, is characterised by a group of small suppliers that are dependent on one or a few buyers in their resources and market access – and tend to operate under conditions set by particular buyers. Fifth, hierarchal governance. This type of governance is characterised as chains with full vertical integration where the lead firms operate the whole chain in-house (Gereffi & Lee, 2012, p. 26).

3.3. Supporting theory – Global Production Networks (GPN)

GPN and GVC theories are interrelated in the sense that both aim at understanding "the key drivers of the changing global economic landscape within the current paradigm of functional integration of spatially dispersed economic activities, and the resulting organisational and spatial configurations of production systems" (Blažek & Steen, 2022, p. 2044). The theory from the GPN framework (2.0) focuses more on the organization, the different dynamics and strategies that are fundamental to GPNs and how they shape economic development (Coe, 2021, p. 11).

In addition, the GPN theory conceptualizes that the dynamics of the market development is a negotiated outcome where both the producers and customers are involved in a market creation process – where the producers seek greater revenue and profits through market expansion and the customers through becoming more demanding for better products/services at lower prices (Coe and Yeung, 2015, p. 37).

Value capturing is a key concept in the GPN literature on how firms need to optimize costs and capabilities to create and sustain a market for the goods and services produced. This will depend on various reasons. First, firm-level capabilities, being the managerial expertise or the capacity to raise financial capital. Second, the power relations between network members. Third, industry specificities, a growing or stagnant market, intensity of cost competition or rates of technological change. Fourth, the extent to which activities are supported and facilitated by local policy and incentive structures in particular places. These value capture trajectories are thought of as building blocks of economic development (Coe, 2021, pp. 110-112).

3.3.1. Strategic coupling

A key concept in GPN theory regarding regions is strategic coupling. This is how the building blocks of economic development influence at a regional scale. Strategic coupling is a concept that "allows us to bridge between individual firms and global production networks and their collective development impacts on regions" (Coe, 2021, p. 113). In other words, how a region connects to a GPN.

Strategic coupling has five defining characteristics. First, it requires intervention from both regional institutions. Second, the strategic decisions made can be taken elsewhere than the coupled region. Third, some regions can benefit from the coupling while others lose. Fourth, the same production stage of the same industry may be different depending on the region itself. Fifth, it is a dynamic process where the coupled region can lead to decoupling and recoupling (Coe, 2021, p. 115-116).

3.3.2. Upgrading

In general, upgrading refers to the strategies that firms, countries, or regions implement to move toward higher value-added activities and increased value capture" (De Marchi & Alford, 2021, p. 90). There are different ways to measure upgrading. However, the thesis focuses on product upgrading and process upgrading. This can either be making it more efficient, upgrading in the sense of making better products, or being skill-based, moving into more skilled activities (Humphrey & Schmitz, 2002, p. 1017).

3.4. Evolutionary Economic Geography Approach

3.4.1. Origin of EEG Framework

The main source of inspiration of EEG has been evolutionary economics. The EEG framework "explains the spatial evolution of firms, industries, networks, cities and regions from elementary processes of the entry, growth, exit and (re-)location of firms" (Boschma & Frenken, 2007, p. 635).

In the 1990s, economic geographers began to explore how evolutionary principles, such as bounded rationality, variety, localised learning, path dependence and disequilibrium could be applied and integrated in research in economic geography. In essence, the evolutionary approaches to economic geography tend to share a focus on historical processes to explain uneven spatial development and transformations of the economic landscape (Boschma, 2022, p. 4).

3.5. Supporting theory – The technological innovation system (TIS)

In addition, the thesis will employ a theoretical approach based on the technological innovation system (TIS) framework. The framework, built on the foundation of (Hekkert et al., 2007), (Bergek et al., 2008) proposes six key processes that evaluate how the system works. This is a process-based perspective on industry formation and can be interpreted as aggregates of the distributed agency in an emerging technological field, which forms distinct resources for the actors involved in a new path as well as for the future evolution of the industry (Binz, Truffer & Coenen, 2016, pp. 179-180).

First, is entrepreneurial experimentation. A TIS evolves under uncertainty in terms of technologies, applications, and markets. The reduction of uncertainty is through probing entrepreneurial experimentation, and a TIS without vibrant experimentation will stagnate. Second, knowledge development. Knowledge development is concerned with the knowledge base of the TIS. This captures the breadth and depth of the knowledge base and its evolution and changes over time. Third, influence on the direction of the search. This entails that there must be firms and organisations that are willing to enter the industry and the combined strength of those in terms of technologies, markets etc. Fourth, market formation. This captures what phase the market is in, and who the users are and analyses both market development and what drives market formation. Fifth, legitimation, refers to the strength of legitimacy, the value base in the industry, what (or who) influences legitimacy, and how. Sixth, resource mobilisation. This entails the extent the TIS can mobilize competence/human capital, as well as financial capital and complementary assets such as products, services, networks and infrastructure (Bergek et al., 2008, pp. 414-417).

3.6. Path creation

A key concept in EEG is path creation. Certain key conditions must be met for new paths to emerge in capital-intensive and highly complex sectors such as energy (Steen and Hansen, 2018, p. 193). Path creation is mainly describing the emergence and growth of new industries and economic activities in regions (MacKinnon et al., 2019, p. 113).

3.6.1. Path-as-process (path creation as a process of resource alignment)

The thesis will employ the definition of path creation from the definition by Binz, Truffer, and Coenen (2016) that introduces it as part of the path-as-process perspective. They define "path creation" as

> *"a new path is created in a region if it contains a set of functionally related firms and supportive actors and institutions that are established and legitimised beyond emergence and facing early stages of growth, developing new processes and products"* (Binz, Truffer and Coenen, 2016, p. 177).

Binz, Truffer and Coenen introduce an analytical framework that specifies the formation of generic resources in embryonic industries. It suggests that path creation processes are conditioned not only by pre-existing regional capabilities and technological relatedness but also by how firm and non-firm actors mobilize and anchor key resources for industry formation (Binz, Truffer & Coenen, 2016, p. 172).

Referring to the literature on technological innovation system (TIS) as an analytical framework, Binz Truffer and Coenen (2016) are shortening the six key processes from the TIS framework from (Hekkert et al., 2007) and (Bergek et al., 2008) into four distinct key resources: knowledge, (niche) markets, financial investments and legitimacy (*Table 2*). "These four key resources can be understood as necessary conditions for industry emergence: if any of them are missing, the emerging industry will face a significant development barrier" (Binz, Truffer & Coenen, 2016, p. 182).

Table 2 - Key processes in resource formation

Key resource	Formation Process	Definition	Indicators
Knowledge	Knowledge creation	Activities that create new technological knowledge and related competencies (e.g. learning by searching, learning by doing: activities that lead to exchange of information among actors, learning by interacting and learning by using in networks)	R&D projects, number of involved actors, number of workshops and conferences, activities of industry associations, linkages mong key stakeholders, spatial dynamics in underlying knowledge networks.
(Niche) markets	Market formation	Activities that contribute to the creation of protected space for the new technology, construction of new market segments	Number of niche markets, supportive tax regimes and regulations, subsidies.
Financial investments	Investment mobilization	Activities related to the mobilization and allocation of basic financial inputs such as bank loans, venture capital or angel investment	Availability of financial capital and complementary assets for key actors, total sum of investment in companies in the field.
Legitimacy	Technology legitimation	Activities that embed a new technology in existing institutional structures or adapt the institutional environment to the needs of the technology	Rise and growth of interest groups and their lobbying activities, institutional entrepreneurship by the actors in a new technological field.

(Binz, Truffer & Coenen, 2016, p. 181).

First, is knowledge creation. Knowledge is central, and knowledge creation is the decisive mechanism through which firms create and sustain their competitiveness. Contains explicit and tacit dimensions, experience-based know-how, and network-based know-who. Early movers in a new field depend directly on creating and/or mobilising this key resource (Binz, Truffer & Coenen, 2016, 180). The innovation process of firms and industries is dependent on their knowledge base. This thesis will differentiate between an analytical and synthetic knowledge base. An analytical knowledge base refers to the scientifical knowledge and industry-university links. R&D is needed in the process of knowledge creation. A synthetic knowledge base refers to the innovation taking place through existing knowledge or new combinations of knowledge (Asheim & Coenen, 2005, p. 1176).

Second, market formation. It is considered a resource since market segments for radically new technologies and products do not pre-exist but must be created by the actor themselves (Binz, Truffer & Coenen, 2016, 180). An example is the early phase of the German solar PV industry. The German government implemented a support programme in 2004 for de-centralizing on-grid PV systems worldwide. This led to market subsidy schemes all over the country and a PV market boom (Dewald & Truffer, 2011, p. 408).

Third, investment mobilisation, is often a scarce resource for the actors in a new industrial field, especially in a very early industry formation phase (Binz, Truffer & Coenen, 2016, p. 180). An example is when China and India mobilised financial resources to build a domestic TIS in the wind energy sector. The two countries both implemented national-level policies for the public sector in China and the private in India to further develop the wind energy sector (Surana & Diaz Anadon, 2015, pp, 346-348).

Fourth, technology legitimation depends on aligning the new industry and its products with the relevant institutional contexts (Binz, Truffer & Coenen, 2016, p. 180). This relates to Aldrich and Fiol's definition of legitimacy. They examine social processes surrounding the emergence of new industries and define legitimacy from two related perspectives. First, the cognitive, how taken for granted a new industry is. Second, the socio-political, to the extent the new industry conforms to recognised principles or accepted rules and standards (Aldrich & Fiol, 1994, pp. 645-646).

These four key resources are necessary conditions for industry emergence, and if any of them are missing the industry will face a development barrier. The function of path creation, accordingly, explains how the industry emerges from the systematic interplay between relevant actors, networks, and institutions (Binz, Truffer & Coenen, 2016, p. 182).

3.7. Summary – the GVC-EEG nexus

This theoretical section explains two theories. First, the theory of global value chains framework through supporting theory of global production networks (GPN). Second, the evolutionary economic geography through technological innovation systems (TIS) and path creation defined from a path-as-process perspective.

In this thesis, the use of GVC theory explains the formation, the tasks, and functions of the industry, while the EEG theory explains the activities that lead to an industry emerging. However, existing research claims that there is a potential overlap between the two theories (Boschma, 2022). The most important overlap between the two, is that both aim to understand the global economy and focuses on the development and emergence of new industries in countries and regions. However, one must also put emphasis to the development and emergence to understand what differentiates the two theories.

On the one hand, in the GVC theory, it emphasises more on certain tasks or functions rather than products or industries (Boschma, 2022). GVC research emphasise that certain regions or countries are more specialised than others, also known as strategic coupling and focuses on which regions can capture value (Coe, 2021). However, this field of specialisation can also be lost or transferred to other countries and regions through decoupling and recoupling (MacKinnon, 2019). On the other hand, in the EEG theory, it highlights the new activities in industries (Boschma, 2022).

Chapter 4 – Methods

The following chapter, methodology, will be identifying a clear description of the methodology used in the thesis. First, I will outline my research design, highlighting why I chose case study research and semi-structured interviews as my method of choice. Second, I will describe how I sampled the data and the data analysis, including its challenges and further reflections. Lastly, I will outline the potential limitations and ethical considerations.

The reason I chose to research the solar PV industry is mainly two-fold. First, during the previous semester, I was part of the renewables team at the *Store Norske* group at Svalbard. Store Norske operates the last coal mine in operation in Norway, but aims to end their production of coal, and transfer to more renewable sources of energy (Tallaksrud, 2023). During the internship there, Store Norske deployed solar PV as one of the renewable energy sources. My work tasks included researching the approval processes for building solar PV systems on building and solar parks. This sparked my interest in solar PV further. If it is possible to assemble solar PV systems at Svalbard, you can assemble them wherever in the world. Second, solar PV is seen as one of the key drivers for implementation of RES in the world and Europe, but is not really prioritised, or seen as a well-established opportunity in Norway.

4.1. Research design

This master's thesis is qualitative employing a case study approach of the Norwegian PV industry. The thesis uses triangulation, employing both primary data in the form of semi-structured interviews and secondary data in the form of reports and news articles. The informants have mainly been firms in the Norwegian solar PV industry and one expert related to the Norwegian PV industry.

This thesis is done in a qualitative fashion. Qualitative research entails that it is primarily focused on being non-numerical and rather in the form of texts, documents, and recordings. The questions asked in qualitative research in human geography concern understanding the link between the social and spatial processes and people's lives in past or present contexts. It stems from a highly epistemological approach, meaning it seeks to understand the conditions for human beings and the ways of being in the world to generate knowledge production (Hay & Cope, 2021, pp. 4-6).

In the research design, I have chosen to do it via triangulation. Triangulation is the process of mixing different methods and drawing on different sources or perspectives to maximise an understanding of the research question (Clifford, French & Valentine, 2010, p. 8).

In this thesis, the semi-structured interviews are the primary source of data. The secondary source of data are reports and news articles. The primary data is from semi-structured interviews. "Semi-structured interviews are a data collection method that pairs predetermined survey questions interviewer-initiated open-ended, ad hoc follow-up probes. These probes allow the respondent to provide more detailed information based on their initial answer" (Ahlin, 2019, p. 2). The main reason for choosing semi-structured interviewing as a method is its flexibility. It is recognised to have some degree of predetermined order and topical prompts and that the interview focuses on the content and deals with issues or areas judged by the researcher to be relevant to the research question. It allows the researcher to focus on the content and deal with the issues relevant to the research question (Dunn, 2021, pp. 149, 158).

The method of semi-structured interviewing has some strengths. First, semi-structured interviews are a flexible research method. The method is made so the researcher is less restricted to deploying all the questions made in the interview guide. This will make it easier to conduct the interview in case the interview runs out of time, or whether the informant has already answered a question. This makes it a flexible method for the researcher as an interviewer and for the informant being interviewed. Second, most of the questions that will be posed in a semi-structured interview should allow for an open response, so the informant is able to describe certain events or offer his or her opinions emphasising what is relevant to the informant only (Dunn, 2021, p. 150).

> *"Although the interviewer prepares a list of predetermined questions, semi-structured interviews unfold in a conventional manner offering participants the chance to explore issues they feel are important"* (Longhurst, 2010, p. 103)

4.2. Sampling of the data

I decided to collect data from two samples. For my interviews, I have chosen two different samples. The first sample is managers or executives working in corporations in Norway that are contributing to the value chain in solar photovoltaics in Norway. This sample would involve people who work in corporations in the upstream, midstream, or downstream section of the value chain in solar photovoltaic in Norway. The second sample is government officials, experts or academics associated with/or relevant to the solar photovoltaics industry in Norway. This sample involves people that are not working in corporations in the value chain of solar photovoltaics in Norway but is involved through their knowledge of the industry.

Table 3 - Overview of the informants

Actor	**Informants**
Project leader, downstream PV firm	Informant 1
Marketing manager, downstream PV firm	Informant 2
Marketing manager, downstream PV firm	Informant 3
CEO, upstream PV firm	Informant 4
Manager, upstream and downstream PV firm	Informant 5
Project leader, downstream PV firm	Informant 6
CEO, downstream PV firm	Informant 7
Partner, Downstream PV firm	Informant 8
Research scientist, research institute	Informant 9
Project leader, downstream PV firm	Informant 10
CEO, downstream PV firm	Informant 11

In the data collection of semi-structured interviews, the researcher needs to have enough background information to evaluate its effectiveness, to collect data and begin the conversation (Ahlin, 2019, p. 12). To find out which actors and firms are interested in solar energy, I used The Norwegian National Solar Energy Cluster's ("*Solenergiklyngen*") partner overview to sample my Informants. The sampling began at the end of February and lasted until late April. Unfortunately, the process to complete this data collection, took longer than expected because some of the informants I wanted to interview were only available to have an interview four weeks after reaching out.

I made a spreadsheet of all the actors that were members of the cluster. Then, I chose the actors that had experience with solar PV. Next, I went to their website and found the mail of the Informant I wanted to interview depending on my sample. Then, I made a general template for an e-mail to the informants asking whether they could participate in the interview and the general theme of the master's thesis. If there was a positive answer, I sent them the information letter of consent and agreed when to conduct the interview. For one informant, I used snowballing, referring to a technique where you are using one contact to help you recruit another contact (Longhurst, 2010, p. 109). I was asked by Informant 4 whether I had interviewed Informant 8 and got their contact information through Informant 4.

All the interviews were conducted through Microsoft Teams. The benefit of using Microsoft Teams to interview is that I can reach out to actors all over the country without having to travel to the informants. At the same time, during some of the interviews, I experienced that the screen froze, and I could not catch what the informant(s) said. After reconnecting again, I asked the informant if it was possible to repeat what was said when the screen froze. On the one hand, I always got it repeated back to me when asking. On the other hand, some of the answers might have been shorter due to the informant thinking about what he or she said when it froze. During the interviews, the process was recorded and transcribed using Microsoft Teams function with the consent of the informant and then transcribed verbatim after the interview was finished.

In the sampling of the data, I had 12 interviews, but in the data analysis, I only sampled 11. During sampling the data, I chose not to include the twelfth interview in the analysis. The reason is that compared to the rest of the interviews, this firm specialised in something outside of the theme of solar PV systems. When transcribing, nine out of the eleven interviews were transcribed verbatim from the start of the conversation until the end, except for the last two. They were transcribed verbatim, but I chose to cut out the small talk at the beginning and the end. This was because the interviews were conducted too close to the final submission date and related time issues.

4.2.1. Trustworthiness of the data

Validity is referred to as the credibility of the research, but it is often cited as a threat to qualitative research because it does not involve either numbers or quantification of responses. Reliability is referred to as the consistency in data and generalizability to other samples. In qualitative research such as semi-structured interviews, its validity is favourable because such methods provide in-depth detailing of an Informant's perspective, and the data is gathered directly from the source. However, the method choice of semi-structured interviews has low reliability because it allows researchers and informants to explore relevant areas related to the research that are not specified through direct questioning and not asked of everyone (Ahlin, 2019, pp. 10-11). The researcher can also use strategies such as triangulation as part of a tool kit to ensure the reliability of the results (Cope, 2010, p. 441)

When working on the thesis, I conducted a total of 12 interviews. However, I only used 11 of them when completing the data analysis. 11 in-depth interviews can bring many different perspectives useful for data collection. To increase the reliability of the interviews, the thesis is using triangulation because semi-structured interviews cannot explain everything. In addition to the results from the interviews, it has also included other sources of data in the form of reports and news articles to ensure more reliability.

4.3. Data analysis

Before sampling my data, I identified certain topics that I wanted to be mentioned during the data collection which would help the coding and data analysis. Before making the questions, I divided the questions into topics. The first topic I wanted to analyse was the Norwegian solar industry itself, focusing on the origin and development of the firm's position in the value chain. Second, I wanted to investigate the firm's strategies and barriers, making understanding the drivers and barriers for the companies in the value chain easier. Third, I wanted to explore further development and how international responses and policies, like the REPowerEU and IRA, influence the future of the companies in the Norwegian solar PV industry.

After sampling the data and transcribing the interviews verbatim, I started the coding process of my data. "The core operation of coding involves examining a coherent portion of your empirical material – a word, a paragraph, a page – and labelling it with a word or short phrase that summarizes it contents" (Linneberg & Korsgaard, 2019, p. 259). According to Basit, coding, or categorising data has an important role when working on the analysis. It involves both subdividing data and assigning categories. The codes or categories are tabs or labels for allocating units of meanings to the descriptive or inferential information compiled during a study (Basit, 2003, p. 144).

In this thesis, I started coding both manually and digitally. First, do it manually by printing out the transcriptions of the interviews. I read the transcription of the interviews one-by-one several times. Then, when I was examining the data, I tried to find commonalities between the different interviews. Then, I used markers in different colours to mark different categories. The categories I were using were the key resource formation processes; knowledge, (niche) markets, financial investments, and legitimacy.

Second, doing it digitally. After conducting the interviews and transcribing them into word-documents, I converted the transcribed documents to PDFs. Then, I used the Adobe Acrobat program to load all the documents into one program. After this, I used the “Advanced search” tool in Adobe Acrobat to find commonalities between the documents. This tool was helpful in finding out words or phrases that were recurring during the interviews. During the process, I wrote down some keywords for each category.

In addition to this. I made two spreadsheets in Microsoft Excel to do the coding process. In each spreadsheet, I made a table of the results from the interviews. The first spreadsheet included a table showing the questions for the interview along the vertical columns and the informants along the horizontal rows. Then, I wrote down the answers for each question in the cell under each interview. I did this to get a broader overview of what each informant answered to each question. The second spreadsheet included a table showing the key resource formation processes along the vertical columns and the informants along the horizontal row. Besides the columns for the key resource formation process were columns that described the most important details of each formation process. The first and second columns described the definition and the different indicators of each formation process, as shown in *Table* 2. The third column described the keywords I noted down previously when searching for commonalities. The fourth column defined the key areas of the keywords I found. Instead of focusing only on words, the key areas made categorising the information I got from each interview into themes easier. The themes were then put as headings in the cells under each interview. Under the headings were information and direct quotes from each informant related to that specific theme.

4.4. Reflections

This section describes my personal reflections on the sampling of the data and the data analysis. This entails what I have done, what worked out, and what did not work out.

4.4.1. Reflections on the sampling of the data

The data sampling was related to sampling informants, the process of interviewing and the questionnaire. First, the process of getting informants was prolonged. My first interview was at the end of February, and my last was in late April. Many of the informants I contacted never answered, and less than half of the people I contacted answered my mail. I made two samples in the interview guide, I only got one interview for my second sample when collecting informants.

Second, during the sampling, I had one conversation rather than an interview with an expert, which did not count as an interview in the data collection because of time issues. A positive aspect was that I got more insight into how I could organise the thesis and the theories employed. The negative was that I did not get the information needed to qualify it as an interview. In addition, some of the firms I interviewed, had newly emerged and had less experience than other firms. Although it was useful to get their perspective, some of the questions asked were irrelevant to their firm.

Third, in retrospect, even though my questions were related to both firms in the entire value chain, I realised after the interviewing process was over that the questions were more directly linked towards companies in the upstream rather than the core and downstream. The positive aspect was that two out of eleven informants were in the upstream PV sector. These informants

Fourth, when asking the questions, I ensured that almost all the questions began with me asking “how”, “what” or “which” so that my questions would be open-ended. I made the questions open-ended to make it easier for the informant to give out more details, make the conversation flow better and lead to more elaborate answers, and prevent answers like yes or no. After the interviews, I felt that this was mostly successful and that the informant was most of the time able to express their own opinion and what was important for them, and not necessarily answer either yes or no. However, using these open-ended questions sometimes ended up with the informants explaining something out of their interest or the firms’ interest rather than answering the question.

4.4.2. Reflections on data analysis

Before I conducted the interviews, I identified certain topics to make the work the data analysis easier. After doing the data analysis, this did not make sense. The topics only related to the questions I asked and made no sense when I got the answers. However, the topics were useful to make the questions for the interviews. At the same time, as mentioned in the reflections above the questions were mostly successful, and that it gave me useful answers.

After the process of interviewing, I coded the material both manually and digitally. The benefit of doing it both manually and digitally is that I developed a great understanding of the data. First, by doing it manually, I felt I got a nice overview of the informants' answers, and it was easy to differentiate the categories. However, it was an extensive amount of text and difficult to sort out the data other than the categories in the different colours.

Second, the digital coding process went much better than the manual coding. It was easy to find commonalities between the informants. In addition, it was easier to get an overview of what the respondents said by making the spreadsheets. Therefore, most of my work on the data analysis went digitally. For future research, I could have used analytical programmes that facilitate coding such as NVivo. However, I did not code in that program because of issues related to learning the programme and time constraints.

4.5. The ethical issues

There are mainly two important ethical issues, confidentiality and anonymity. First, considerations related to confidentiality, participants must be assured that the data collected is secure under a lock or a database accessible by password only. In addition, the information supplied should remain confidential and that the participants will remain anonymous and that they have the right to withdraw from the research at any time without explanation. Second, the ethical considerations related to the informant during an interview, are that he or she may express sexist, racist or other offensive views or that the interviewer needs to investigate power relations or cultural contexts (Longhurst, 2010, pp. 111-112).

Before the interviews were conducted, I sent out an informed consent letter. The document described the confidentiality of the research project and some information about the research project. During the interview process, to guarantee both confidentiality and anonymity, in addition to ensuring the ethical considerations were in place, I sent out the letter for informed consent when the Informant reached out and accepted to be interviewed. Additionally, I mentioned the informants’ rights at the beginning of every interview to ensure that the ethical considerations were in place. First, by saying that the interview is being recorded. Second, followed by the Informant’s right of withdrawal and lastly, the data collection in the interview will remain anonymised and only between my supervisor and me. In some of the interviews, I got the document signed back during the interview to make sure they did the right thing. However, some Informants had signed the letter and sent it back before the interview was conducted.

Chapter 5 - Analysis of the results

5.1. The Norwegian PV industry

The evolution of the solar photovoltaic industry is varying on a country level. In this section, I will explain the development of the Norwegian solar PV industry. Then, I will link it to the global development of solar photovoltaics from Binz, Tang and Huentler (2017). I will discuss the development of Solar PV as a case of how "a sector that emerged in a highly globalised pattern with a significant shift of activity towards emerging economies" (Binz, Tang & Huentler, 2017, p. 386).

In this section of the analysis, I will focus on the spatial shifts to explain the development of the solar PV industry. This is because spatial shifts in the organisation of industries is of key importance for national and regional development (Binz, Tang and Huentler, 2017, p. 387). The analysis will divide the life cycle of the PV industry into three main phases, covering the spatial dynamics of solar PV both from a manufacturing and market perspective from the work of Binz, Tang and Huentler (2017) and Hipp and Binz (2020). By using the Norwegian PV industry as a case, I will examine how it fits the global development history by Hanson (2018) and Klitkou and Coenen (2013).

5.1.1. The fluid phase (1965-1990)

First, the period from 1965-1990 is recognised as the fluid phase**.** Before 1990, most of the activities in the industry were viewed as mainly experimental and exploratory. The fluid phase is characterized by several firms entering and exiting the industry (Binz, Tang and Huentler, 2017, p. 389). According to Hanson, when pre-production begins marks the start of an exploration phase characterised by searching and learning (Hanson, 2018, p. 69).

During this fluid phase, the manufacturing in the solar PV industry was mainly dominated by the two pioneering countries, Japan and the US. In this era, manufacturing volumes remained low, and input materials were often leftovers from the semiconductor industry. Most market deployments were niche with unclear future development prospects, and this period proved crucial for experimentation, learning and technological standardisation (Binz, Tang and Huentler, 2017, p. 390).

The fluid phase in Norway was highly dominated by manufacturing. In 1969, today, what is known as Elkem rebranded itself from the name "Det Norske Aktieselskab for Elektrokemisk

Industri", specialising in processing aluminium and magnesium technology, which later spilt over to processing silicon. The spillovers occurred due to their interaction with complementary electricity producers and metal-processing industries. In the 1970s, Elkem worked on metallurgic silicon for solar PV cells, but the quality was not sufficiently high enough, and developing new process technology was necessary. In the 1980s, Elkem became more popular as solar PV installation programmes were implemented in Japan and Germany, and global demand for silicon increased (Klitkou & Coenen, 2013, p. 1805). The market in Norway at the time is seemingly non-existent.

During this phase, it seems that the only lead firms focusing on making solar PV systems were in Japan and the US, and not yet recognised by the rest of the world. Since the making of solar PV systems was in its explorative phase, it seems that the goods and services were recognised by being very complex, and not too easily codified. The mode of governance globally in the fluid phase was therefore recognised as a form of captive governance because the suppliers were dependent on one or a few buyers. In Norway, it was also highly explorative, and not yet a market for solar PV systems. The process was highly complex, not easily codifiable and had few suppliers, which also relates to a more captive mode of governance.

5.1.2. The transitional phase (1990-2005)

The next phase, the period from 1990-2005 is characterised as the transitional phase. This period was recognised by a dominant design, the emergence of mass markets for technology, and new companies from all over the world entered the industry (Binz, Tang & Huentler, 2017, p. 389). In Norway, this period is viewed as the end of the exploration phase and the beginning of the formation phase. During this phase, the emergence of new PV companies and knowledge spillovers are central, involving adaptation and improvement of technologies from foreign providers through incremental process innovation (Hanson, 2018).

In the transitional phase, reliable manufacturing starts. While US manufacturing declined, manufacturing in Japan and Germany expanded. In general, the market deployment was concentrated in the EU and Japan. An important aspect of the market deployment was the implementation of the subsidy, the national feed-in tariff (FiT), in Germany. This essentially created the world's first mass-market for commercial and private solar PV systems (Dewald and Truffer, 2012) (Binz, Tang and Huentler, 2017, pp. 390-391).

In Norway, manufacturing becomes increasingly important. In the mid-1990s, a central researcher at Elkem, Alf Bjørseth, left the firm and started various companies in the solar PV industry, which later merged into one firm, REC (Renewable Energy Corporation). One of the companies, ScanWafer, was using residuals from the US semiconductor industry for producing wafers with German technology. ScanWafer induced spillovers onto other companies in the solar PV industry, and many regard the establishment of ScanWafer as the starting point for the Norwegian PV industry (Klitkou and Coenen, 2013, p. 1805). Market deployment in Norway during the transitional phase is also somewhat limited.

Both from a global perspective and a Norwegian perspective, this phase marks the end of innovation and exploring, and more the emergence of a new industry. The information and knowledge about the products are no longer as complex, and the process industry of solar PV starts to ramp up seeing there are more suppliers in the world than ever before. The information is easily transmitted as new industries begin to emerge all over the world, including Norway, and there are incentives in countries like Germany to introduce mass markets for solar PV. Therefore, the mode of governance that best explains the transitional phase globally is modular governance.

5.1.3. The standardised phase (2005 – today).

Third, the period from 2005 until today is the standardised phase, recognised as a period where PV modules became a globally standardised commodity, and consolidation and a shakeout occurred (Binz, Tang & Huentler, 2017, p. 389). Third, this describes the end of a formation phase (Hanson, 2018) and the beginning of a momentum phase in Norway witnessing increased competition and demand for more efficiency and mono-crystalline polysilicon, which lead to different technological solutions (Klitkou and Coenen, 2013, p. 1804).

This period is crucial to understand the solar PV industry today. Before the financial crisis in 2008, most of the manufacturing was in Europe. From a market deployment perspective, the growth in the EU surged as Italy and Spain, copied Germany’s approach with the FiT leading to 80% of market deployments of solar PV happened in Europe by 2010. However, in the aftermath of the financial crisis 2008, most manufacturing activities relocated to China and the FiT in the European countries lost its legitimacy. Consequently, China was forced to support its manufacturing industry. China deployed a domestic program at the same time as the prices decreased on technology. At the same time, manufacturing and market volumes were high, and China has since led the industrial development in solar PV (Binz, Tang and Huentler, 2017, p. 391). Chinese firms expanded their capacity rapidly through production of scale. The Chinese government contributed with sufficient support schemes, national policies and regulations such as a *Renewable Energy Law* to create an environment enabling for rapid develelopment of solar PV (Sun et al., 2014, pp. 222-223).

In Norway, the standardised phase marks a new manufacturing and market deployment era. Manufacturing starts to ramp up. The main reason is spillovers from other co-located factories in the country. ScanWafer used residuals from the US semiconductor industry for producing wafers and technology from a German company. Hydro, an aluminium company, gave investment support to take over the factory to facilitate for silicon production in Porsgrunn. In addition 2005, NorSun was established, a firm specialising in producing mono-crystalline wafers. This was also a collaboration with Hydro and a replacement for the existing aluminium production (Klitkou & Coenen, 2013, p. 1805).

As the name suggests, solar PV systems became a standardised commodity during the standardised phase. Compared to the other phases, it no longer demands complex information or procedures that are difficult to codify. The mass markets that emerged during the previous phase is still highly relevant but is now affected by financial constraint. However, China becomes the leading player, and the Chinese government’s incentives make them powerful. Therefore, in this period, it started with the mode of governance being characterised as market governance where suppliers can make products with little input and coordination from buyers. However, after China’s entrance, it can be discussed whether this can lead to a hierarchical mode of governance.

Table 4 - Evolution of the top 10 solar PV markets in the world from 2011-2021

RANKING	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	ITALY	GERMANY	CHINA	CHINA	CHINA	CHINA	CHINA	CHINA	CHINA	CHINA	CHINA
2	GERMANY	ITALY	JAPAN	JAPAN	JAPAN	USA	INDIA	INDIA	USA	USA	USA
3	CHINA	CHINA	USA	USA	USA	JAPAN	USA	USA	INDIA	VIETNAM	INDIA
4	USA	USA	GERMANY	UK	UK	INDIA	JAPAN	JAPAN	JAPAN	JAPAN	JAPAN
5	FRANCE	JAPAN	ITALY	GERMANY	INDIA	UK	TURKEY	AUSTRALIA	VIETNAM	GERMANY	GERMANY
6	JAPAN	FRANCE	UK	SOUTH AFRICA	GERMANY	GERMANY	GERMANY	TURKEY	AUSTRALIA	AUSTRALIA	BRAZIL
7	BELGIUM	AUSTRALIA	ROMANIA	FRANCE	KOREA	THAILAND	KOREA	GERMANY	SPAIN	KOREA	AUSTRALIA
8	UK	INDIA	INDIA	KOREA	AUSTRALIA	KOREA	AUSTRALIA	MEXICO	GERMANY	INDIA	SPAIN
9	AUSTRALIA	GREECE	GREECE	AUSTRALIA	FRANCE	AUSTRALIA	BRAZIL	KOREA	UKRAINE	SPAIN	KOREA
10	GREECE	BULGARIA	AUSTRALIA	INDIA	CANADA	TURKEY	UK	NETHERLANDS	KOREA	NETHERLANDS	POLAND
RANKING EU	1	1	2	3	3	4	5	4	2	2	2
MARKET LEVEL TO ACCESS THE TOP 10											
	426 MW	843 MW	792 MW	779 MW	675 MW	818 MW	944 MW	1 621 MW	3 130 MW	3 492 MW	3 710 MW

(IEA PVPS Trends Report, 2022, p. 13).

In *Table 4*, shows the evolution of the top 10 markets for solar PV in the world from 2011 to 2021. In the very beginning, from 2011-2012, the EU has the biggest market share and European countries are the majority of the top 10 countries with the biggest market However, this declines in a steady pace. From 2012 and beyond, countries in Asia, and China becomes the market leader in solar PV. In 2011, six countries from Europe represented the top 10 markets in the world. However, 10 years later, in 2021, only 3 countries represented the top 10, showing a massive downfall in the market share. One of the main findings is that China has been the market leader consecutively for the last eight years and continues to dominate the market in solar PV. On the other hand, Germany, the biggest market leader in Europe, has fluctuated in the middle of the rankings with the biggest market share in the world in 2011, and their lowest in 2019, ranking eighth. The US has consistently been in the top three after China became the world's market leader, emphasising the competition between the two countries.

In these next sections of the thesis, I will describe and illustrate my central findings from the semi-structured interviews. This is supplied with information from secondary sources such as previous research, reports, news articles etc. I have organised the rest of my analysis into the following key resource formation processes; knowledge, (niche) markets, financial investments, and legitimacy to understand how the global emergence of the solar PV industry is organised. I will use these four processes to discuss the drivers and barriers of the Norwegian solar PV industry in relation to conditions for growth.

5.2. Knowledge

In this section, knowledge will be referring to the activities that relate to technological knowledge, competence, skills, and expertise in the field of solar PV. According to Informant 9, knowledge development in the Norwegian PV industry can be traced back to the establishment of the firm ScanWafer in 1996-97, an original solar PV firm, not just a spin-off of the metallurgical industry. Firms that are upstream mentioned that the main foundation of local knowledge on solar in Norway is largely developed from the metallurgical silicon industry. Therefore, the industry has been of great importance concerning further growth of the solar PV industry in Norway. Norway has a process industry with low margins and a strong focus on cost-effective solutions. However, today, most of the new firms in Norway are in the downstream part of the value chain. Informant 5 explains the reason for this as follows:

> *«Majority of the people entering [the Norwegian solar industry] today are installers, or installation firms, and many of them enter because it is more lucrative to install electricity/power, or solar power in Norway, and the high price has had an effect, but based on products.. there should be room for more Norwegian [firms] as well, because there is much competence in Norway* (Informant 5).

In addition, Norway has built up a strong research environment of solar PV. Furthermore, Norway has strong environments connected to research-, education-, and competence.

> "*If you are going to build something that is sustainable, you must include research and academics to increase the competence. This must be done so you have a foundation of knowledge in the country, a substantial core of knowledge, and this is not something that done in a snap"* (Informant 4).

The most important environments connected to research are assembled in the research centre FME SUSOLTECH (Roadmap, 2020, p. 34). Another key competitive advantage for development of solar PV is the collaboration between Elkem and the research institute Sintef in Trondheim. The purpose was to develop the knowledge base on silicon materials for solar cells at the Norwegian University of Science and Technology (NTNU) (Klitkou and Godoe, 2013, p. 1591).

> *"We have really good environments connected to research, and many who have worked in the industry, but with the current standings in Norway, I do not think*

> *establishing something in Norway is attractive enough. Only if the political situation in Norway changes"* (Informant 5).

In the upstream sector, the firms mention that Norway represents a unique position in the value chain in solar PV because of its technological knowledge of materials and industrial processes. The materials include quartz production, polysilicon, ingots, and wafers, and the unique kerf recycling process in REC Solar (Informant 8). The unique kerf recycling process is a good example of the upstream part of the Norwegian PV value chain do process and product upgrading in the value chain. The kerf process is a recycling method of the polysilicon in the beginning of the value chain. When you cut the polysilicon ingot into a wafer, around 70% of the material leads to being a wafer, while the other 30% is waste. This waste product is pure silicon, and this can recycled raw material (Informant 5).

Informant 9 claims that Norway in general

> *"have a huge industrial opportunity based on competence, the price of electricity, traditions in the industry, and company towns that have shift workers that are used to work both day and night to manage the company, the environment around competence, which have contributed to being a step ahead and being innovative"* (Informant 9).

The competence of industrial processes to make these products are fundamental for the knowledge creation. The Norwegian firms that are upstream emphasise that they have much knowledge of each specific part of the value chain. Informant 4 emphasises that, e.g. we know a lot about the industrial process of making ingots. According to Klitkou and Godoe (2013), the knowledge base on solar PV stems from the important role of the Research Council of Norway's (RCN) next R&D programmes that promoted development of a Norwegian PV manufacturing capacity (Klitkou and Godoe, 2013, p. 1590).

The challenge for the firms in the upstream sector of the value chain in Norway is the difference between the firms. Informant 8 mentions the following:

> *"You have everything to build something that can potentially be valuable for Europe and the rest of the world, but the disadvantage is that everything is spread out, the companies have a different view and strategy, and the scale is wrong"* (Informant 8).

From a global perspective, Norway might have the competence and knowledge on ingot and wafers, which gives them an advantage but lacks certain types of companies that are part of the value chain. For example, in the upstream part of the value chain, Norway does not have a cell/module firm, and if we are going to enter that part of the industry, we need a semiconductor business, and that is an area where Norway lacks knowledge, according to Informant 4.

In the downstream sector, the local firms often mention the level of competition between the companies. There is little to no cooperation between the companies in the downstream sector in Norway yet. In the downstream part of the value chain, the companies are worried about the competence of other companies to a much larger degree. Informants share their worries over new actors and emerging companies that might not have the competence or the right equipment to install solar power. While informant 4, in the upstream part of the value chain, claims that the upstream companies in Norway are not competitors but rather cooperate, and it is rather the Chinese that are competitors.

The companies in the downstream sector emphasise that there is a lack of knowledge and competence around solar PV, especially in Norway and the rest of the Nordics which makes it challenging. The reasoning behind these statements is that the solar PV industry is new, there is little development regarding competence and little to no control over what is being done in the sector.

The downstream companies also emphasise the lack of professional expertise and competent people working on solar. Since the industry is in such a developmental phase, there is a lot of growth, but not enough competent people to catch up with the growth according to Informant 7. Another downstream actor emphasises that he experienced that their firm was earlier than others in some of the processes and shared many of their experiences and that people have started to do the same right after. At the same time, he claimed cooperating is probably necessary to prevent negativity connected to the industry.

5.3. Market formation

In this key formation process, the (niche) market formation will be looking at the value chain position and the geographical orientation of the firms. The global perspective of the market formation in solar PV is mainly concentrated in Europe, North America, and Asia.

I will divide this market formation into two processes to explain the key resource formation in more detail. First, market deployment. Second, industrial development.

5.3.1. Market deployment

The trend shows that solar PV is increasing every year. According to the IEA PVPS (IEA Photovoltaic Power System Programme), the report "Trends in Photovoltaic Applications 2022", shows that the global PV installed capacity represented 945,4GW of cumulative PV installations, and that 173,5GW was the minimum amount of capacity installed in 2021. China leads superiorly over the rest of the countries in the world, having installed almost 55GW in 2021. In second place, is the EU, with 28,7 GW. In third place, the United States with 26,9 GW installed (IEA PVPS Trends, 2022, pp. 12-13).

The total installed solar PV capacity in Norway in 2022 was 299 MW. The number is one-thousandth of the total power production in Norway. The 299MW doubled the installed capacity from the previous year. The 299 includes both small-scale solar PV systems for cabin and housing, and larger scale like solar PV parks and PV systems on roofs for businesses (NVE 2023).

According to the IRENA capacity statistics on solar PV, Norway had a total installed capacity of 321 MW in 2022 but is still far behind other European countries. In Scandinavia, Sweden tops with 2 606 MW installed capacity, while Denmark has 2 490 MW. Other comparable countries like Finland had 591 MW installed capacity, while the European giants like Germany, Netherlands, and Italy had respectively 66 554 MW, 22 590 MW and 25 083 MW installed (IRENA Renewables Energy Capacity Statistics, 2023, pp. 22-23).

Some of the firms in the downstream industry do not install the solar PV system themselves. Many of them emphasise that there is insufficient competence in the market, especially specialised competence related to PV systems in Norway regarding snow. Informant 3 claims that Norway has the possibility to do so.

> *"[Norway] has enormous possibilities for the deployment of solar, but we have some regulatory challenges that do not release the full potential. The way the solar PV industry in Norway is rigged, it is only prepared for, call it, small installations and the electricity grid is partly a reason for that, which is not prepared to take in the amount the market can install"* (Informant 3).

In addition, there is a lack of people with the competence to do the installations needed. However, regulatory measures can be important in controlling the situation. Increased market growth and limited competence in solar PV can lead to wrong installations and insurance claims according to Informant 3. He states an example from Denmark in 2012, where the

Danish government decided to remove a support scheme and notified it eight months in advance. The positive aspect was that the market increased tenfold. The negative aspect was that the Danes are still struggling with complaints and insurance claims after the removal of the support scheme. In addition, Swedish policymakers have also made changes to the regulatory framework that governs installations by introducing a subsidy that covered 70% of the investment cost (Andersson, Hellsmark and Sandén, 2021, p. 6).

An issue in the upstream is the production and the barrier of the current high electricity prices. When a country has lower electricity prices, the energy intensity of the economy is higher (Verbič, Filipović & Radovanović, 2017, p. 64). According to Informant 5, their barrier in the upstream solar PV in Norway, or the main problem, is that they are not able to produce anything now because of the current high electricity prices in Norway.

Another issue is the lack of places to install solar PV systems. Informant 2 says that we need more local societies connected to energy. According to Informant 3, installers are not competent enough to understand what installing a solar PV system really implies. Regarding Norway, Informant 3 also emphasises the need to take into consideration that there is a different climate in Norway than the rest of the world and there are few comparable cases. Informant 10 also gives emphasis to the main challenge being the electricity grid of Norway.

> *"It is the electricity grid which is the challenge, and areas of land. We have e.g. many flat land areas in the inner areas of Eastern Norway, etc. However, it ends up clashing with being a place where it is no electrical power. There are no electricity grids there. There are electricity grids along the coast and close to the large cities. However, you cannot deploy solar there" (Informant 10).*

5.3.2. Industrial development

When it comes to where the downstream sector gets the solar PV systems from, the main answer is China. One firm in the downstream sector, Informant 1, claims they get their products from South Korea, but it is likely that some of their panels are also Chinese. Informant 4 claims that there are no firms in Norway that buys solar PV systems from firms to save the planet. The only reason is it is a way to make money and that is mainly why firms buy from Chinese suppliers.

Informant 7 argues that "In Norway, if we [Norway] are ever going to have a chance, since Norway is such a marginal area of the world, we have to point out some niche alternatives". However, Informant 9 claims that

"It is very easy to think that we need to make niche products that are expensive, but what we have learnt from solar PV is that on the road to niche products is firstly scale to create a frame, the core, really cheap and then adjust it accordingly" (Informant 9).

The findings entail that upstream firms are more connected to the international, global market than the firms in downstream, which focuses more on the local market in Norway. Informant 5, emphasis that

"It is often people like you and me, the private sector, that worries about the price tag, getting it as cheap as possible. I know that some actors will buy our panels if they are as cheap as the Chinese ones, but there is a reason they are that cheap. When it comes to our panels, we sell majority of the panels to the US. We sell everything we produce, and we could sell even more" (Informant 5).

The upstream actors measure themselves with actors in China, while competition in the downstream sector revolves around firms in Norway.

The analysis covers different actors in different parts of the value chain. Most of the interviews were connected to actors in the downstream sector, while there were a few in the upstream sector and two experts connected to the industry. Most of the firms in downstream emphasise that they operate in the private sector in Norway, and the companies do not operate outside of Norway. Most of the companies also emerged during the mid-2010s, and all companies in the downstream are involved in the installation of solar PV in Norway, except one, Informant 3, which is a supplier of solar panels to firms in Norway. Two of the companies in the downstream sector have currently not installed any solar PV yet. There are differences in the installations. Some of the Informants works on building solar PV parks, while others work of solar PV on buildings.

The firms in the upstream sector name their competition with China. China controls large parts of the value chain and it is much cheaper to get panels from China than it is in Europe. To be able to compete with China, Informant 4, claims that there must be an interest for products that have a higher product quality in the market and that the rest of Europe and Norway needs large scale and funds to survive in a global market. The main problem is that Norway is not part of any large financial programs, like IPCEI, that can be introduced in solar PV to fund R&D and innovation across the value chain. IPCEI (Important Projects of Common European Interest) is a support scheme by members of the EU to provide funding. It contributes to economic growth, jobs as well as in the green and digital transition and competitiveness by bringing together knowledge, expertise and financial resources throughout the Union (EU, 2023). Informant 7 claims that Europe lacks "a sense of urgency" when it comes to taking over the market.

Another thing that the upstream actor, Informant 4, claims that is a massive challenge to the upstream sector is that all the equipment that is needed to operate in the upstream value chain is also produced in China. There are no European suppliers that can deliver the equipment with the same quality or speed as the Chinese suppliers. The upstream sector in Norway is struggling at the moment.

> "*Time has run out because the equipment is too old. You cannot compete with China regarding cost. Not because there is something wrong with access to knowledge, because the knowledge is there, but because you do not have access to the money or the resources needed to upgrade the capacity, neither the amount of size or equipment*" (Informant 8).

In addition, the cost of investing in European solar panels is a possible barrier. When asking the downstream companies whether they would buy European solar PV panels rather than Chinese, the cost of doing so is the main obstacle. Informant 1 mentions the price. There are not a lot of European products available within the same price range. The cost is high, but it all depends on whether the end customer wants it. If the value chain is being brought back to Europe, they would "most definitely, given that it is on a price level that the market will pay for" (Informant 2). Informant 3 reveals that customers are not willing to pay that amount. "There are those people who say it is important for them [more green alternatives], but the important thing is the cost" (Informant 3). On the other hand, in the upstream sector, Informant 4 emphasises that:

> *"This business, and I stress the business, not the company, this business. I think it has never made profit. It has chased after a reduction in costs, and it has been really good to do it, but never been able to catch up"* (Informant 4).

5.4. Resource mobilisation

This section will use resource mobilisation as a term rather than financial investments. In Binz, Truffer and Coenen's framework, this is named financial investments and refers to the activities around financial inputs and investment opportunities. I argue that there is more to financial investments than just financial capital and investment and that it also includes activities around manpower, utilisation of new technologies and production. Chasanidou, Hanson and Normann (2021) define resource mobilisation as the “mobilisation of different types of resources for the development, diffusion and utilisation of new technologies, products and processes. This includes capital, competence and human resources and infrastructures (2021, p. 11).

A prosumer is here defined as “small-scale end-user who, in addition to, using electricity from the grid, generate power for their own use and export back into the electricity grid” (Inderberg et al., 2018, p. 258). According to Inderberg et al. (2018), Norway has been an energy frontrunner, but less developed in the prosumer market. As of 2016, there were roughly 700 prosumers out of 5.3 million inhabitants (2018, p. 264).

Informant 9 claims that the Norwegian government has also been important in paving the way for solar and one of these measures is the Enova scheme. There have been attempts to encourage the development of solar PV in Norway, involving both the public and private sectors. One of the first was the establishment of SkatteFUNN, a tax credit scheme that started in 2002. Second, Public and Industrial Research and Development Contracts administered by Innovation Norway. Third, co-founding (subsidies) that were provided by the Norwegian Industrial and Regional Development Fund (SND) and the Government Consultative Office for Inventors (SVO). Fourth, there were several regional policy instruments, such as county-based investment funds and business development incubators. This included industrial investment funds from large industrial players and multinational corporations (MNC) like Norsk Hydro, which helped promote the development of a new manufacturing industry (Klitkou and Godoe, 2013, p. 1590). Today, these subsidies like the SND and SVO, are under the Innovation Norway and has been since 2003 (Innovasjon Norge’s Årsrapport, 2003).

The central support schemes are electricity certificates, capital subsidies, and self-consumption. The public sector issues electricity certificates to stimulate electricity generation from RES. The capital subsidies are from Enova, a government-owned institution in Norway that aims to ensure a more secure energy supply, as well as reduce greenhouse gas emissions and develop new materials and technologies (Xue, Lindkvist and Temeljotov-Salaj, 2021, p. 5).

However, according to Inderberg et al., Norway lacks support schemes for personal use, and it is only the most developed one, the Enova scheme, a direct national support programme that effectively targets prosumers (Inderberg et al., 2018, p. 265). At the same time, Enova has been criticised for its late entrance to the prosumer market. It was not before 2018, that the Enova scheme supported solar PV systems for cabins (TU 2018).

Both in the upstream and downstream sectors the focal point is costs. When asked, every informant in the downstream part of the value chain wishes that the value chain of solar PV will be brought back to Europe, but that it will involve challenges to price. The upstream sector claims that they can compete with China with their knowledge and operating with clean energy, but Informant 5 mentions that

> "*There is a lack of 'special agreements' connected to the renewable industry, especially the solar industry. The Norwegian state says that it operates without these special agreements, but they have it in the oil- and gas industry, so why can't they have it "here"*" (Informant 5).

Another thing the local upstream sector struggles with is the price of electricity in Norway. This price has been record high lately making it impossible to invest further and operate in the value chain since the upstream value chain is dependent on high power usage, and therefore low price of electricity. That means that one of the previously competitive advantages of the Norwegian solar industry is no longer an advantage. The barriers for the upstream value chain now are too few investors according to Informant 9.

> "*I think there are too few investors that dare to make decisions based on the scale. The state [Norway] can do whatever it wants, but the investor that builds a factory needs to have a long-term plan, and with today's price of electricity, it does not look pretty."* (Informant 9).

When compared to other upstream actors, like the ones in China, the US and India, the informants emphasise the importance of subsidies and support. According to Informant 4, it looks like every country starts to create their regional value chains, like the US with the IRA, India with the PLI and China with their own methods. Norway has no incentives to scale up the solar energy sector the same way. Informant 9 claim that there have been According to informant 8 states that the support and subsidies are the reason they are developing so fast.

> “*The fascinating thing about China is when they build towards capacity, they build for 30 GW each time and you are maybe wondering how many months it takes? It takes nine months, and the government builds the factory for free, and gives subsidies for factory equipment”* (Informant 9).

Informant 10 is more unsure and discusses whether these subsidies will work out. He mentions that subsides in the downstream have been of varying success outside of Norway. A firm in the upstream and a firm in the downstream are both unsure whether it is possible to introduce subsidies without looking at the possible consequences.

In the downstream sector, they emphasise the cost of solar PV systems. The firms emphasise that they would like to buy European solar panels instead of Chinese, but the cost of buying European panels is too high. The downstream firms claim that to be able to survive in the industry, they cannot buy the most expensive ones. Another worry is that the demand for energy will increase a lot. Informant 2 claims that

> “*The demand of energy will increase dramatically, and I am afraid that the prices on energy will be very high because of the free market. If it is going to be realistic, [that is: goal to 2030], we need to increase production of electric energy much, much faster than we do today"* (Informant 2).

In addition to this, upstream companies emphasise that Norway lacks a sufficient line of production compared to China as a global actor. Since China has a better line of production with better and improved equipment, Norway must rely on the knowledge and competence of how to use the equipment.

However, an interesting statement from Informant 8, is the making of quartz crucibles in the beginning of the value chain. There is only one type of high-quality sand that can be used to make high-quality crucibles, and there is not enough supply of this sand in China. The only place you can find this sand is in the US, and it is only extracted by two companies, which have a joint venture in Norway. Since China does not have direct access to this high-quality sand, it is leading to a reduction in the high-quality production capabilities China currently has (Informant 8).

In addition, another important aspect is the level of automation and use of manpower that distinct upstream manufacturing in Norway compared to China. The Chinese have different schedules regarding shift work only having three shifts for the workers. In Norway, there are five shifts (Informant 4). An example from Informant 8 shows the difference in manpower. "If a Chinese factory needs 100 men for a daily shift, you need 300 employees. For a daily shift in a Norwegian factory, you would need 500 employees for the same workload" (Informant 8).

5.5. Legitimacy

Legitimacy, the technology legitimacy will be divided into two different aspects. The technology legitimacy as formation process will entail two perspectives. First, the acceptance for enabling solar PV as a source of energy regarding policies and regulations in Norway. Second, where does the technology to install solar PV come from?

For the companies in the upstream sector, the Norwegian state is not appreciating enough that Norwegian companies have advantages in technology. At an earlier stage in the industry, there was more acceptance for promoting the manufacturing capacity in Norway regarding upstream companies. In addition to the previously mentioned RCN's R&D programmes under the knowledge dimension, other programmes facilitated the development of upstream manufacturing in Norway.

The downstream sector emphasises that the Norwegian state does not care too much about solar energy in Norway, and also emphasises the actors NVE and the transmission system operators (TSOs) in Norway as a brake pad. In the downstream sector, many portray the role of NVE and the TSOs in a negative fashion for further growth. Informants 6 and 11 especially give emphasis to how fast NVE can process applications for deploying solar PV systems. The two informants are two firms that are in the beginning phase of installing solar, getting their applications approved is important. In general, there is a consensus among the informants that getting applications approved takes too much time. Informant 6 emphasises that it is understandable because solar PV is quite a new industry in Norway. Therefore, it is possible that the applications need some time to do it properly. At the same time, NVE and the TSOs are also described by Informant 3 as a brake pad when explaining a specific incident regarding a law regulation in the Energy Act.

Another regulatory hinder is the electricity grid. Unfortunately, there is not a lot of available capacity in the Norwegian electricity grid, which impacts both producers and consumers of electricity – whom both have right to access, but where only producers must go through an application process. A limited amount of access to the electricity grid influences people developing solar PV systems in two ways. First, projects will not be realised, or potentially, reduced in scale or get postponed. Second, project developers will apply for different applications e.g. solar PV in combination with batteries. This implies a reduction in the capacity in the electricity grid (Kapital 2023).

Both the upstream and downstream sector is mentioning environmental product declarations (EPDs) as something that could be advantageous. Informant 4, however, claims that declarations are created mainly to show that European panels get a premium compared to Chinese ones. These declarations will only have an effect if it entails looking at work conditions, because declarations regarding environmental production are something China is also able to do. Regarding the working conditions, both upstream and downstream emphasise the polysilicon production in the region of Xinjiang, and its consequences.

The problems are related to the polysilicon wafers which are produced in this area. Informant 6 stresses that a few reports are made on the Xinjiang situation and that it is important for them as a downstream firm, that they do not have a connection to it. He underlines that is a challenge because a large share of the polysilicon produced in the world is from that area. The report “In Broad Daylight” claims that 95% of all solar modules rely on solar-grade polysilicon, and that polysilicon manufacturers in this region account for approx. 45% of the world’s solar-grade polysilicon supply (In Broad Daylight, 2021).

It is important for the downstream firms not to have solar PV systems that have silicon from the Xinjiang region, that is known for forced labour and labour camps. Informant 5 claims this is important when public high-profile actors want to install solar PV systems. The informant states a recent example. In mid-2022, the University of Bergen in Norway was accused of installing solar PV panels from a company that was involved in forced labour. The outcome of the case led to the university paying for panels that would cost more, but which secured that the solar PV systems were produced under safe and secure working conditions (Khrono, 2022).

However, assuring this can be a difficult procedure. According to Informant 3, when their firm is asking their Chinese suppliers about certain declarations, the answer from the supplier varies. Sometimes they will send the declarations at once, while other times they do not know what it is and asks for an example.

> *"We deliver EPDs, declarations of origin on every public quotation, but we need to be clear, that we personally, me personally, or rather, as a company, cannot vouch for the content in those documents. We must obey to what is being said and that the supplier can vouch for the content."* (Informant 3).

The environmental product declarations are more an example of just trying to create a premium of European panels compared to Chinese ones according to Informant 4. Being in the upstream sector, he claims that this kind of "premium" will only account for work-related issues, and when requesting full traceability in the value chain. Informant 4 wonders how this will get operationalized and how long it is okay to have a premium. When it comes to environmental production and having a low carbon footprint, which right now is an advantage in Norway, this is something China also can do in a while. Another Informant in the upstream sector, Informant 5, also thinks that regarding legitimacy, customers could be more specific in their requests, especially in public quotations, to what is being installed, hoping that it is for ethical reasons, not necessarily for being called out by the local newspaper.

Chapter 6 - Discussion

The analysis in the previous chapter has described the current situation for Norwegian upstream and downstream companies in the solar PV industry. The discussion in this chapter will focus on the key factors to further develop and expand the Norwegian solar PV industry. The discussion will detail the drivers and barriers to the development of the industry in Norway.

This section will discuss the research question:

1. What are the key factors influencing the further development and expansion of the Norwegian solar PV industry?
2. What are the drivers and barriers for the Norwegian solar PV industry?

I will argue that three key factors influence the further development and expansion of the Norwegian solar PV industry. The three are the already established knowledge base in Norway, the cost development in Norway, and the Norwegian regulatory frameworks that affect further development. An important aspect is the development in Norway relative to the global scale, and how the development in the global solar PV industry affects the development in Norway.

6.1. Knowledge and the crucial importance of competence

As established, the existing knowledge base is crucial to the innovation of an industry and industry formation (Bergek et al., 2008). A key driver for the development in Norway is the already established competence in solar PV. Norway already has an established knowledge base for solar PV, unlike many other countries. At the beginning of the fluid phase, only a few countries, like Japan, and the US, had favourable growth conditions for the industry. Being the two only countries entailed a captive mode of governance (Gereffi, Humphrey & Sturgeon, 2005). Being only two countries, made other countries like Norway further create opportunities in the industrial development of solar PV.

These upstream activities are the foundation of the manufacturing value chain in solar PV (Hipp & Binz, 2020). The knowledgeable upstream sector was the central area for deploying the solar PV industry in Norway during the transitional phase in the 1990s. This was a time when Norway most rapidly benefitted from industrial development, having both the knowledge and many competitive firms in the solar PV sector. The main reason for the industrial development was that Norway was early involved in the solar PV industry through its R&D and competence in the silicon industry.

The findings illustrate the point by Asheim and Coenen (2005). In addition to the activities silicon industry, the industrial development of the Norwegian PV industry has benefited from having an analytical knowledge base on solar PV with links between academia/research and the industry. The informants representing upstream firms in Norway especially emphasise this. They emphasise that there are conditions for growth because of the important basis of knowledge already existing as emphasised by (Binz, Truffer & Coenen, 2016). Furthermore, Norway has a huge potential for growth in the deployment of solar PV, seeing how Norway has used the university-research link previously. In the future, this analytical knowledge link between the research institutes and industrial opportunities through universities has the potential to research further develop the solar PV industry. In addition, the connection link can be useful for both the industrial development of firms in the upstream sector and market deployment for the firms in the downstream sector.

An example of countries who invested for future growth are China and India who built up their domestic wind energy sector via investments from the public sector (Surana & Diaz Anadon, 2015). Since Norway was one of the few early countries contributing to the development during the fluid phase that contributed to the solar PV industry by producing silicon, one should consider that this could have been one of the key investment areas of the state for future growth. However, the barrier to further expansion of the solar PV industry in Norway is that it is not an attractive enough opportunity for the Norwegian state. The informants point out there are few incentives for firms and organisations to emerge in the industry. There must be sufficient incentives for the firms and organisations for an industry to emerge (Bergek et al., 2008). Although the Norwegian companies' knowledge of the value chain is useful enough to be of importance, it is still a small industry nationally. Both the upstream and downstream companies claim that the knowledge exists in both areas, but there are challenges related to more than just competence that prevents it from continuing at a faster pace.

The main knowledge base in solar PV is in the upstream sector of the value chain in Norway. However, currently, few firms are trying to enter the upstream sector. All the new firms that enter the solar PV industry in Norway today and see opportunities for growth are in the downstream sector. This is good news for developing and expanding the solar PV industry in

Norway. On the one hand, it shows that solar PV is still an industry of interest and an area where new firms and activity probably will continue to emerge. On the other hand, one of the main reasons new establishments take place in the downstream sector is that it is much more lucrative than the upstream. However, it is positive for the economic development and expansion of the Norwegian solar PV industry that activity takes place in both the upstream and the downstream part of the value chain.

However, the barrier to the expansion of new firms in the downstream sector is that the existing knowledge in this sector is limited. The findings by Binz, Truffer and Coenen (2016), illustrate that knowledge creation is the decisive mechanism through which firms create and sustain their competitiveness. The competence on the installation of solar PV in Norway has some gaps. The climate here is harsher compared to many other countries, and this can lead to low-quality or wrongful installations and possible insurance claims over the years. The emergence of new firms in the Norwegian PV sector with limited knowledge can challenge the industry's future reputation. The downstream companies claim that the downstream part of the solar PV industry is small and is still in its initial phase in the solar PV industry in Norway. Therefore, a bad reputation can have a negative impact on future development in the industry and consequences for the rest.

Another key aspect of competence of the findings from Binz, Truffer and Coenen (2016), related to the future growth of the industry is the extent of competitiveness in the sector. The informants from the upstream sector claim that they largely compete against the Chinese companies, and there is no need to be competitive with other firms in the same part of the value chain. On the one hand, the reason that it is more competitive in the downstream sector is that it is now more lucrative to enter the industry now that the price of electricity is high and there is a fight to take the position of market leader for solar PV. On the other hand, the emergence of a large number of downstream firms makes it more complicated to create collaboration between themselves. At the same time, the downstream firms emphasise that they need to earn money to survive in the industry and refer to the importance of cost.

6.2. Cost development

Possibly one of the main barriers to developing and expanding the solar PV industry in Norway is the cost level in Norway. This is emphasised by informants in both the upstream and downstream sectors. The main challenge is related to cost is China’s presence and ability to do everything at a very low cost, from manufacturing to producing equipment (Sun et al., 2014). In the upstream part of the value chain, it is related to the scale of production, and in the downstream, it is related to the cost of products (Zhang & Gallagher, 2016).

While Norway has focused more on knowledge and industrial development, China has established itself as a global leader in both the solar PV sector's market deployment and industrial development through supportive measures (Sun et al., 2014). The findings from Dewald and Truffer (2011, 2012) and (Andersson, Hellsmark and Sandén, 2021), illustrate that also in Europe, subsidies and support programs lead to market growth using the example of Germany and Sweden. On the one hand, the competitive advantages of Norway from the knowledge base and comparably low electricity prices have led the upstream firms in Norway to be able to challenge the competition from China. On the other hand, in recent times, the cost of electricity has increased, and there are currently not sufficient subsidies to keep the production running leading to Norwegian upstream firms stopping production and closing down. This is a huge barrier because Norway is one of the few countries that has upgraded the value chain through process upgrading (Humphrey & Schmitz, 2002). The upgrade is in the production of polysilicon through the kerf process. That being one of the first processes essential to the value chain, makes this process necessary for making a solar PV module.

The market formation in the path-as-process perspective, argues that market formation is characterised by new actors wanting to enter a segment of interest and where there are new possibilities for growth (Bergek et al., 2008). It is established that when a country has lower electricity prices, the energy intensity of the economy is higher (Verbič, Filipović & Radovanović, 2017). One of the main barriers to the future growth of companies in the upstream sector regarding cost is the currently high electricity prices. The high electricity prices have made it less profitable to produce the materials needed, and the production facilities are forced to close. Therefore, few upstream firms want to emerge in the industry as it is not profitable conditions for growth. However, even though the high price of electricity is recognised as a barrier in the upstream, it can be recognised as a driver for the installation firms in the downstream that are currently entering the market. The lucrative solutions and possibilities for growth has increased the amount of downstream firms entering the PV market in Norway.

Regarding the cost level, state regulatory measures and subsidies will have a great impact, which I will discuss below.

6.3. The regulatory role of the state

Although the knowledge of the industry is present, the market deployment of solar PV in Norway is low. In previous years, the Norwegian government have tried different approaches to increase market deployment, but with no success yet. When it comes to ways to increase the development of solar PV, in Norway, one method has been through support schemes, among those, the Enova scheme, which has supported individuals being prosumers (Inderberg et al., 2018). However, the scheme has been unsuccessful, and there are few prosumers today. Regarding international programmes, it seems that there are no programmes that currently support the upcoming solar PV. Some of the informants emphasise that Norway missed out on IPCEIs in the past, and this error must not be repeated if an IPCEI on solar PV should appear. However, the Government is claiming international support schemes are important in the future growth of the industry (Roadmap for Green Industry Growth, 2023).

The main barrier for the firms in the downstream sector of the Norwegian solar PV industry is the regulatory acceptance to install solar PV systems. This is both beneficial and an obstacle for the firms that are in the downstream part of the value chain. The downstream firms mention the obstacle being they cannot install enough solar PV systems because of the regulatory governing by NVE. The Norwegian state and the TSOs govern the electricity grid in Norway, meaning they control what is being installed and how much capacity. Again, the NVE controls the applications, and the companies claim that there is too much waiting to get these approved. This hinders the developing and expanding solar PV as a RES in Norway. At the same time, it is beneficial, and they can understand the importance of having such regulatory measures to prevent wrong installations and that there is a need for regulatory control to ensure the safety and quality of installations. This prevents the market from getting out of control, and there are regulations set so anyone can join the market. In addition, this way, the regulatory measures also protect the firms against massive competition.

At the same time, it seems that the larger barrier to deployment in Norway is regarding the installations. In Sweden, market formation increased because of policies regarding installations (Andersson, Hellsmark & Sandén, 2021). When it comes to the market formation in Norway, a barrier to deploying solar PV is the regulatory challenges involved in the installations. According to the informants, there is massive potential for the deployment of solar PV in Norway, but the electricity grid is close to bigger cities and along the coast. The locations where the solar PV could be installed, flat areas in the inner parts of the country, where it is favourable to install solar PV systems, are no connection to the electricity grid.

Another driver is the support of the Norwegian state to support more solar PV. The support for market formation succeeded in Germany (Dewald & Truffer, 2012). During the transitional phase, it looked like there were a lot of different support schemes for the upstream solar PV sector. There were around four schemes and potential subsidies, among them, a tax credit scheme and support from other MNCs. However, today, all these schemes are collected under Innovation Norway as a sole actor. One can discuss whether collecting all these schemes to one actor has led to fewer incentives for the upstream solar PV firms to get support. In addition, if the timing was right. The four schemes were connected to Innovation Norway in 2003 when Solar PV was during its transitional phase globally but during the end of the formation phase and near the beginning of the momentum phase in Norway. The German PV industry had success after what the German government did in 2004 (Dewald & Truffer, 2011), and it can be argued that the four schemes should have been implemented during the momentum phase in Norway to boost growth in PV. In the momentum phase, when the companies started to compete against each other, it would be important to have enough economic support to withstand strategic coupling and other companies from developing countries with better capabilities.

At the same time, issues have been raised about how the Chinese PV modules are manufactured. Key to technological legitimacy is the value base of the industry (Bergek et al., 2008). Many informants emphasise the importance of the polysilicon used in Chinese solar PV modules. Many of the Chinese solar PV modules are made in the Xinjiang province of China, an area known for forced labour which is not positive for the industry's socio-political legitimacy (Aldrich and Fiol, 1994).

A competitive advantage would be to have Norwegian silicon, as Norway is known for its high standard to safety, environmental and human resources. The GPN theory states that producers seek greater revenue and profits through market expansion and the customers through becoming more demanding for better products/services at lower prices (Coe and Yeung, 2015). This illustrates a barrier, in which the Norwegian products have a higher price level compared to Chinese products. Informants in the downstream sector of the value chain in Norway emphasise that they are not using Norwegian materials since they can get the same materials from China at a much lower price. Norway is one of the few countries that have a competitive advantage because of its clean upstream production. However, because of the high-quality silicon and the clean energy used to manufacture these solar PV modules, the cost is too high for downstream companies to deploy these end-products and they will prefer to import products from China. They emphasise that they would have preferred Norwegian, but due to the profitability, the Chinese alternative is cheaper making the choice easy.

Chapter 7 - Conclusion

This thesis aims to examine the key factors for development and expansion in the Norwegian solar PV value chain and examining it through industrial development and market deployment to get a broader perspective. Moreover, it maps out the formation of the solar PV industry through GVC. Additionally, the thesis explains whether the Norwegian solar PV industry emerged through path creation using the path-as-process perspective.

The thesis has analysed it through a qualitative case study of the Norwegian PV industry by conducting 11 semi-structured interviews and triangulated data from reports and news articles. The data give emphasis to the drivers and barriers for the development and expansion for the firms in the solar PV value chain in Norway.

The thesis points out three key factors that can further influence the development and expansion. These three key factors are the knowledge base in Norway, the cost development in Norway, and the Norwegian regulatory frameworks.

Key to the industrial development of solar PV, Norway started early with a metallurgical industry that later led to the production of silicon and R&D, and then later evolved into a competitive industry involving the production of ingots and wafer. Today, a few Norwegian companies in the upstream value chain can compete with China in the global solar PV industry today because of competitive advantages in the beginning of the manufacturing value chain and the knowledge base. However, because of high costs, the future does not look bright for further investments. The regulatory frameworks that exist in Norway does not provide sufficient support schemes that lead to further growth.

In the downstream, from a market deployment perspective, Norway is still a small actor in a global scale. However, this is also something that starts to ramp up. Several firms in the downstream sector observe that this is a lucrative industry, and on a global level, there is growing attention to develop more solutions in RES, where-by installing solar PV systems are one of them. However, the knowledge in this sector is still limited and need to be improved to further develop the industry. The cost of European solar PV modules is too expensive, and the firms are still dependent of Chinese products because of its low cost. Lastly, the status quo of the regulatory frameworks leads the Norwegian solar PV industry to a standstill.

Norway can prove to be one of the most important countries in Europe for industrial development of solar PV, when the EU wishes to develop and expand the manufacturing value chain to Europe. To make this happen, Norway must learn from their past experiences on solar PV and focus on the development of the entire value chain. First, the current knowledge base that exists in the country needs appreciation. The knowledge base in Norway is huge, which is important for future development and can influence more growth. Second, the cost development. The upstream part of the value chain needs support schemes to increase the scale of production, while the downstream sector needs incentives to import products that are not from China. This will increase both market formation and the legitimacy of the Norwegian PV industry. Third, there is a need for de-regulation of the electricity grid and improvements in regulatory frameworks. These actions can prove to be vital for further development and expansion on solar PV.

Bibliography

Ahlin, E. M. (2019). Semi-structured interviews with expert practitioners: Their validity and significant contribution to translational research.

Aldrich, H. E., & Fiol, C. M. (1994). Fools rush in? The institutional context of industry creation. *Academy of management review*, *19*(4), 645-670.

Andersson, J., Hellsmark, H., & Sandén, B. (2021). Photovoltaics in Sweden–Success or failure? *Renewable and Sustainable Energy Reviews*, *143*, 110894.

Asheim, B. T., & Coenen, L. (2005). Knowledge bases and regional innovation systems: Comparing Nordic clusters. *Research Policy*, *34*(8), 1173-1190.

Basit, T. (2003). Manual or electronic? The role of coding in qualitative data analysis. *Educational research*, *45*(2), 143-154.

Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., & Rickne, A. (2008). Analyzing the functional dynamics of technological innovation systems: A scheme of analysis. *Research Policy*, *37*(3), 407-429.

Binz, C., Tang, T., & Huenteler, J. (2017). Spatial lifecycles of cleantech industries–The global development history of solar photovoltaics. *Energy Policy*, *101*, 386-402.

Binz, C., Truffer, B., & Coenen, L. (2016). Path creation as a process of resource alignment and anchoring: Industry formation for on-site water recycling in Beijing. *Economic geography*, *92*(2), 172-200.

Blažek, J., & Steen, M. (2022). Global production networks and regional innovation systems: contrasting or complementary policy implications? *European Planning Studies*, *30*(10), 2043-2062.

Boschma, R. (2022). Global value chains from an evolutionary economic geography perspective: a research agenda. *Area Development and Policy*, *7*(2), 123-146.

Chasanidou, D., Hanson, J. & Normann, D. (2021). *The Norwegian Solar Energy Innovation System*. (Rapport 40). NTRANS – Norwegian Centre for Energy Transitions.

Clifford, N., French, S., & Valentine, G. (2010). *Key methods in geography* (2nd ed.). SAGE Publications Ltd.

Coe, N. M. (2021). *Advanced Introduction to: Global Production Networks*. Edward Elgar Publishing Limited.

Cope, M. (2010). Coding Transcripts and Diaries. In N. Clifford, S. French, & G. Valentine (Eds.), *Key Methods in Geography* (2nd ed., pp. 440-452). SAGE Publications Ltd.

Davy, E., Hansen, U. E., & Nygaard, I. (2022). Localizing the solar value chain in Kenya? *Innovation and Development*, 1-24.

De Marchi, V., & Alford, M. (2022). State policies and upgrading in global value chains: A systematic literature review. *Journal of International Business Policy*, *5*(1), 88-111.

Dewald, U., & Truffer, B. (2011). Market formation in technological innovation systems—diffusion of photovoltaic applications in Germany. *Industry and Innovation*, *18*(03), 285-300.

Dewald, U., & Truffer, B. (2012). The local sources of market formation: explaining regional growth differentials in German photovoltaic markets. *European Planning Studies, 20*(3), 397-420.

Dunn, K. (2021). Engaging Interviews. In I. Hay & M. Cope (Eds.), *Qualitative Research Methods in Human Geography* (5th ed., pp. 148-185). Oxford University Press.

European Union. (2023, February 1st). *A Green Deal Industrial Plan for the Net-Zero Age.* https://commission.europa.eu/document/41514677-9598-4d89-a572-abe21cb037f4_en.

Fernandez-Stark, K., & Gereffi, G. (2019). Global value chain analysis: A primer. In S. Ponte, G. Gereffi, & G. Raj-Reichert (Eds.), *Handbook on global value chains* (pp. 54-76). Edward Elgar Publishing.

Franco, M. A., & Groesser, S. N. (2021). A systematic literature review of the solar photovoltaic value chain for a circular economy. *Sustainability*, *13*(17), 1-35.

Frederick, S. (2019). Global value chain mapping. In S. Ponte, G. Gereffi, & G. Raj-Reichert (Eds.), *Handbook on global value chains* (pp. 29-53). Edward Elgar Publishing.

Frenken, K., & Boschma, R. A. (2007). A theoretical framework for evolutionary economic geography: industrial dynamics and urban growth as a branching process. *Journal of economic geography*, *7*(5), 635-649.

Gereffi, G. (2011). Global value chains and international competition. *The Antitrust Bulletin*, *56*(1), 37-56.

Gereffi, G., Humphrey, J., & Sturgeon, T. (2005). The governance of global value chains. *Review of international political economy*, *12*(1), 78-104.

Gereffi, G., & Lee, J. (2012). Why the world suddenly cares about global supply chains. *Journal of supply chain management*, *48*(3), 24-32.

Hanson, J. (2018). Established industries as foundations for emerging technological innovation systems: The case of solar photovoltaics in Norway. *Environmental Innovation and Societal Transitions*, *26*, 64-77.

Hay, I., & Cope, M. (2021). *Qualitative Research Methods in Human Geography* (5th ed.). Oxford University Press.

Hekkert, M. P., Suurs, R. A., Negro, S. O., Kuhlmann, S., & Smits, R. E. (2007). Functions of innovation systems: A new approach for analysing technological change. *Technological Forecasting and Social Change*, *74*(4), 413-432.

Hipp, A., & Binz, C. (2020). Firm survival in complex value chains and global innovation systems: Evidence from solar photovoltaics. *Research Policy*, *49*(1), 1-16.

Humphrey, J., & Schmitz, H. (2002). How does insertion in global value chains affect upgrading in industrial clusters? *Regional studies*, *36*(9), 1017-1027.

IEA (2022), *Renewables 2022: Analysis and forecast to 2027*, IEA, Paris https://www.iea.org/reports/renewables-2022

Inderberg, T. H. J., Tews, K., & Turner, B. (2018). Is there a prosumer pathway? Exploring household solar energy development in Germany, Norway, and the United Kingdom. *Energy Research & Social Science*, *42*, 258-269.

Innovasjon Norge. (2003). *Årsrapport 2003.* https://www.innovasjonnorge.no/no/om/oppdrag-og-resultater/arsrapport2/arsrapport-2003/

IRENA. (2023). *Global landscape of renewable energy finance 2023.* https://www.irena.org/Publications/2023/Feb/Global-landscape-of-renewable-energy-finance-2023.

Klitkou, A., & Coenen, L. (2013). The emergence of the Norwegian solar photovoltaic industry in a regional perspective. *European Planning Studies*, *21*(11), 1796-1819.

Klitkou, A., & Godoe, H. (2013). The Norwegian PV manufacturing industry in a Triple Helix perspective. *Energy Policy*, *61*, 1586-1594.

Linneberg, M. S., & Korsgaard, S. (2019). Coding qualitative data: A synthesis guiding the novice. *Qualitative research journal*, *19*(3), 259-270.

Longhurst, R. (2010). Semi-structured Interviews and Focus Groups. In N. Clifford, S. French, & G. Valentine (Eds.), *Key Methods in Geography* (2nd ed., pp. 103-115). SAGE Publications Ltd.

MacKinnon, D., Dawley, S., Pike, A., & Cumbers, A. (2019). Rethinking path creation: A geographical political economy approach. *Economic geography*, *95*(2), 113-135.

Masson, G., Kaizuka, I. (2022). *Trends in Photovoltaic Applications 2022* (Report IEA PVPVS T1-43:2022). IEA. https://iea-pvps.org/trends_reports/trends-2022/

McKinsey&Co. (2022, December 13). *Rebuilding a competitive solar-PV supply chain in Europe*. https://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/building-a-competitive-solar-pv-supply-chain-in-europe.

NVE. (2023, May 26th). *Solkraft*. https://www.nve.no/energi/energisystem/solkraft/.

Nærings- og fiskeridepartementet. (2022, June 26th). *Veikart for grønt industriløft*. https://www.regjeringen.no/no/dokumenter/veikart-for-gront-industriloft/id2920286/

Ponte, S., Gereffi, G., & Raj-Reichert, G. (2019). *Handbook on Global Value Chains*. Edward Elgar Publishing. https://doi.org/10.4337/9781788113779

PV Magazine. (2022, September 10th). *The weekend read: What is the future of solar for ESG finance?* https://www.pv-magazine.com/2022/09/10/the-weekend-read-what-is-the-future-of-solar-for-esg-finance/?utm_source=dlvr.it&utm_medium=facebook.

Simson, K. (2022, March 31st). *Keynote Speech by Commissioner for Energy Kadri Simson at the Solar Power Summit*. European Commision. https://ec.europa.eu/commission/presscorner/detail/en/SPEECH_22_2405.

Solenergiklyngen (2020). *Veikart for den norske solkraftsbransjen mot 2030*. Sulsotech & Solenergiklyngen.

Steen, M., & Hansen, G. H. (2018). Barriers to path creation: The case of offshore wind power in Norway. *Economic geography*, *94*(2), 188-210.

Sun, H., Zhi, Q., Wang, Y., Yao, Q., & Su, J. (2014). China's solar photovoltaic industry development: The status quo, problems and approaches. *Applied energy*, *118*, 221-230.

Surana, K., & Anadon, L. D. (2015). Public policy and financial resource mobilization for wind energy in developing countries: A comparison of approaches and outcomes in China and India. *Global Environmental Change*, *35*, 340-359.

Tallaksrud, S. (2023, Mai 11). *Etter 100 år er det slutt - Norge er snart ferdig med kull.* Tekna Magasinet. https://www.tekna.no/magasinet/fra-kull-til-fornybar-energi/?fbclid=IwAR1jOgV4YG4HIAgEtG-rFQZzTytlkoLDJ7D8B7anabI-EhmZkzA7dcE69bg

Teknisk Ukeblad. (2018, January 5th). *Enova snur: Nå kan du få støtte til solceller på hytta.* https://www.tu.no/artikler/na-kan-du-fa-stotte-til-solceller-pa-hytta/438993

Verbič, M., Filipović, S., & Radovanović, M. (2017). Electricity prices and energy intensity in Europe. *Utilities Policy*, *47*, 58-68.

Xue, Y., Lindkvist, C. M., & Temeljotov-Salaj, A. (2021). Barriers and potential solutions to the diffusion of solar photovoltaics from the public-private-people partnership perspective–Case study of Norway. *Renewable and Sustainable Energy Reviews*, *137*, 110636.

Yeung, H. W.-c., & Coe, N. (2015). Toward a dynamic theory of global production networks. *Economic geography*, *91*(1), 29-58.

Zhang, F., & Gallagher, K. S. (2016). Innovation and technology transfer through global value chains: Evidence from China's PV industry. *Energy Policy*, *94*, 191-203.

NTNU

Norwegian University of
Science and Technology