Assessing The Norwegian Solar Industry.

The Role of Learning towards Solar Adoption in Norway

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Abstract

There is an urgent need for a more renewable energy source to reduce the effect of the greenhouse gas emissions in the world (EU 2010). This need for a renewable energy source as an alternative to fossil fuel has given rise to government incentives and subsidies in the solar industry in Norway. Amidst the subsidies, there are still challenges that have prevented optimal diffusion of the solar technology in Norway. For this reason, this study aims to examine the solar industry and to understand the underlying reasons behind the low solar technology diffusion in Norway.

There is a large body of literature on the role of R&D and Government incentives in stimulating the adoption and diffusion of solar in Norway. However, this project contributes to expound on the role of firms' action in stimulating solar adoption in Norway**.**

This study combines the learning curve theory and organizational learning theory as a framework for this project. The learning curve was used to assess the influence of experience on the performance of the firms while the organizational learning theory was used to explain how learning is likely to affect solar adoption. The study uses both a quantitative and qualitative research method to examine the past, the current state and the influence of learning on the future of the solar technology.

The results showed that there was no significant relationship between firms' experience and the firm's performance due to learning.

The study finally proposes that high performance in the firms alone is not enough to boost adoption unless other external problems are rectified. Thus, increased interaction between the firms and its environment is likely to result in better knowledge and understanding that will lead to increased solar adoption.

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1 Introduction

Energy use has been and continues to be a critical driver of economic growth, social development, and poverty reduction. Today, fossil fuels constitute about 80% of the world's energy use and is the largest contributor of green gas emissions(EU 2010). Emission issues have been the topic of huge debates on climate change, talks concerning cutting down energy use from fossil fuels and finding alternative means to generating electricity so as to reduce carbon footprints.

In 2007, the European Council adopted an ambitious energy and climate change goal for 2020. The objectives for 2020 were (a) to reduce greenhouse gas emissions by 20% (b) to increase the share of renewable energy to 20% and (c) a to make a 20% improvement in energy efficiency (EU 2010).

The International Energy Agency (IEA) is among those pioneering climate change policy. At a meeting in Paris, the IEA stated that some of the keys to achieving a low-carbon energy sector was to reshape investment and to accelerate innovation in low-carbon technologies (Hoeven 20 November 2014). This has led to actions and policies by various governments and countries to meet the stated targets to reduce greenhouse gas emissions.

This policy, as well as the shift to more renewable energy alternatives all over the world, has led to governmental programs and reforms that encourage people and companies to invest in renewable energy solutions. The use of subsidies is an example of such policies. Subsidies have lowered the entry barriers in the renewable energy market while at the same time enabling diversification for existing businesses. An example is the proliferation of electric vehicles in Norway.

The shift towards renewable alternatives like solar energy has been facilitated in Norway by government incentives coupled with the country's long history in silicon production(Energi21 September 2013). In the Norwegian market, there are two types of solar energy technology available; solar photovoltaics (PV) or solar electricity and solar thermal collectors or solar heating. Solar PV is a method of converting solar radiation into direct current electricity using semiconducting materials that exhibit the photovoltaic effect. Solar thermal collectors or solar heaters collect heat by absorbing sunlight.

As highlighted in the preceding paragraph, the Norwegian government through its renewable energy support organ - Enova - grants subsidies to both private and commercial consumers to facilitate solar energy adoption. Despite the subsidies, Norway has very low solar technology adoption compared to neighboring countries like Sweden, Denmark, and Germany as shown in Figure 1.0 below.

Solar energy in Norway

	Solar heaters (in 2012, IEA SHC)	Solar cells (in 2013, EPIA)	Total solar energy	Population (in 2012, IEA SHC)	W per inhabitant
Sweden	315 MW_{th}	40 MW	355 MW	9 573 256	37,1
Denmark	479 MW_{th}	548 MW	1 027 MW	5 543 453	185,3
Germany	11 809 MW_{th}	35 715 MW	47 524 MW	81 305 860	584,5
Norway	27,4 MW_{th}	~0 MW	27 MW	5 021 106	5,4

Figure 1.0 Comparison of Solar adoption in Norway to Germany, Sweden and Denmark (Sørensen 2015).

Despite Norway's present low installed solar capacity, there is a great potential for increased solar adoption. Norway has a strong research base that has been instrumental in production and manufacture of silicon, a raw material for solar PV production(Energi21 September 2013). There is an increasing activity and calls for collaboration by renewable energy networks whose functions are to disseminate information along the value chain. However, greater participation and collaboration among firms and other stakeholders is needed in a more practical way.

1.1 Research Problem

There are about 75 companies in the solar energy industry in Norway (Bjørn Thorud, personal communication April 21, 2016). Many of the companies operate primarily in Norway while some others operate in other countries as well. The main components for solar electricity are the solar cells[1] which make up the solar panels. The cost of solar cells or photovoltaic (PV)

[1] Solar cells are made of semiconductor materials and produce electricity when they are exposed to solar radiation.

cells have plummeted over the years from $4 in 2008 to about $0.5 cents in 2016(Aanesen, Heck et al. May 2012) & (email source).

This fall in prices has mainly been due to subsidies by governments especially China, who slashed down the prices to about 75% in order to dominate the market (Aanesen, Heck et al. May 2012). The lowered PV prices paved the way for many downstream operators like construction and installation companies to enter the market. Despite the price cuts, many firms are still struggling due to the high cost of investments and a low volume output(Merlet and Ruud November 2014). Subsidies are said to be unsustainable. Hence, there are speculations that the subsidies may stop(Reuters April 2015), and prices may even decline (Woody 2013). There is an urgent need for solar companies and other solar stakeholders, to improve business performance and position themselves to capture business profits as well as sustainably meet the rising energy demands.

1.2 Research Question

Learning is recognized as an important factor in organizational performance and evolves as experience is gained (Argote 2013). In other to examine the performance of the Norwegian solar firms, it is necessary to ask the following question

1. What is the relationship between the organization's experience and organizational learning?

This thesis will attempt to answer the principal research question above by investigating the following:

a. What is the relationship between firms' experience and the cost of installing solar solutions?
b. What is the relationship between the firm's experience and efficiency of the solar energy systems?
c. What is the relationship between firms' experience and the speed of installation?
d. What is the relationship between firms' patent stock and experience?
e. How will learning facilitate solar adoption?

1.3 Objective of the research

The aim of this research is two-fold:

i. assess the solar adoption in Norway to understand the underlying reasons behind low solar adoption.

ii. understand how learning in the industry will facilitate an increase in solar adoption.

The first step will be to understand the effect of organizational experience so far on firms' performance. The study will go further to investigate the reasons for the findings and ways for improvement.

This study focuses on what and how one element of the Norwegian solar ecosystem - the entrepreneurs - should overcome the socio-technical barriers facing solar adoption in the country. However, due to time constraints, this thesis will not investigate these concepts through the eyes of the consumers who install the solar systems nor will I consider the international market for some of these Norwegian solar firms.

1.4 Significance of the research

Studies have shown that learning improves future performance(Fiol and Lyles 1985). More so, Cost effectiveness, efficiency, and high technological knowledge have been seen to be indicators of performance(Argote 2013) Hence Increased learning in the firms and the industry will create an environment that will boost solar adoption and will determine how the individual firms differentiate to compete sustainably.

Furthermore, policy makers' broad knowledge of the industry, will result in regulations that are effective in stimulating competition and innovation across the value chain.

1.5 Thesis Structure

The thesis is presented in six chapters. Chapter 1 introduces the research topic and establishes the objectives and significance of the study. In Chapter 2, a detailed review of existing literature and the theoretical framework is presented. This chapter starts with the operationalization of the variables that will be encountered along the way. This will establish the basis for understanding the concepts used followed by a presentation and analysis of past works that relates to my approach to learning in solar energy firms. The theoretical framework presents the lens through which learning in the solar firms will be studied. Chapter 3 presents the methodology and the research design including the design approach, the unit of analysis, the rationale for the approach and the research timeline. In Chapter 4, the results are presented as well as a detailed analysis of the findings. Chapter 5 presents the discussions. Finally, Chapter 6 contains the conclusion, recommendations, and implications for further research.

2 Literature Review

2.1 Definitions of Organizational Learning.

Organizational learning has had different definitions over the years. It has been defined as a change in the range of potential behaviour (George P. Huber 1991); as the capacity of an organization to act competently (Pentland 1992); and as the process of improving actions through better knowledge and understanding (Fiol and Lyles 1985). Others have defined organizational learning include as the process of translating experience into knowledge (Argote and Miron-Spektor 2011), and as technical change as a function of learning derived from the accumulation of experiences in production (Arrow June 1962).

In this study, organizational learning is defined as the change in the organization's knowledge (improvement of actions through better knowledge and understanding) that occurs as a function of experience (Fiol and Lyles 1985). The above definition best aligns with the theoretical framework used in this study. The study framework theorizes that the internal actions of the organizations interacts with the organizational context to produce knowledge that enhances performance(Argote and Miron-Spektor 2011).

2.2 Measures of Organizational Learning

Extant literature has measured organizational learning in different ways. For instance, (Huff and Jenkins 2002) studied learning by measuring cognitions of organizational members in the firms. (Gherardi, Emberson et al. 2006) measured learning by the knowledge embedded in the practices and routines in the organization, (Rapping 1965) examined the relationship between cumulative output and the unit cost of production to assess whether organizational learning has occurred.

Similarly, in this study, learning will be measured by observing changes in the indicators of performance such as efficiency, speed (installation time), and reduction in cost (Dutton and Thomas 1984, Argote, Beckman et al. February 1990). Productivity gains were found to be derived from improvements in capital goods, labour skills, materials, engineering, and managerial expertise (Dutton and Thomas 1984). Likewise, (Lieberman 1987) indicated that the productivity gains stemmed from a variety of underlying sources, including improvements in capital equipment, improvements in product and process designs, and improved organizational and individual skills. (Arrow June 1962) formalized a model that explained the technical change as a function of learning derived from the accumulation of experience.

Knowledge is at this moment defined as the outcome of learning and can manifest itself in changes in cognitions or behaviour. Knowledge can vary from the explicit knowledge that can be articulated to the tacit knowledge that is difficult to articulate (Argote and Miron-Spektor 2011)

Cost is the present value of the total cost per produced or saved kilowatt hour (Sidelnikova, Weir et al. 2015). Cost in this study mostly reflects the cost of the solar cell modules such as procurement cost and BOS[2] cost.

Experience is defined as the process by which the firm as an entity increases its stock of know-how (Argote 2013). Cumulative output and age have been used in several literature as a proxy for experience. The aggregate measure - cumulative output - is preferable because the ventures have to juggle different activities some of which determine the input structure, the output mix, selling and financing techniques. All of which improve over time (Argote 2013).

Age will be used in this study as a proxy for experience because it requires time. (Barkai and Levhari 1973)

Table 2.0: Summary of definitions and measures of organizational learning.

Measurement of Organizational Learning	**Definitions of Organizational learning.**
By measuring cognitions of organizational member (Huff and Jenkins 2002).	As a change in the range of potential behaviours (George P. Huber 1991).
Knowledge embedded in practices or routines (Gherardi, Emberson et al. 2006).	The capacity of an organization to act competently (Pentland 1992).
Productivity gains (Barkai and Levhari 1973).	Organizational learning as a change in the organization’s knowledge that occurs as a function of experience (Fiol and Lyles 1985)

[2] BOS (Balance of System): components of a photovoltaic system other than the photovoltaic panels such as wiring, switches, a mounting systems, solar inverters, a battery bank and battery charger

Changes in characteristics of performance, such as its accuracy or speed which shows that knowledge was acquired (Dutton and Thomas 1984, Argote, Beckman et al. February 1990).	The process of improving actions through better knowledge and understanding (Fiol and Lyles 1985).
Patent stock and citation as a measure of knowledge flow (Park and Park 2006, Alca´cer and Gittelman 2006).	The process of translating experience into knowledge (Argote and Miron-Spektor 2011).
Quality as measured by complaints and defects (Argote 1993); service timeliness as measured by late products per unit (Argote 2000).	Technical change as a function of learning derived from the accumulation of experiences in production (Arrow June 1962).

Organizational learning as a change in the organization's knowledge that occurs as a function of experience has emerged to be the dominant definition (Fiol and Lyles 1985). Knowledge is seen as an outcome of learning and includes both declarative knowledge or facts and procedural knowledge or skills and routines. In most literature learning has been attributed to experience or practice. Learning is said to be adaptive if experience improves performance and maladaptive if experience impairs performance (Argote 2013).

2.3 The Learning Curve: A Tool for Assessing Learning.

The learning curves were first used by psychologists studying behaviours (Mazur & Hastie, 1978), but became the trend in strategic management during the 1960s and 1970s. It was promoted by management consultants and the US Government. Extant literature has adapted the learning curve approach to assessing empirically whether organizational behaviour has changed as a result of experience (Argote 2013).

The classic form of an organizational learning curve is AC = aK^-b

where **AC** is the average cost of the last unit produced (dependent variable),

a is the average cost of the 1st unit produced and

K is the cumulative activity level (independent variable,)

-b is the learning rate.

The basic principle underlying the learning curve is that production experience produces knowledge that improves productivity (Argote 2013).

The diagram below is an example of a learning curve showing the efficiency of crystalline PV from 1940 to 2000.

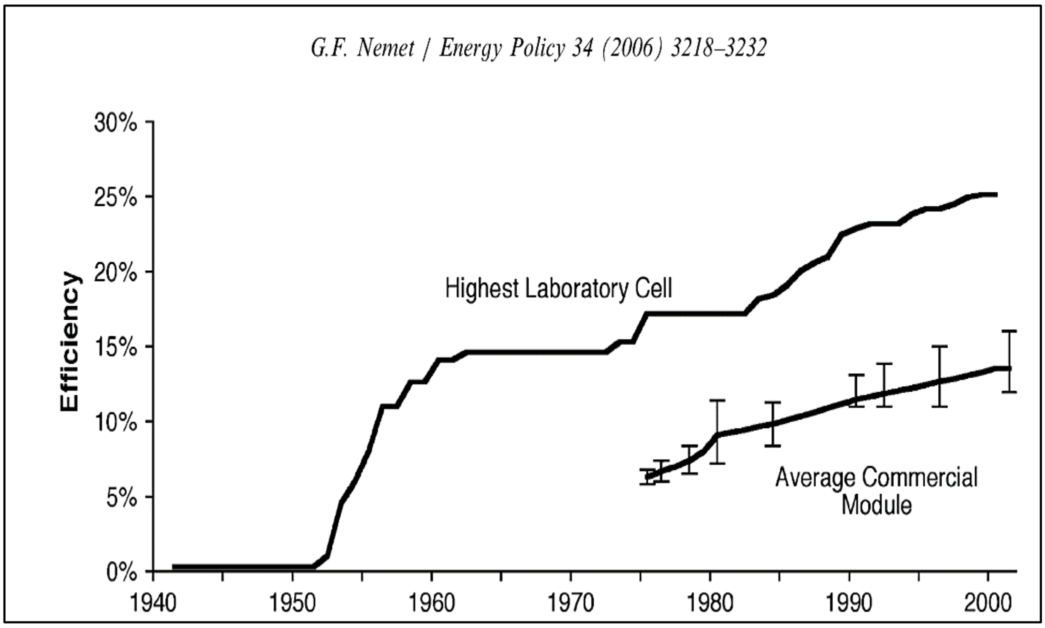


Figure 2.1: Crystalline PV efficiency: highest laboratory cells vs. average commercial modules (Nemet 2006)

The learning curve expresses that as experience is gained in performing a task, the number of mistakes reduce at a declining rate, and as organizations produce more of a particular product, the unit cost of production decreases at a declining rate (Argote 2013). The learning curve was originally applicable to labour intensive industries but (Dutton and Thomas 1984) argued that it can also explain learning in continuous process industries. There is no consensus on the use of the terms: learning curves, experience curves and progress curves. However, in some literature, these terms have been used to assess learning for the different levels of analysis; learning curve has been used for individual levels of analysis, progress curve for organizational level and experience curve for the industrial level of analysis (Argote 2013). The learning curve expresses that the average unit cost decreases when the cumulative production level increases (Wiersma Dec 2007). More so, the learning curve has been used to explain success rate, completion times and productivity in Kibbutz farming (Barkai and Levhari 1973).

Wright (1936) reported that the amount of labour it took to build an aircraft decreased exponentially as the total number of aircraft produced increased (Argote 2013). There is a greater tendency for learning curves to plateau (level off) in machine intensive industries and organizations (Baloff 1971).

A special form of the learning curve is Swanson's law or effect which is specific to the solar energy industry. Swanson's law states that with every doubling of production and shipment of solar panels, there has been a 20 percent reduction in the cost of panels (Swanson 2006).

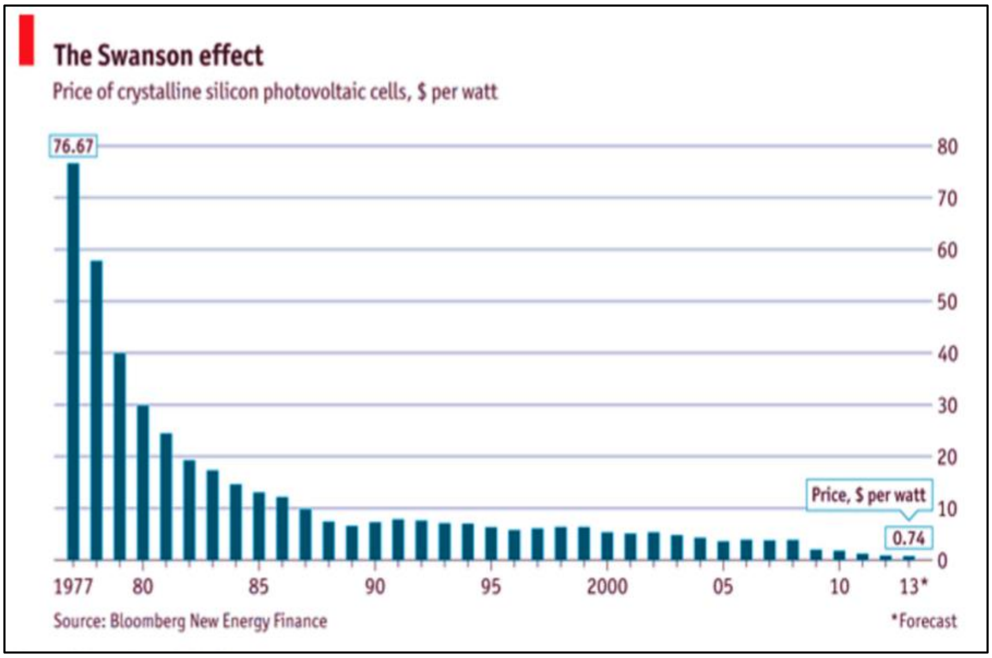


Figure 2.2: The Swanson effect on PV prices as published in the Economist in December 2013. Note that the price forecast for 2013 was $0.74/W. The prices today are around $0.5/W.

There has been observed differences in the rate at which industries and organizations learn (Dutton and Thomas 1984, Argote, Beckman et al. February 1990).

There are three basic factors that contribute to productivity due to experience:

i. increased proficiency of individuals including managers and engineers
ii. improvement in the Organization's technology.
iii. improvements of structures, routines and methods of coordination

Learning generally occurs by and through individuals in an organization. For organizational learning to occur, the individual has to deposit the knowledge in a repository such as a database, routine and transactive memory system (Argote and Miron-Spektor 2011) (Teece;, Pisano et al. 1997). The knowledge repositories allow knowledge to be preserved and accessible even when the original members are long gone.

The present study's approach to the learning curve and the choice of indicators of performance (speed, change in cost, and efficiency) is based on (Argote, Beckman et al. February 1990), (Argote 2013), (Dutton and Thomas 1984). These were indicators that could be measured through surveys and interviews rather than from observation. Also, the measures were relevant, measurable and suitable to the solar energy firms. Other measures like knowledge embedded in practices and routines were more abstract and require first hand observation and therefore was not measured in this study.

The learning curve approach is a suitable strategy used by managers, policy makers, firms and even start-up companies to assess opportunities and strategies for cost reduction. It is also used for planning and forecasting purposes (Argote 2013). One of the reasons for adopting the learning curve approach in this thesis was its relevance to start-up firms, established firms and policy makers alike. However, this study did not go further into the functional forms of the learning curves (AC = aK^-b) because that would require quantitative inferential analysis and the researcher had no access to the relevant data.

2.4 Government Regulations

There is a growing consensus in extant literature that intervention by national governments may be essential to effectively promote energy efficiency programs (Bird, Bolinger et al. 2005). Government can establish regulations relevant to the electricity market that favours renewable energy. Some of these regulations include R&D funding, demonstration grants, financial incentives (Zhai 2013) such as feed-in tariffs (FIT)[3]s also called renewable energy payments**,** extension of production tax credits for renewables and setting up markets for energy trading (Bird, Bolinger et al. 2005).

[3] Feed-in tariffs (FIT) is a policy mechanism designed to accelerate investment in renewable energy technologies by providing the producers a fee ("tariff") above the retail rate of electricity. The mechanism provides long-term contracts to renewable energy producers, typically based on the cost of generation of each technology.

Two types of financing approaches have been used to promote renewable energy in Europe. One is the so-called ‘market-based’ renewable obligation in the UK, which issues renewable energy generators ‘renewable obligation certificates’ (ROC) and requires electricity suppliers to supply a target portion of their electricity from renewables or suffer penalties. On the other hand, in places like Germany and Spain, the law requires that renewable energy generators are paid through a tariff[4]. The establishment of a market for ROCs will mean that suppliers will make an effort to purchase the cheapest ROCs, thus reducing the cost of fulfilling the ROC targets (Toke and Lauber 2007).

Nationalized low-interest loans and public financing has proven to be successful (Lewis and Wiser 2007). (Sovacool, 2009) explored the impediments and the favoured policy mechanisms for renewables and energy efficiency. In his study using semi-structured interviews of energy experts from 93 institutions, he found out a financial and market impediment of information dissemination. Producers did not distribute accurate or readily available information about renewable power projects. Another impediment was the regulatory and political barriers of bureaucracy. According to “Bigdeli 2008” changes in behaviour and significant greenhouse gas reductions will only happen if policy reforms include at least the removal of subsidies and more accurate electricity pricing (Sovacool 2009). He concludes that in many instances, advocates of certain policies substitute one for the other instead of seeing them as a piece of a whole. He argued that eliminating subsidies for conventional and mature electricity technologies, pricing electricity accurately, passing a nationwide feed-in tariff, and implementing a national systems benefit fund to raise public awareness as well as protecting lower income households and administering demand side management programs should all be implemented as a comprehensive whole rather than in isolation.

Comments on Government Regulations

Sovacool’s methodology was quite interesting in that the interview participants spanned across North America, Europe and Asia and this was conducted as a longitudinal study for three years. (Sovacool 2009) was able to acquire an overview of the existing and reliable policies because of his approach. However, it might be theoretically possible to implement those policies as a “whole” but might not be practical. He did not take cognizance of the individual continent’s

[4] An electricity tariff is the price unit at which electricity is sold and it is measured in rate per kilowatt hour of power consumed (kWh).

context which might be different from the other continents and might have a huge impact on the comprehensive implementation of the policies. I will argue that there are assumptions and environmental factors that govern every country which intensifies and gets compounded as it broadens out and therefore restricts flexibility.

Is Germany a Success?

Germany's Renewable Energy Sources Act (EEG) is widely considered to be very successful in terms of increasing the share of ‘‘green’’ electricity in the total energy mix and has thus been adopted by numerous other countries (Frondel, Ritter et al. 2008). Under the law set by the EEG in April 2000, utilities were obliged to accept the delivery of power from independent producers of renewable electricity into their own grid, thereby paying technology-specific feed-in tariffs far above own production cost. Since then, the share of renewable energy in total electricity production has increased from about 6% in 2000 to roughly 14% in 2007, while the annual amount of feed-in tariffs has grown eightfold, to 7.4 billion euros.

Despite huge promotions of the PVs through subsidizations, there was no significant positive impact on the climate and employment in Germany (Frondel, Ritter et al. 2008). The authors argue that subsidization of PV solar electricity has long-lasting financial consequences as it imposes a substantial drain on the budgets of private and industrial consumers, which leads funds away from alternative, possibly more beneficial investments. Any assessment of the real cost induced by subsidizing PV requires information on the volume of PV electricity generation, feed-in tariffs, and conventional electricity prices. They further proposed that from an environmental perspective, it would be much more economically efficient to achieve reductions in greenhouse gas emissions via the EU's Emission Trading Scheme (ETS), rather than by subsidizing PV. After all, it is for efficiency reasons that emissions trading is among the most preferred policy instruments for the reduction of greenhouse gases in economics literature. Therefore, what the EEG has effectively done was just a shift rather than a reduction of greenhouse gas emission.

2.5 Knowledge Requirements in Solar Energy Firms.

1. Effect of proximity to solar adoption areas.

In an empirical study of the diffusion of Photovoltaic (PV) systems, we find that smaller centres contribute to adoption more than larger urban areas (Graziano and Gillingham 2014). Their empirical study showed a strong relationship between adoption and the number of nearby previously installed systems, hence neighbour effects dissipate over time and space. Using a large dataset of PV system adoptions in California, they showed that one additional previous installation in a postal code area increases the probability of a new adoption in that postal code by 0.78%. They further found evidence of even stronger neighbour effects at the street level within a postal code. In a similar vein, Muller & Rode found a clear statistically significant relationship between previous nearby adoptions that diminish with distance (Graziano and Gillingham 2014).

2. Goal Oriented awareness programmes.

In a study conducted by (Abrahamse, Steg et al. 2007) to examine the effect of intervention on the consumption of energy, argues that since households contribute a significant amount of greenhouse gas emissions to the environment, targeting energy-related behaviours at home would result in a reduction in the households' impact to the environment. According to (Abrahamse, Steg et al. 2007), US households account for 21% of greenhouse gas emissions in their country, households in the UK for 15%, and households in the Netherlands for 17%.

Their suggested intervention included tailored information, individual goal setting and tailored feedback to households for efficient energy consumption behaviours. Although there had been previous interventions, they rarely incorporated these three measures simultaneously. Interventions work better when used in combination Gardner & Stern, 2002 (as cited in (Abrahamse, Steg et al. 2007)), because different households are prevented from action by different barriers. Providing the information alone was not sufficient as knowledge did not increase in the participant households. However, simultaneously combining tailored information, individual goal setting and tailored feedback, resulted in a significant observable reduction in energy consumption in the households. The study further examined the effect of group goal setting and group feedback. According to "Hutton et al., 1986", feedback has been seen to be an effective strategy for energy conservation (Abrahamse, Steg et al. 2007). It is especially effective when it is frequently given. When feedback is given about own energy savings, households can observe the effectiveness of their efforts to conserve energy. Feedback can also be given about energy savings of other people which could be used as a comparative or group feedback. Group feedbacks make salient a social norm in favour of energy conservation; it becomes clear that others are actively engaged in energy conservation as well as an important contribution to reducing energy-related problems. In effect (Abrahamse, Steg et al. 2007) argued that if the aim is to effectively encourage households to conserve energy, then it is necessary to examine changes in energy use, energy-related behaviours, and behavioural antecedents. The result of the experiment on a sample of 189 households after a five-month study, showed that households in the experimental group had reduced their energy consumption by 5.1%. On average households who received the combined interventions reduced energy use by 5.0% and households who also received a group goal and group feedback reduced their energy use by 5.3%. In contrast, the households in the control group used 0.7% more energy.

The researcher thinks it is remarkable from the study (Abrahamse, Steg et al. 2007) that it is not enough to just provide information, in other words, knowledge may increase but may not necessarily lead to an improved action. Providing information that is streamlined to the expected goal, and demanding commitment on the part of the consumers to perform tasks or to undertake a promise facilitates the learning process. Also, implementing strategies by using tools geared towards regular and frequent feedbacks ensures that the knowledge acquired will result in a change in behaviour.

From the results, the combination of the interventions (tailored information, individual goal setting and tailored feedback) obviously worked. However, I am not certain that five months was enough to produce a lasting change in the energy habits of the participating households. It is quite possible that the participants used energy differently during the study period because of their awareness of the ongoing research.

According to the above observation, two things could have done differently in the cited study. Firstly, the study could have been conducted over a longer period. This is to ensure that energy behaviours that are learnt over a long period lead to a more energy efficient habit. Secondly, the researchers could have gone back to investigate the energy behaviour of the experimental group after several months (say after 3 or 6 months) to observe the effect of their intervention. Obviously, the study shows the immediate effect of the interventions but does not show if households continued with energy conserving practices after the study.

2.6 Effects of Experience on Production Cost

Building on the definition of learning as a technical change due to experience, (Nemet 2006) sought to understand the drivers behind technical change in PV[5] systems. He utilized empirical data from the period 1975 to 2001 to understand the mechanisms linking factors such as cumulative capacity and R&D. The analysis began by identifying factors that changed over time and had some impact on PV costs. These factors included, (i) module efficiency, (ii) plant size, (iii) yield, (iv) polycrystalline share, (v) silicon cost, (vi) silicon consumption and (vii) wafer size.

The study showed that plant size, cell efficiency, and to a lesser extent, the cost of silicon were most important in explaining the cost declines from 1975 – 2001. However, the seven factors together explain less than 60% of the change in cost over the period. In other words, there were aspects of PV costs that were not captured or explainable by the cumulative output.

Experience curves are based on the theory that experience creates opportunities for firms to reduce costs. Indeed, in the case of PV, cumulative capacity is a strong predictor of cost (Nemet 2006). Overall, the ‘‘learning’’ and ‘‘experience’’ aspects of cumulative production do not appear to have been major factors in enabling firms to reduce the cost of PV systems, which is the assumption underlying the experience curve model. Examples from three PV firms in Nemet’s study indicated that limited manufacturing experience did not preclude rapid increases in production.

Comment on The Effect of Experience on Cost

This thesis is related to the study by (Nemet 2006) in the sense that both examine the extent to which experience (cumulative output) lead to changes in the cost of the PV. Nemet (2006) show that learning derived from experience is only one of several explanations for the reductions in PV cost. There could be other factors not explained by experience. This is very important and illustrates the fact that care should be taken when using experience or learning curves for planning and forecasting purposes, as is being done in strategic management today (Dutton and

[5] **Photovoltaics** (**PV**) is a method of converting solar energy into direct current electricity using semiconducting materials that exhibit the photovoltaic effect.

Thomas 1984). Hence, it is very crucial to consider the underlying conditions when we use experience curves to predict technical change.

One criticism by the present researcher of the existing literature in learning curve is the lack of congruency in the exact function of the learning curve. There is still a fine line of misunderstanding in its usage. For instance, Arrow (1962) says that the basic principle underlying the learning curve is that production experience creates knowledge that improves productivity while other writers posit that the learning curve approach does not assume that behaviour changes as a result of experience but examines whether behaviour changes as a result of experience (Argote 2013).

2.7 Effect of Research and Development on Cost

Funding R&D in order to trigger significant technology improvements appears to be a more promising avenue to efficiently achieve substantial cost reductions in early technology stages. This can be better than the heavy subsidization of market penetration, a policy alternative where technological improvements are rather by-products. For instance, on Germany's energy policy, the International Energy Agency recommends considering ''*policies other than the very high feed-in tariffs to promote solar photovoltaics*'' (IEA, 2007, p. 77). This recommendation is based on the grounds that *''the government should always keep cost-effectiveness as a critical component when deciding between policies and measures''* (IEA, 2007, p. 76). Consequently, the IEA proposes policy instruments favouring research and development.

2.8 Industry and Marketplace Communication

The emergence and use of internet-based social media have made it possible for one person to communicate with hundreds or even thousands of other people about products and the companies that provide them. Thus, the impact of consumer-to-consumer communications has been greatly magnified in the marketplace. Integrated marketing communications (IMC[6]) is the

[6] Integrated marketing communications (IMC) attempts to coordinate and control the various elements of the promotional mix——advertising, personal selling, public relations, publicity, direct marketing, and sales promotion——to produce a unified customer-focused message and, therefore, achieve various organizational objectives.

guiding principle organizations follow to communicate with their target markets (Mangold and Faulds 2009).

Tools and strategies for communicating to consumers are changing especially with the emergence of social media or customer generated media. Social media enables companies to talk to their customers, as well as enables customers to talk to one another. Social media also enables customers to talk to companies.

The intent is consumers educating each other about products, brands, services, personalities, and issues (Mangold and Faulds 2009). Some of the social media outlets include blogs, discussion boards, e-mail, consumer product or service ratings websites, moblogs (sites containing digital audio, images, movies, or photographs and social networking websites). These media have been instrumental in influencing various aspects of consumer behaviour including awareness, information dissemination, opinions, purchase behaviour, and post-purchase communication and evaluation. However, the popular business press and academic literature offer marketing managers very little guidance for incorporating social media into their IMC strategies.

Comments on Industry and Marketplace Communication

Communication and information dissemination is central to consumers and other solar stakeholders' awareness level**.** The adoption of adequate and effective utilization of communication tools will facilitate solar technology awareness in the society and eventually speed up customer acquisition, as well as enhanced product offerings. According to (Gillin 2008)''*Conventional marketing wisdom which has long held that a dissatisfied customer tells ten people is now outdated. Instead, in the new age of social media, he or she has the tools to tell 10 million consumers virtually overnight*". This method is unique because of the magnitude of the communication and its capabilities of a global reach. Every firm and government policy maker should look for ways to harness the power of social media for their good.

2.9 Theoretical Framework

2.9.1 Problem Statement

Most of the industrial players in Norway's solar energy sector are located in the downstream segment. About 60% of the firms are in the installation segment of the value chain(Energi21 September 2013). This is represented schematically in Figure 3.0 below.

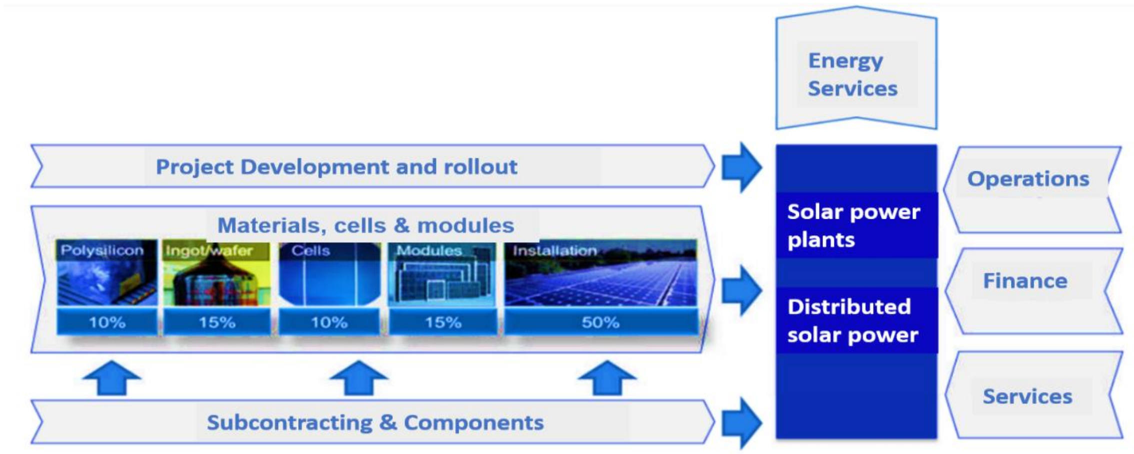


Figure 3.0: Schematic representation of the value chain solar cells and associated business. The proportion that is related to installation (BOS) is currently high and is at 60%. There are cost pressures throughout the chain, and the relative distribution is continually changing. Modified from (Energi21 September 2013).

The industry has seen a steady fall in the price of solar PV systems from about $4 in 2005 to about $0.5 in 2016 (Aanesen, Heck et al. May 2012). This has led to the consolidation of several upstream firms. For instance, REC Wafer – which used to be the largest manufacture of multi-crystalline wafers worldwide - declared bankruptcy in 2012 and laid off 1000-1500 employees in Norway. Similarly, the Norwegian arm of SiC Processing which was one of the biggest suppliers to REC Wafer also went bankrupt same year due to price pressure(Bugge May 2013). However, the decline in prices led to the birth of many downstream firms. Despite this seemingly good news for firms in the downstream segment, there are many challenges for these businesses in Norway such as:

i. The high costs associated with installing solar systems compared to neighbouring countries (Sørensen March 2015) pg14.
ii. The considerable amount of time that goes into acquiring and educating customers.
iii. There are low volumes of installation output as a result of strong competition for new customers.

iv. There is a lack of standardizations and clear rules concerning solar energy producers who want to connect to the grid systems.

Although there is an overall low output yield in Norway, it can be argued that older firms should be better able to mitigate the high cost and efficiency challenges that exist in the industry because of their experience. Hence this study will seek to investigate four hypotheses as laid out in section 2.9.2 below.

2.9.2 Hypothesis

H1: There is a negative relationship between a firm's experience and installation cost.

H2: There is a positive relationship between experience of the firms and the efficiency of the modules.

H3: There is a negative relationship between firms' experience and the speed in PV installation.

H4: There is a positive relationship between experience and patent stock.

2.9.3 Model

According to the organizational learning framework, the organizational experience is theorized to interact with the organizational context to create knowledge (Argote and Miron-Spektor 2011).

This framework seeks to show that organizational learning occurs in a context, which includes the organization and the external environment in which the organization is embedded. The environmental context includes elements outside the boundaries of the organization (Argote 2013) such as its structure, culture, technology, identity, memory, goals, incentives, and strategy. In this case, organizational context include educational and research institutions, the regulators, solar energy networks and forums, financial investors, advisers and consultants and other competitors. This is represented schematically in Figure 3.1 below.

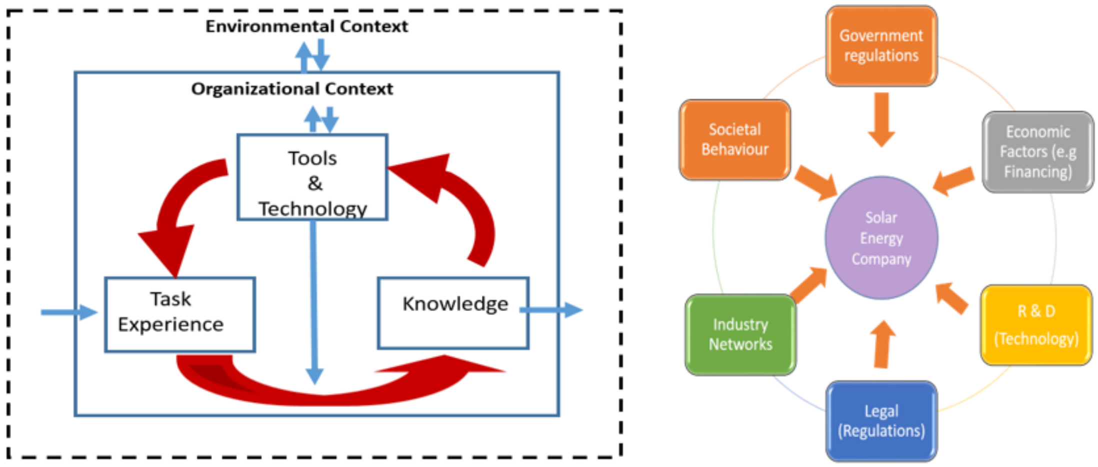


Figure 3.1: Schematic of the interaction of the firms and the organizational context. Modified from (Argote 2013).

This conceptualisation builds on the framework that the core elements of organizations are members, tools & tasks, and the networks formed by across these elements.

2.9.4 Rationale

For organizations to grow and survive, they need to align with their environment to innovate and compete effectively "Barnard, 1938" as cited in (Fiol and Lyles 1985). Hence, when firms learn, they generate knowledge which encourages the growth of industrial concentration and affects the structure of the domestic industry (Dasgupta and Stiglitz 1988).

3 Methodology

3.1 Approach

This study takes on a deductive approach and applies the well-known theory of the learning curve. This theory postulates that as organizations gain experience, their performance improves. Also, the study will employ the organizational learning framework which proposes that learning in firms occurs in an environmental context, in other words, organizational experience interacts with the organizational context to create knowledge (Argote and Miron-Spektor 2011).

3.2 Research Philosophy

Due to the nature of the research questions and the study objectives, the research philosophy adopted is partly a positivist one involving an empirical study. This philosophy requires moving from theory (Learning curve) to observing the relationship between experience and the indicators of performance in the firms (Wilson 2010). At the same time, taking on an interpretive stance to analyse the social activities and interactions of the solar industry players within their cultural setting (Wilson 2010). The approach adopted here should elicit an understanding of the underlying reasons behind low market scale.

3.3 Research Strategy

The research is a combination of a **qualitative** and **quantitative analysis**. It is partly qualitative for the purpose that the study seeks to understand how the entrepreneur's knowledge change is likely to increase solar market scale. On the other hand, a quantitative approach is necessary to test the age long theory of the learning curve on the research sample. Learning curve data exists for the solar industry in Norway. However, industry data is filled with aggregates of different factors and may have been collected for a different purpose other than that addressed by this research study (Wilson 2010).

3.4 Research Design

3.4.1 Descriptive Research

According to (Wilson 2010 page 104), descriptive research typically (a) uses ‘what’ and ‘how’ questions to describe existing or past phenomenon, (b) can be either qualitative or quantitative, (c) are often preliminary studies that lead to further research and (d) can be used to provide accurate information and help to form the basis of decision making.

The descriptive design was considered to be an appropriate method to observe the learning curve because learning (knowledge change) tends to evolve over time. Predicted learning curves change as events change but at the same time gives an indication of the stage of a technology adoption as well as predicts its future. To this end, this method seems to be appropriate as it can be used for planning and gives a basis for future decision makin g(Dutton and Thomas 1984). The descriptive research will hereby be conducted in a correlational context to find the relationship between experience and organizational learning.

3.4.2 Research Design Type

The data collection for this study follows the cross-sectional design method. This method involves (1) data collection from a number of cases, and (2) data collection at a single point in time (Wilson 2010).

Consequently, the data for this research were collected from different firms in Norway at a single time. The firms span across the solar value chain. One of the limitations of this method though was the inability to conduct the research over an extended period of time. A longitudinal design would have been most appropriate for the study but for time constraints, the cross-sectional design was more feasible.

3.4.3 Unit of Analysis

The unit of analysis is the solar energy companies in relation to their external context.

3.4.4 Reason for the chosen research design

The rationale for choosing a descriptive design that employs both cross-sectional data collection and unstructured interviews was because of the nature of the research questions. Secondly, there is the need for data triangulation which can be achieved by scanning the industry to understand the effect of experience on the firms’ performance and an understanding of the interaction of the firms. This approach is better illustrated by the diagram below.

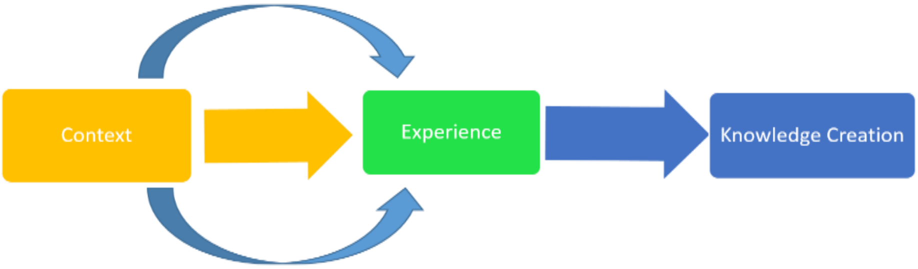


Figure 4.1: A simplified view of the interaction between the firms and the organizational context.

Figure 4.1 above shows that the actions and tasks of the firms generate a certain kind of knowledge which in turn affects the its's environment. In other words, the actions of the firms affect the industry and vice versa.

3.4.5 Timeline

Table 4.0 showing the dates the primary data were collected.

Activity	**Timeline**
Business development and IPR Workshop	24th Nov 2016.
Solar Energy workshop	13th January 2016
1st Interview	29th January 2016
2nd Interview	2nd Feb 2016
Green capital Seminar	9th March
Sent Survey	16th March
Final Reminder	29th March
Interview with Kube energy	7th April
Interview with Jon	8th April 2016
Interview with IFE	12th April
Interview with Multi Consult	21st April

3.5 Research Method

3.5.1 Data Collection

Before proceeding to explain the data collection process, it is imperative to define some of the terms used in this context.

- Norwegian solar energy companies are defined as those companies established in Norway but may also operate outside Norway. They include companies whose primary business is solar electricity, solar heating or both as well as related R&D entities, solar technology financing firms and related law firms (Thorud B, Personal communication April 21, 2016).

- The population of solar energy companies in Norway is officially about 75 with around 1000 employees. The criteria for defining the staff strength is the number of full-time positions related to solar energy in this firms.

The term '**officially**' is used internationally in the definition of the population above to exclude firms with only a very small section of their business devoted to solar energy (Thorud B. April 21, 2016). Similarly, some firms without a website were not included in Multiconsult's classification of solar energy companies.

- Employees: The employees are the number of staff that pay tax to the Norwegian government. This does not include employees who work for Norwegian solar firms outside the country.

3.5.2 Data Collection Instruments.

Initial Interviews

After reading several relevant literature, the researcher interviewed two solar energy firms with four year's and six years' experience respectively. One of the firms provided services ranging from project planning to installation of solar panels for electricity generation. The second company with six years' experience focused on the solar heating segment. The company (six years old) had a patent on a solar technology developed for heating water and buildings.

This interview was semi-structured with some initial guiding questions. However, the researcher used the responsse and discussions to determine subsequent questions.

Network Meetings and forums

In addition to the interviews, the researcher attended a number of solar industrial networking forums which function to facilitate knowledge sharing and understanding of the environmental context in Norway's solar industry. In attendance, were financial investors such Innovation

Norway, solar business advisors and consultants, researchers and entrepreneurs. One of the things highlighted was the importance of a good business model in securing investment.

Survey

The researcher used a survey after the initial interviews to measure the dependent variables (speed, efficiency, cost) and the independent variable (experience). The age of the firms was used as a proxy for experience. The survey instrument was designed and sent to the email list of contacts received from the Oslo Renewable Energy and Environmental Cluster (OREEC) in addition to the email lists from the Solar Energy Association (Norsk Solenergiforegning).

The survey were sent out to 101 email addresses representing 101 companies and received a total of 37 responses.

Second Phase Interviews

The responses from the survey elicited a second phase interview to fine tune the data collected. There was a need for clarifications on some technical questions such as efficiency of the solar panels, an explanation of the capacity and yield of solar systems. For the purpose of anonymity, the names of the firms and specific information of the firms are omitted.

Table 4.1 Lists of firms interviewed after the survey.

Interviewee	Value Chain	Position of Interviewee	Age of Company	Duration
A	Solar Leasing	CEO	1 year	1 hr
B	Solar mirroring	Founder	Prototype testing	1 hr
C	R & D	Centre Director	1948	1 hr
D	Consulting	Senior Advisor	Nil	1 hr

The first two interviewees in Table 4.2 represent firms at the start-up phase. They were Norwegian firms focused on the international market right from the beginning.

The choice for these interviewees was due to their seemingly odd position compared to the other companies. They were both based in Norway but focus their operations abroad. The researcher was curious to know why they chose Norway as a base when their projectsare in Africa for example.

The interviews with the R&D organization and the consulting firm yielded an in-depth understanding of the organizational context. Issues discussed related to the effect of PV cost and installation cost on the industry players. The knowledge of efficiency of solar technology and processes was better captured through an interview rather than a survey. Other factors discussed included the major costs incurred in setting up and installing solar panels/solar heaters, the ease of acquiring capital and nearness to the Norwegian regulating /policy makers. This will be covered in more detail in the discussion chapter.

Email Correspondence

The researcher intermittently sent emails to some of the survey respondents who signified their willingness in answering further questions.

3.6 Sample Description

The setting is solar energy firms in Norway as defined in section 3.5.1 above. All samples were collected from a solar energy network site. The samples were not based on regions as there were no significant regional differences. The Norwegian state is an institutional context that equally affects all the companies irrespective of the region.

3.6.1 Business Areas.

Table 4.2. Distribution of survey sample into solar energy business areas.

Business area of sampled firms	Frequency	Percent
Solar Electricity	16	43.2
Solar Heating	2	5.4
DSO	2	5.4
Both	12	32.4
Other	5	13.5
Total	**37**	**100**

Table 4.2 above shows the distribution of the 37 solar energy companies sampled. 43% of the sample are into solar electricity alone, 5% focus on solar heating alone, 32% offer both solar heating & solar electricity, distribution system operators (DSO) constitute about 5% and others (R&D, financial advisors, legal advisors) 14%. In effect, 75% of the respondents have experience with solar electricity, while 37% had experience with solar heating.

3.6.2 Age

Table 4.3 Description of the firms' age (proxy for Experience)

Age of sampled firms (years)	Frequency	Percent
0-6	18	48.6
7-12	9	24.3
13-18	4	10.8
19-24	1	2.7
25-50	3	8.1
51 & above	2	5.4
Total	**37**	**100**

Table 4.3 above shows that the sample constitutes firms with experience from 0 to above 51 years. About 49% of the companies in the sample are between 0-6 years, followed by 24% percent between 7-12 years, 11% between 13- 18 years, 3% between 19-24 years, 8% of companies were between 25-50 years and 5% of the firms were above 51 years.

The above distribution show that the industry is still in its early phase and suitable for studying the learning rate. According to (Wiersma Dec 2007) learning rate is appropriate to study in firms in the early stages of the learning curves where processes can be redesigned, and slacks can be cut from inefficient processes.

3.6.3 Value Chain representation

Table 4.4 below is a representation of the firms in the downstream segment of the value chain. The value chain includes turnkey, consultants and advisory, construction and installers, design and architects and others (energy companies who distribute produced solar electricity through the grid system). The installation and construction firms are most represented in the value chain.

Table 4.4: The value chain representation

Position in Value Chain	Frequency	Percent
Turnkey	5	13.5
Advisor & Turnkey	6	16.2
Supplier	2	5.4
Design/Architect	2	5.4
Advisor & Consultants	5	13.5

Construction & Installation	10	27
Other	7	18.9
Total	**37**	**100**

3.6.4 Company Size

Tables 4.5: Distribution of company size (number of employees).

Number of Employees	Frequency	Percent
0-4	18	48.6
5-15	4	10.8
16-30	3	8.1
61-100	2	5.4
101-500	9	24.3
Above 500	1	2.7
Total	**37**	**100**

Table 4.5 above shows the distribution of the company sizes. 49% of the companies had between 0 to 4 employees, 11% had 5 to 15 employees, 8% had 16 to 30 employees, none of the firms size was between 31 to 60 employees, 5% had 61 to 100 employees, 24% had 101 to 500 employees , and 3% of the firms had more than 500 employees.

3.6.5 Summary of the Sample Description

From the descriptive above, it was evident that the Norwegian solar industry consist of more companies towards the downstream than the upstream segment. The industry is still young with most of the firms below thirteen years of age. The firms are small sized with few employees working there. However about 24% of the firms have staff strength between 100 and 500 which are probably firms who had diversified from other businesses into solar.

3.7 Survey Preparation

A common challenge with students and data collection is low response rates from the sample population. The survey was prepared to mitigate that problem. Hence, most of the questions were multiple choices instead of free text. Questions were asked based on relevant knowledge from literature and industry practice. This approach facilitated a good response rate of about 37%. However, due to the nature of the variables under study such as cumulative output/volumes, change in labour costs and change in PV costs, the survey was inefficient in collecting all the relevant data.

3.8 Limitations of the study

The learning curve seeks to assess whether the average cost per unit produced decreases when the cumulative production level increases (Wiersma Dec 2007). Ideally, since experience is observed or occurs in the firms as an ongoing process, production and cumulative output should be used as the standard measure of experience rather than age (Rapping 1965). However due to time constraints and data sensitivity constraints, the researcher had no access to cumulative output data from the firms other than the industry data that included many aggregates and assumptions. Also, the industry is quite young in Norway as is evidenced by the age of the firms in the study sample. As a result, there might not have been an observable impact of any knowledge change since inception (Fiol and Lyles 1985).

3.8.1 Reliability

Reliability concerns the extent to which a measurement of a phenomenon provides stable and consistent results as well as the possibility for repeatability (Wilson 2010). A possible threat to this study is the possibility that the surveys might not have been answered by the appropriate persons in the firms. Another threat was the inaccessibility to some of the industry players. It would have been enlightening to interview some more entrepreneurs like those within the utility and grid business and those in the upstream segment. Most of the firms' representatives were very busy so were unavailable for interviews.

Furthermore, there were missing data from some respondents as some of the needed data (cumulative volumes of sales, cumulative output, labour costs, price costs) were sensitive company data. Finally, the use of the cross-sectional research design instead of a longitudinal design is a factor when considering the reliability of this work.

3.8.2 Validity

Validity is concerned with measuring what one intends to measure (Wilson 2010). In other words, the relationship between the construct and its indicators. Previous studies have used the learning curve to examine the relationship between experience and learning outcomes in firms. Performance characteristics (such as rate of change of costs, efficiency and speed or service timeliness), patents and profitability have been used by extant literature to measure learning, as was also done in this study.

3.8.3 Data Triangulation

The current research employed various means available such as interviews, surveys, emails, personal attendance at seminars and discussion forums. The researcher also spoke to various players such as representatives from installation companies, consulting firms, R&D firms, and financial investors.

4 Analysis & Findings

4.1 Data Analysis

4.1.1 Operationalization and Measurements.

In this section, the analysis of the survey results is presented and begins with refreshing the definitions of some relevant terminology.

Organizational learning is defined as the change in the organization's knowledge (improvement of actions through better knowledge and understanding) that occurs as a function of experience (Fiol and Lyles 1985)

The survey questions were designed to provide data for assessing two different measures of organizational learning as described below:

Measure 1. Changes in performance of a firm such as its cost, efficiency or speed which shows that knowledge was acquired (Dutton and Thomas 1984, Argote, Beckman et al. February 1990)
Measure 2. The collection of patent stock (Alca´cer and Gittelman 2006), (Park and Park 2006)

4.1.2 Research Questions

Below is a reminder of the research questions which the survey was designed to help answer.

Question 1: What is the relationship between a firm's experience and organizational learning?

i. What is the relationship between experience and the cost of installing solar PV?

ii. What is the relationship between firms' experience and efficiency of the solar systems?

iii. What is the relationship between firms' experience and the speed of installation?

iv. What is the relationship between firms' experience and their patent stock?

The statistical tool SPSS was used for the quantitative part of the analysis. The dependent variable, ***organizational learning*** was measured by indicators of performance such as changes in ***speed, efficiency, and cost (Argote 2013).*** The Independent variable, ***experience*** is defined as the process by which the firm increases its stock of know-how (Barkai and Levhari 1973). The acquisition of experience requires time or its proxies such as cumulated investment or cumulated output. Thus, experience was here measured by age.

Age measures the impact of time on the entity as an economic or social organism (Barkai and Levhari 1973).

Presentation of the Analysis.

Experience (independent variable) was correlated with each of the measures of organizational learning: speed, cost, efficiency and patent stock.

1a. What is the relationship between experience and PV cost?

Q11b: On average what percentage of your revenue is cost			
Range	**Frequency**	**Percent**	**Valid Percent**
<10%	1	2.7	4.3
10-25%	1	2.7	4.3
26-50%	4	10.8	17.4
51-75%	7	18.9	30.4
76-100%	10	27.0	43.5
Total Valid	23	62.2	100
No answer	14	37.8	
Total	**37**	**100**	

		3. How many years of experience does your company have in this	**11b. On average what percentage of your revenue is cost?**
3. How many years of experience does your company have in this business area.	Pearson Correlation	1	-0.085
	Sig. (2-tailed)		0.701
	N	37	23
11b. On average what percentage of your revenue is cost?	Pearson Correlation	-0.085	1
	Sig. (2-tailed)	0.701	
	N	23	23

Figure 5.0: The correlation between Experience and the % of revenue that is cost.

Figure 5.0 shows a weak negative correlation between the age of the firms and the percentage of their revenue that was cost. This means that the age of the firms has no influence on cost percentage.

Finding 1: There is no relationship between age and percentage of revenue that is a cost for the solar energy firms.

1b. What is the relationship between experience and efficiency of the solar panels?

Alternatively, efficiency (here measured as energy capacity) versus Age

		3. How many years of experience does your company have in this	9c. On average, how much energy (KWh) does 1 meter squared of your installed solar panels produce?
3. How many years of experience does your company have in this	Pearson Coefficient	1	-0.024
	Sig. (2-tailed)		0.947
	N	37	10
9c. On average, how much energy (KWh) does 1 meter squared of your installed solar panels produce?	Correlation Coefficient	-0.024	1
	Sig. (2-tailed)	0.947	
	N	10	10

Figure 5.1: The relationship between Experience and Efficiency

Figure 5.1 above shows a weak relationship between the age of the firms and the energy yield of installed panels. Also, the relationship is not statistically significant based on the Pearson coefficient.

Finding 2: There is no relationship between firms' age and the energy yield of the solar panels.

1c. What is the relationship between experience and speed?

(Speed is here measured by completion/installation time (Argote 2013))

Correlations

			3. How many years of experience does your company have in this business area.	9b. Approximately how long does it take your company to install 5 meter squared solar panels? (hr)
Spearman's rho	3. How many years of experience does your company have in this business area.	Correlation Coefficient	1.000	-.892**
		Sig. (2-tailed)	.	.001
		N	37	10
	9b. Approximately how long does it take your company to install 5 meter squared solar panels? (hr)	Correlation Coefficient	-.892**	1.000
		Sig. (2-tailed)	.001	.
		N	10	10

**. Correlation is significant at the 0.01 level (2-tailed).

		3. How many years of experience does your company have in this Business area.	9b. Approximately how long does it take your company to install 5 meter squared solar panels? (hr)
3. How many years of experience does your company have in this Business area.	Pearson Correlation	1	-0.550
	Sig. (2-tailed)		0.100
	N	37	10
9b. Approximately how long does it take your company to install 5 meter squared solar panels? (hr).	Pearson Correlation	-0.550	1
	Sig. (2-tailed)	0.100	
	N	10	10

Figure 5.2: The relationship between experience and speed of installation.

Figure 5.2 shows that there is a strong negative relationship between firms' experience and the time used for installing the solar panels. Hence as firms gain experience, the time used in installation reduces and the relationship was statistically significant on the 2- tailed test. This is quite logical and supports the learning curve theory.

1d. What is the relationship between experience of the firms and their patent stock?

		3. How many years of experience does your company have in this Business area.	7c. How many of your patented products yield significant revenue?
3. How many years of experience does your company have in this Business area.	Pearson Correlation	1.000	0.953
	Sig. (2-tailed)		0.047
	N	37	4
7c. How many of your patented products yield significant revenue?	Pearson Correlation	0.953	1.000
	Sig. (2-tailed)	0.047	
	N	4	4

Figure 5.3: The relationship between firm's experience and the patent revenue.

Figure 5.3 above shows that there is a strong positive relationship between the age of the company and the company's patents that yield significant revenue. The correlation is significant at the two tailed level 0.05, but the sample is relatively too small to make a strong claim.

Financial performance as a measure of organizational learning

Profitability was not used as a performance measure because many of the literature did not use that as a direct measure. Also, the curve (Figure 5.4) below shows that the first four years of the start-up venture are characterised by a negative cash flow. During this period, there are several uncertainties and trial & errors. As a result, investors are unwilling to invest in fragile and risky ventures until it becomes less risky and promises to be profitable. In this study, about

50% of my sample falls within this age group, and therefore, profitability will show a skewed representation of performance.

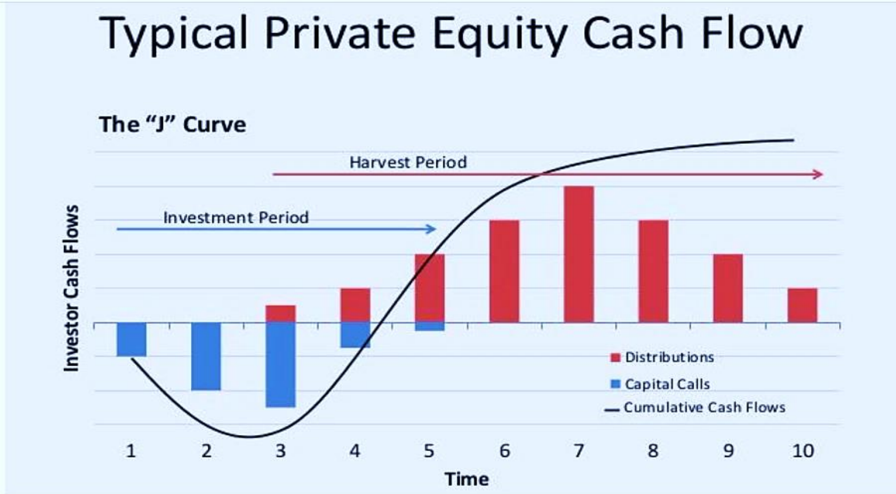


Figure 5.4: The financial performance of firms in the early years(Lillebo and Lein-Mathisen March 2016)

4.2 Summary of the Quantitative Analysis.

Finding 1: *There is no relationship between the age of the firms and cost percentage of the firms.*

A possible explanation could be that these companies are still new in this market so they might not have secured buying power for large volumes so as to utilize economies of scale to get reduced prices. Another explanation could be that they spend so much on operational cost and customer acquisition. The total cost of setting a solar PV system = cost of manufacturing and packaging solar modules (procurement) + BOS[7] cost.

Finding 2: *There is a weak relationship between the age of the firms and the energy yield of the panels.*

There seems to be no effect of experience on the energy yield of the solar energy systems. This validates the case that the energy capacity of the solar panels has very little to do with the actions of the installers. The panels carry with them inherent energy capacity from the point of manufacture and therefore does not depend so much on the way the panels are installed. There are factors that determine the efficiency of solar panel systems such as (i) The angle of inclination of the solar plant system, (ii) The cloud cover, (iii) The particle weather, (iv) The

[7] BOS : Includes all components of a photovoltaic system other than the photovoltaic panels for example wiring , switches, a mounting systems, solar inverters, a battery bank and battery charger

geographical location and (v) The time of the day, and time of the year (Vindtek Dec 2013). It seems therefore that what affects the efficiency of the panels are more of the technical properties of the cells and the environmental conditions rather than the single act of installation. In effect, the solar system cannot be improved beyond the efficiency of the module through the installation process. On the other hand, the processes of installation can be improved.

Finding 3: *There is a strong negative relationship between the firms' experience and the time for installing the solar panels.*

This means that as firms gain experience, the time used in installation reduces. The relationship was statistically significant on the two- tailed test. This means that older firms are becoming much faster in installation.

Finding 4: *There is a strong positive relationship between the age of the companies and the company's patents that yield significant revenue and the correlation is significant.*

This means those firms with more years in the business show they had some technical knowledge that others (younger firms) do not possess(Park and Park 2006). However, the sample size was very small to make a strong case. At first, the researcher thought the older firms were firms that had diversified from other technology areas into the solar industry and perhaps had a spill-over effect from previous technology. Rather, a close look showed the firms that had solar-related patents were aged one to five years. This provides an indication that the business is built around the patented technology.

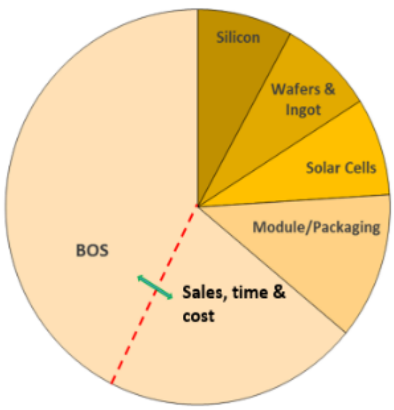


Figure 5.5: Cost component for Installation Companies.

From the quantitative results, the researcher discovered that performance in the firms was quite low. The firms that had more experience regarding age in business show no striking difference from others with less experience. Usually, 40% of the cost of setting up a solar system arises from the manufacturing and procurement of the PV cells, while 60% arises from the Balance of System (BOS)(Energi21 September 2013). It is assumed that as firms gain experience, their cost of procurement reduces. Leveraging economies of scale from large procurements as well as reduced BOS from efficient techniques and better coordinating processes. Logic holds that, the most experienced firms would have established reliable networks to get the electrical devices at a more affordable price, as well as more referrals from previous clients. However, the researchere observed that as firms gained experience, the time used for installation reduced. In other words, Speed increased.

4.3 Findings from Secondary data

This section examine the drivers of solar adoption, the barriers and challenges in the industry and also how improved performance will elicit increased market scale.

4.3.1 Antecedents of Solar Energy in Norway.

Norway has had a strong upstream silicon industry(Energi21 September 2013). Silicon is an essential component in the manufacture of PV solar modules. The availability of raw materials like silicon and aluminum coupled with access to cheap electricity powered by hydropower made processing possible and thus played a big role in the emergence of the solar industry in Norway.

As highlighted in the introduction of this report, the fall in the price of PV cells was facilitated by the Chinese PV manufacturers. They have helped driven prices by 75% since 2007 by competing against the US and the world to gain market share (Plumer March 2013). As a result, PV prices fell from $4 per Wp[8] in 2008 to just under $1 per Wp by January 2012 and from $0.7 in 2013 to $0.5 in 2016 (Aanesen, Heck et al. May 2012).

[8] Wp = Watt peak and specifies the output power achieved by a Solar module under full solar radiation (under set Standard Test Conditions). Peak power is also referred to as "nominal power" sincee it is based on measurements under optimum conditions, the peak power is not the same as the power under actual radiation conditions. In practice, this will be approximately 15-20% lower due to the considerable heating of the solar cells.

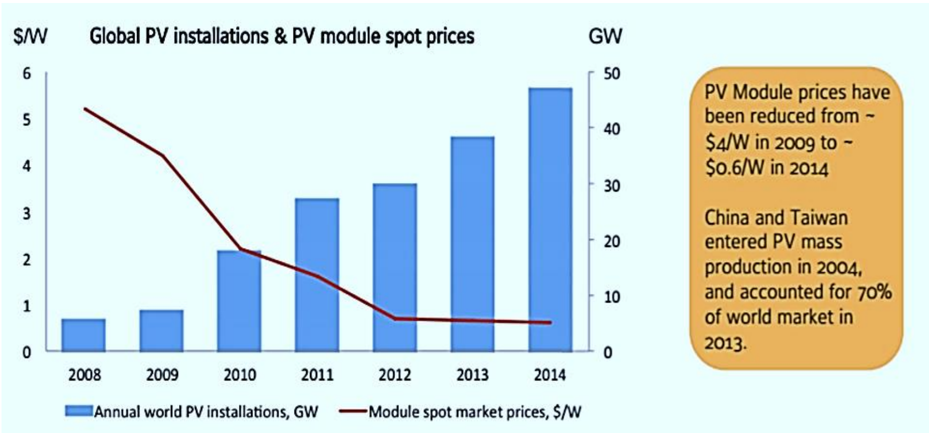


Figure 5.5: The price decline (red line) and annual growth frequency (Osmundsen, Ulltveit-Moe et al. 2015).

From figure 5.5 above, the price decline from 2008 has led to an overproduction and consequently more installations of solar PV systems. This gave rise to an increase of downstream installation firms. Below is a diagram showing the distribution of the value chain in Norway.

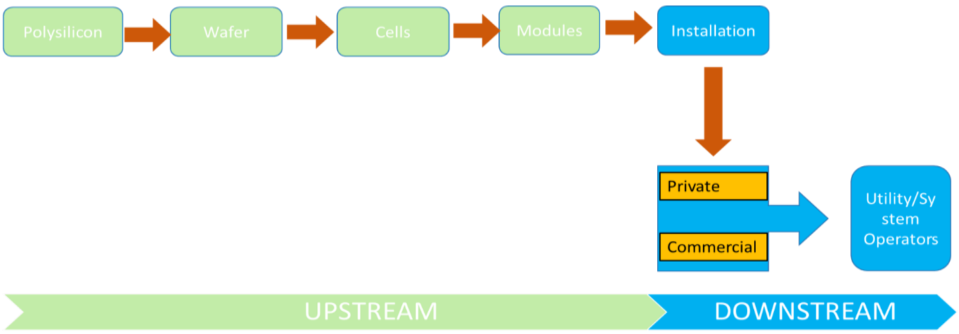


Figure 5.6: Solar Energy Value Chain in Norway.

The illustration in Figure 5.6 above shows the solar energy value chain in Norway. Examples of companies in the upstream segment include:

Polysilicon production: REC Silicon, Elkem and Wacker

Wafer production: NorSun in Årdal and Norwegians Crystals.

Cell production: There are several smaller companies that focus on subcontracting of parts, materials or processes.

Module production: Cells are assembled into modules (panels). There is so far no module producing company in Norway (Energi21 September 2013) .

Consequently the main players directly involved in buying and adopting the solar systems are divided as follows:

(I) Installation companies: they purchase the solar modules and to sell the set up solar systems to the consumers.

(II) Commercial / building companies.

(III) Private property owners.

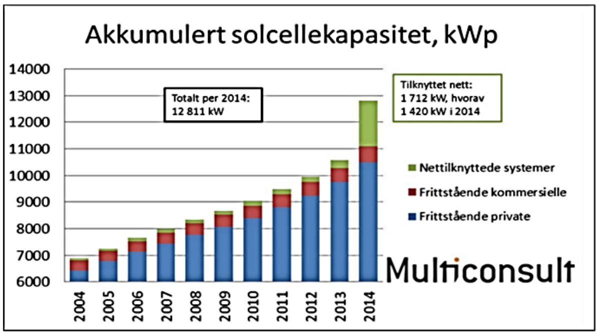
Adoption of this technology depends to a great extent in what they (listed above) perceive as challenges and benefits. In Norway today, 60% of the Solar energy firms are distributed around installation (Energi21 September 2013).

Research in Norway: Continuous innovation and improvement in the efficiency of the PV modules is facilitating solar adoption. A strong collaboration between the industry players in Norway for example Elkem Solar, and the research institutes like IFE[9],SINTEF, NTNU[10] and Technova exists. The solar energy board has called for further developments in the upstream silicon technology and a research base that is, visible and attractive in the international market (Energi21 September 2013).

4.3.2 Learning Curve for Solar Energy in Norway.

The growth rate for solar cells in the world was 48% in the period 2000-2007 and 72% in the period 2007 – 2011 (Energi21 September 2013). Then there was a decline in investment of 21% from 2011-2013, but investment picked up again almost immediately as reflected in Norway. As at 2014, cumulative installation in Norway was 1712kW out of which 1420kW was installed in 2014 (cabins and lighthouses). Manufacturing capacity is expected to double over 3-5yrs and the underlying costs expected to drop by 10% annually until 2020 (Aanesen, Heck et al. May 2012).

[9] Institute for Energy Technology
[10] Norwegian University of Science and Technology



a

	Solfangere (I 2013, IEA SHC)	Solceller (I 2014, IEA PVPS)	Totalt solenergi	Befolkning (I 2013, IEA SHC)	W/innbygger
Sverige	318 MW_{th}	79 MW	397 MW	9 647 386	41
Danmark	564 MW_{th}	606 MW	1 170 MW	5 556 452	210
Tyskland	12 281 MW_{th}	38 250 MW	50 531 MW	81 147 265	623
Norge	31 MW_{th}	13 MW	44 MW	5 085 582	9

b

Figure 5.7: Accumulated Installations of solar PVs in Norway(Sørensen 2015)

Figure 5.7a shows the accumulated installations for Norway from 2004 to 2014. The green bar above shows the installed solar PVs that are connected to the grid system; the red bar represents commercially installed systems that are not connected to the grid and the blue are private buildings installed systems not connected to the grid system (cabins). The diagram shows that there was an increase in the number of installations that was connected to the grid in 2014. On the other hand, figure 5.7b shows that Norway has a very low market scale compared to Denmark, Sweden and Germany.

4.3.3 Motivation and Drivers of Solar Energy Technology

In other to understand why people adopt a technology, it is important to know what motivates them to move from considering the technology to adopting it.

1. **Energy Performance of Buildings**

Future CO2 prices and regulation by organizations like the EU and IEA are the main drivers for the renewable technologies. Given that building constitute about 40% of energy consumptio(Sørensen March 2015), the Norwegian government set up regulations and incentives implemented through the construction sector to build more energy efficient houses (40%) as a means to reduce greenhouse gas emissions. The goal is (i) to build more passive houses[11] by 2015, (ii) to build houses that are nearly Zero energy[12] level in 2020 (Sørensen March 2015)

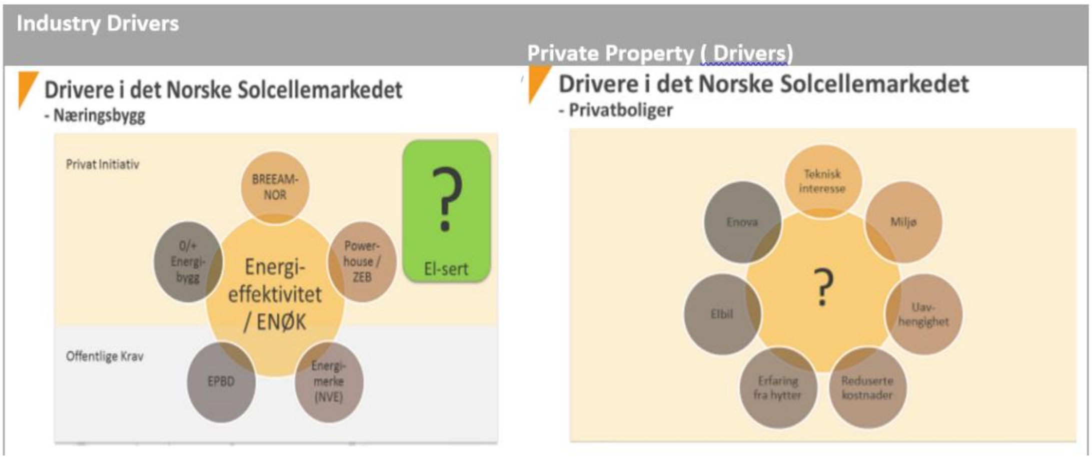


Figure 5.8: The Drivers in the Building sector modified from B.Thorud (private communication, April 21, 2016)

A. Regulations in Commercial Buildings

Some regulations have been in place to ensure that buildings are energy efficient to limit energy consumption. Figure 5.8 above illustrates how the regulations are categorized.

- Private Initiatives: These are assessments in both new and renovated buildings that are aimed at creating sustainable value and efficiency in buildings thereby reducing energy consumption and greenhouse gas emissions. They include: Zero/ Energy plus houses (houses designed to generate more energy than it uses), BREEAM NOR and power Houses[13].” Energy efficient houses are almost impossible without PVs” B.Thorud from Multiconsult.

- Public regulations: These are general assessments in commercial buildings such as energy grades and energy performance of building directives (EPBD). The inclusion of PV in houses automatically improves the grade of a building.

[11] Passive house is a standard for energy efficiency in a building it reduces ecological footprint and results in ultra-low energy buildings that require little energy for space heating or cooling.
[12] Houses designed to generate more energy than it uses. They help reduce energy consumption and climate gas emissions.
[13] Power houses: produces and pay back the energy that was used to build and operate the building over the course of its life time.

B. **Incentives for Private Households**:

The Norwegian Ministry of Petroleum and Energy through Enova gives subsidies to private households to install solar energy systems. For example, Enova gives subsidies of 10.000kr + 200kr per m^2 collector area installed for solar heaters and 10.000kr + 1.250 kr/kWp for solar electricity. In the case of commercial buildings, Enova gives a subsidy of 200kr/m^2 collector area for solar heating (Solenergiforening Autumn 2015). This incentive has attracted many to adopt solar technologies.

Some other motives for adoption of solar energy systems in Norway include

i. Independence: Some are drawn to the feeling of independently owning and producing their energy rather than relying on the conventional electricity grid.

ii. Technology Enthusiasts: This is an important driver for many who usually adopt a new technology early on. Early technology adopters are interested in the technology and the use they can get out of it for themselves or their firms; they do not base their buying on a well-established reference base but rather on intuition and vision (Moore April 2002). They are usually influenced by like-minded people in other industries in this case; the Electric vehicle (EV), and are willing to purchase products that may be costly and incomplete as far as support, reliability, and compatibility with existing infrastructure are concerned. The sole idea that solar cells are central to zero and plus-energy buildings is interesting to the technologically savvy**.**

iii. Good experience from Cabins: Some of those who had solar energy systems on their cabins would be more willing to install it in their houses if they liked it and experienced its efficiency.

2. **Feed- in Tariffs**

This is a policy mechanism designed to accelerate investment in renewable energy technologies by offering long-term contracts to renewable energy producers(Kaunda, Morel et al. 2014). This allows producers to sell surplus energy by connecting it to the local grid system.

4.3.4 Barriers to Mass Adoption

Solar energy has the potential of contributing a large share of energy production as a renewable energy but is plagued with an inability to compete with other energy sources (Hanson 2006). Some of the challenges include,

1. Inadequate Knowledge and expertise within the main players: A survey conducted by Multiconsult in the building and construction sector (builders, property developers, architects and building advisors) showed a consensus about the low knowledge levels of the solar technology within the players (Merlet and Ruud November 2014)page 11). There is a lack of knowledge about both the technology, application and economics of solar. Although some companies have quite a good knowledge of the technology, many say it is still theoretical, and there is a need for more practical experience on installation, operation & maintenance, and more reference projects in Norway. In many cases, for instance, it is the builder who must ask and promote the use of solar projects for it to be a real alternative. The builder, therefore, needs to know what the solar cells cost under different assumptions so as to communicate the solar value to customers. In general, there is a lack of knowledge along the whole value chain.
2. High Investment Cost: The lack of investment support constituted about 90% of the barrier in the survey conducted in the building and construction players in Norway(Merlet and Ruud November 2014).At the beginning of every technology and venture, there are several uncertainties regarding the technology, business model, and doubts about the possibility to make profit exists. Due to the relatively low empirical basis for the use of solar energy technology in Norway, investors have been unwilling to bet on solar energy except those large players who have the ability to back solar pilot projects with little or no profits. There are also regulatory barriers of bureaucracy with the financial support from Enova's. The requirements are seen to be cumbersome and unclear for many firms. Thorud B (Personal communication April 21, 2016).
3. No Standardizations: There are currently no defined feed-in tariffs in Norway. Unlike in Germany, where utilities were obliged to accept and remunerate the feed-in of green electricity at 90% of the retail rate of electricity (Frondel, Ritter et al. 2008). According to the researcher's primary data source, there are no defined parameters for connecting to the grid. The utility companies in Norway set up their requirements to connect to the grid. In the case where a producer wants to connect to the grid, they need to ask about the grid codes and other requirements. The grid codes have a lot of technical parameters

and some grid owners deny producers a connection to the grid. Clearly, establishing standard codes and parameters will stimulate adoption.

4. Lack of Commercial reference projects: There are few commercial reference solar projects in Norway. Due to this, there is a lack of a solid basis for assessing performance and cost in practice for various solar concepts resulting to huge uncertainties(Merlet and Ruud November 2014). This is a very crucial point as for the builders, since they (builders) 'guarantees' energy savings to customers in connection with the energy efficiency of the buildings, there should be high security related to their undertakings. More reference projects will give more opportunities to learn and eventually give a rich experience in cost and performance.
5. Low profitability: There is a barrier to increased investment due to low conventional electricity prices, high investment costs and a relatively low solar electricity production (Merlet and Ruud November 2014)page 16.
6. Long payback time
7. Misconceptions about feasibility of solar power: There is a common misconception that Norway does not receive enough sunlight to make PV installations economically feasible. Studies show that the available amount of solar radiation in Norway is comparable to that in central Europe(C. Good, H. Persson et al. 2011). However, the main limitation is the large annual variations, with more radiation during the long summer days and low variations during the winter.

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5 Discussions

The discussions in this chapter centers around how learning is likely to facilitate increased solar adoption in Norway. According to the framework used in this study; organizational experience is theorized to interact with the organizational context to create knowledge.

Organizational experience + Organizational Context = Knowledge.

In the same manner, learning has been traced to occur from any of these;

1. Increased proficiency of individuals in the firms.
2. Improvement in the organization's technology.
3. Improvements in structures, routines and methods of coordination

5.1 How can Learning improve Firm's Performance

Given that the ultimate purpose of learning is for growth and long-term survival (Fiol and Lyles 1985), it is necessary for organizations to align themselves with their external environment to remain competitive and innovative.

Adoption of renewable energy technologies including solar PV is contingent on improvements in cost and efficiency. Hence, performance in the industry and organizations should result in enhancements in efficiency and cost.

5.1.1 Internal Actions of Organizations

1. Cost-effective goals executed with checklists:

From the interviews, the researcher found that a considerable amount of time was spent on making sales calls and acquiring customers thus increasing the BOS costs. Organizations should have goals geared towards efficiency and cost reduction without compromising on quality and service. Examples of such goals may include cutting down the customer acquisition time by a certain percentage, or improving installation time by a specific amount. Properly communicated goals allow for a targeted focus and should be implemented by the use of checklists. *"Any business that does not have a checklist will soon be out of business"* (Bjorn Thorud, Multiconsult). The use of checklists ensures that essential requirements for realizing the goals are in place.

As an illustration, an installer who went out to install solar panels without a checklist might forget to include some necessary materials. On arriving the job site, the installer will either do a shoddy job with the available materials or waste valuable time in trying to resolve the problem. The use of checklists towards a goal facilitate the pace of learning by reducing the error rate and completion time (Argote 2013). This will minimize and even eliminate non-essential costs.

2. Develop Proprietary Technologies & Competencies

Firms with proprietary knowledge and a head start can carve out an insurmountable cost advantage (Lieberman 1987). This is especially important for firms in the upstream segment.

In addition, developing competencies in areas that complement the core business is likely to provide a competitive advantage for the firms. For instance, one of those interviewed had learned a programming language with which he created a sales administration software. He found the existing tools too complicated and slow and thought it required too much work. Building indirectly related competencies that are not general knowledge to players in this industry gives a competitive edge that can result in reduced costs. In this case, creating a special software that is entirely owned, understood and customizable to meet specific needs of customers can serve as an added value to customers. Knowledge of certain tools and technologies such as apps, social media tools, measurement and analysis of metrics and tools that convert and give remuneration information to consumers, act as differentiation points for products and services.

3. Efficiency In Routines And Processes

Knowledge embedded in practices and routines are viewed as important measures of learning (Gherardi, Emberson et al. 2006). The PV cells come with an inherent efficiency from the producers. However, good planning and designs must be in place to ensure maximum performance of both the PV systems and installation processes. For instance, solar modules are mounted in series therefore prior planning should be done to avoid shading. Planning saves time and contributes to the quality of the work. A good analogy here is the use of a torch light that requires three batteries to light up. The three batteries have to function properly and must be properly aligned for the torch light to work. In effect entrepreneurs (construction and installation firms) will save time, and optimize the solar technology efficiency when adequate planning procedures are established.

Furthermore, routines which include decisions, rules, procedures, standard operating procedures , norms and habits are said to be building blocks of organizational capabilities and can be sources of competitive advantage in organizations(Teece;, Pisano et al. 1997).

4. **Proper Training of Staff**

Knowledge acquired through learning by doing is embedded in individual employees. Most discussions about factors responsible for organizational learning curves include learning by individual employees as a key factor (Fiol and Lyles 1985). Studies suggest that there is a relationship between the knowledge embedded in employees and the performance of the firms ("Engeström et al..1990" as cited by Fiol and Lyles 1985). Thus, there is a need for adequate training of installation and construction workers. Training and practice enhance skills and leads to proficiency in routines. Adequately trained staff will be better at communicating and educating people who are considering to install the solar systems.

5. **An Appropriate Business Model**

The business model is very crucial as it determines how firms position themselves to capture profits. This is one area that investors consider before they make decisions on whether to invest or not. The customer segment must be properly understood to know what is an appropriate business model. For instance, one challenge for some consumers is that they do not want any inconvenience of maintaining and monitoring the solar systems. An appropriate business model for those customer segment will mitigate this problem and act as a differentiation point and serve as a source of competitive advantage.

5.1.2 External interaction of the firm and its context

1. **Active Participation In Knowledge Sharing Associations**

Being isolated from external sources of knowledge leads to a decrement in performance (Argote 2013). There is a need to be actively engaged in information dissemination & network forums so as to learn industry's best practices. The researcher attended some of the network meetings in which industry experts and firms from the value chains were represented. Companies and other players who share and transfer their knowledge are more likely to be at the forefront of industry practice. For instance, the regulating bodies representation at such forums is likely to acquire an understanding of the challenges existing within the industry. Thus, policy makers will be in a better position to make informed regulations by utilising information received at the forums. It would also be useful to coordinate group projects which could serve as references and experience accumulation avenue (Energi21 September 2013) for students, researches, company personnel and regulators . Such reference projects will help mitigate the uncertainties that exist about the solar economics and technology (Merlet and Ruud November 2014). Participation in such networks also increases understanding about each player's role in the Norway's solar ecosystem.

2. **Increased Collaborations with R&D organizations**:
Investment in research and development appear to accelerate the rate of learning among firms Lieberman (1984). Despite the improvements so far in the efficiencies of the solar modules, better efficient modules are still needed. The PV efficiencies to an extent determine the price of the PV cells which also determines the adoption rate. A major problem with the solar technology today is that it is much better at generating electricity than it is at storing it (Hruska April 2014). For instance, the sun's energy that hits the earth in one hour is enough to satisfy global energy needs for an entire year, but existing technology has been unable to capture and store most of it. This makes it difficult to rely solely on solar as a source of electricity. For instance in Norway, there are only high radiations from about May to July and low radiations in the December and January months (Solenergiforening Autumn 2015). Therefore efforts towards developing more efficient batteries will go a long way to improve adoption of solar electricity. Companies who are able to differentiate themselves in this area will surely reap the benefits.

Solar energy companies and the research institutes should together develop dynamic capabilities to venture out and capture interesting opportunities that might be just around the corner. In other words, even as the research institutes and other stakeholders develop their core competencies, they should look outwards for eventual new and unassuming technologies that might prove to be more cost-effective and efficient in producing and storing electricity than the what is available today.

3. **Collaboration With Other Firms To Cut Cost**

Cost is central to the learning curve approach. Volume purchases is a way to reduce costs by leveraging economies of scale. Competing firms can collaborate to make purchases and procurement as a unit to cut costs that will not be realised if they act individually. Such collaborations will increase the individual firm's purchasing power, improve profit margins as well as serve as a motivation to customers. Collaborating with competitors or co-opetition has also been found to be an effective way of creating both incremental and radical innovations, especially in high-tech industries (Ritala and Hurmelinna-Laukkanen 2009).

4. **Educate Consumers about Solar Technology**

Users must understand an innovation well enough to put it to productive use. This suggests that as knowledge barriers are lowered, diffusion speeds up. It is crucial for consumers to understand the system so that they can, for instance, communicate their preferences, make informed decisions, report a technical fault and most importantly reduce the customer acquisition time and cost. According to an interviewee in this study, *"Solar technology is today where Electric cars were ten years ago"*.

For instance, in Germany today, people have a more vivid understanding of solar technology than in Norway. According to Sovacool (2009), making renewable power mandatory without promoting public information and education will ensure that consumers remain uninformed about energy-efficient technologies and practices. Educated consumers make it cheaper and faster for installation and construction firms to acquire new consumers.

5. **Organizations Should Integrate Tools To Interact With Consumers**

In the business model where consumers own the solar plant systems, consumers are responsible for maintaining and ensuring that the systems are working properly. Installation firms, for instance, need to keep open communication lines with their customers through apps and internet services. This will enhance system monitoring, errors or fault detection, tracking of energy savings and consumption. They can work together with consumers - for instance, those who consume large amounts of energy like restaurants and hotels - to provide tailored information, individual goal setting and tailored feedback geared towards efficient energy consumption (Abrahamse, Steg et al. 2007). A goal may be to reduce energy consumption by say 5% or 10%, the solar enerrrgggy companies can then offer tips on best practices to conserve energy like how and when to use warm water, and how to use electrical appliances. All these will help to maximize the effect in conserving energy and increases customer satisfaction. Also, firms should consider the use of marketing tools that enable existing customers to act as ambassadors for the firms by recommending the companies and sharing their experiences. The use of clients as ambassadors is an evidence of neighbour effects (Graziano and Gillingham 2014).

6. The Government Should Enforce Standards And Certifications.

One highlighted barrier to widespread solar adoption is the bureaucracies involved when applying for financial support from Enova[14], especially for large firms. For the financial support to work as intended, the firms should be able to assess the benefits without rigorous and time consuming protocols. Therefore, the requirements should be simplified, clear and easy to understand.

In Norway today, there are no certifications for installers (Bjørn Thorud, Multiconsult). This sometimes leads to substandard and poorly executed projects which undermine the integrity of all involved in the industry. There should be certifications so as to ensure quality measures throughout the value chain. This way consumers can rely on the products and be guaranteed of a quality job.

In relation to selling surplus energy and connecting to the grid, there currently exists no requirement for connecting to the grid. Some solar electricity producers are denied access from connecting to the grid and there often arises processes and procedural uncertainties. A well-defined standard properly implemented will ease connection problems and enhance installation performance. According to (Sørensen 2015), "*Elcertificates15 is currently only relevant for the larger solar PV systems due to fee structure and not yet possible to register.*" Connectivity costs and transmission cost is also an issue.

5.1.3 Further Discussions

How Far Can Subsidies Go?

Subsidies are intended to stimulate adoption and boost investments in renewable energy technologies but has proven to be unsustainable in the long-term[16] and weigh down on the nation's resources (Frondel, Ritter et al. 2008). On April 2015, the Norwegian government announced plans to end its green energy subsidy scheme by 2021(Reuters April 2015). Reasons

[14] Enova is the organ of the Norwegian government that gives financial support and subsidies to encourage adoption and investment into renewable energies.
[15] Electricity cerficates (green certificates) are a market based support tool to promote the cheapest available renewable energy. C. Good, H. Persson, Ø. Kleven, M. Norton and T. Boström (2011). TOWARDS COST-EFFICIENT GRID-CONNECTED PV POWER PLANTS. Hamburg, Germany.

being that long-term investment should be decided by the market instead of subsidies[17]. An interviewee from IFE mentioned that implementing a pollution tax was better and encourages competition than giving subsidies.

Recently in the industry, supply has been more than the demand and strain has been put on margins. Moreover, globally, subsidies are shrinking as a result of the financial crises.

The question is how does that translate to Norway? For instance, a recent report which shows that solar cells are competitive with conventional grid power in 102 countries - without subsidies (Energi21 September 2013) – This is very interesting but should be assessed in the Norwegian context. Given that the electricity from the grid is very cheap today, there is not a big incentive for consumers or utility operators to choose solar. Firms in the solar industry are merely surviving today with the subsidies. What will become of the industry when the subsidies are removed? This researcher will argue that an alternative structure should be in place before the subsidies are finally removed. In effect, the removal of subsidies has to be in parallel to the introduction of an appropriate electricity pricing system in order to be efficient. For a start, a common standard for feeding solar electricity into the grid should be established. In addition, utility companies should be mandated to allow independent producers to connect to the grid as is the case in Germany and the UK.

Removing subsidies will impede adoption as it stands today and will cause the solar electricity fed in to the grid to be much more expensive than the hydropower generated electricity. In turn, utility companies will prefer to buy the cheap hydro generated electricity alternative.

Similarly, considering that conventional electricity in Norway is based on hydropower which is quite cheap and is a renewable source itself, there does not seem to be a strong compelling reason that will encourage mass adoption of solar energy except there are disruptions and shifts in other areas. For instance, it will be ineffective trying to convince people to switch to solar electricity based on the reduction of greenhouse gas emissions argument alone.

Consequently, Norway in collaboration with the research institutes may find other applications for solar to boost its share in the energy mix such as solar-powered vehicles, or solar powered heavy machinery.

The possibility to produce PV modules in Norway

A considerable cost in procuring solar PV modules is the shipment and travel cost. Since Norway has silicon, wafer and ingot production capability, the added ability to package the PV modules locally will save a lot of cost and will improve technical expertise which will in turn increase solar adoption. Energy 21 had called for strategies to improve development in Norway's upstream segment (Energi21 September 2013)

5.2 Forecasts for the Solar Industry in Norway

At present, PV systems account for around 1% of the world electricity production though some countries have achieved higher percentages (IEA 2015). Future forecats however, indicate this will drastically change in the following ways:

- Price Decline: The cost per megawatt hour of solar is declining sharply, technologies are being fine-tuned, and demand is steadily increasing. Large scale development of solar power plants is in the pipeline in many countries (Osmundsen, Ulltveit-Moe et al. 2015). Figure 5.10 below shows the forecasted price decline (in US Dollars) for all the components of the solar energy system up to 2020.

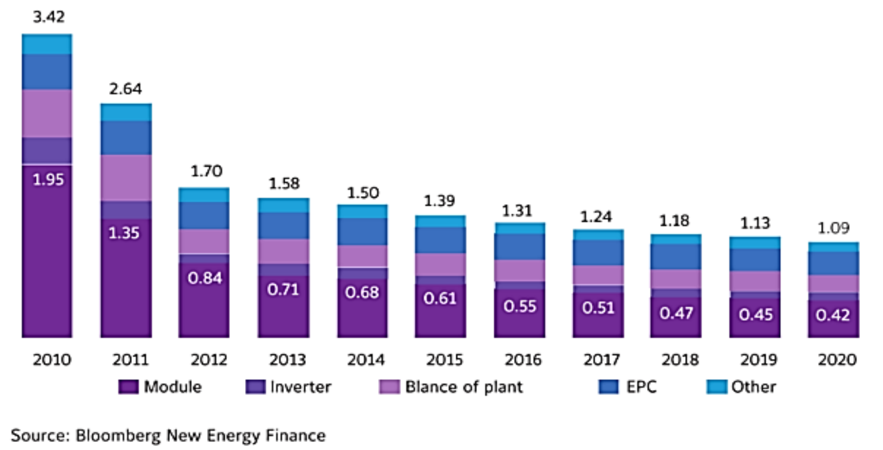

Figure 5.10: The decline in the price of the solar elements (Osmundsen, Ulltveit-Moe et al. 2015).

- Costs of investment will decline: Several energy companies are adopting green bonds called Yieldco's[18] established with the intention of owning operating agents which

[18] Yieldco: is any independent power producing corporation that operates primarily renewable energy assets comprising water, wind and solar. The company is publicly traded, yields a predictable cash flow, and distributes its income or cash flow (about 80%) as dividends to its shareholders.

produce a predictable cash flow. Also at the Climate Summit in Paris 2015, there were talks by the UN to put in place mechanisms to reduce financial cost (Osmundsen, Ulltveit-Moe et al. 2015).

5.2.1 Consequences of the Forecasted growth to Firms.

As a result of the envisaged future growth of solar technology, competition will intensify. This means that downstream and upstream players would have to reduce cost dramatically to succeed, and they will have to deliver distinctive products and services in order to meet particular needs of specific customer segments.

In Norway, silicon and wafer producers in the value chain have good opportunities in the future because of the following:

1. Requirements for high-tech knowledge: Fortunately, Norway has a strong research base that has in the past contributed to technology commercialized by the likes of REC and Elkem.

2. Requirements for low electricity production cost: Norway through its relatively cheap electricity from hydropower provides an advantage for firms in the upstream segment that require large amount of electricity for processing raw materials. About 30% of electricity consumed in the sector, is required for the production of silicon and 15% for wafer/ingot production.

3. Requirements for large consumption of cooling water: For the production of cells and modules, there will be opportunities for niche and subcontracting. In installation and operation,we already see the emergence of Norwegian actors, and here future potential seems to be significant.

5.2.2 Requirement for Upstream players

Upstream players can reduce manufacturing costs by 30- 40% by following these initiatives (Aanesen, Heck et al. May 2012).

Manufacturers need to gain proprietary technological capabilities. Manufacturing may become standardized and commoditized as the industry approaches maturation. Therefore, it is necessary to develop or own differentiated and scalable technologies especially as the costs are flattened.

1. Drive operational excellence in manufacturing: Firms should consider adopting lean production approaches and develop strategic relationships with suppliers.

5.2.3 Requirements for Downstream Players.

1. Downstream players need to differentiate themselves and deliver unique products and services to meet the particular requirements of some customer segment. For instance, by focusing on serving high-value customers at low cost, they can install and operate solar systems across a global network of sites or develop a business model that frees the customer from any maintenance or ownership liabilities.

2. Companies in the downstream must know their customers well. They need to understand the conditions in the areas in which customers are located, the space customers have available for solar installations, the level of power they consume at different times of the day and throughout the year, the amount they pay for power, and their ability to finance purchases.

They must reduce the cost of acquiring and serving customers by applying efficient routines and practices.

6 Conclusions

There is a consensus that investment in renewable technologies is a way to mitigate the climate condition today (EU 2010). Subsidies have been used in Norway to stimulate investments and adoption of renewable technologies including the solar. However, subsidies alone have been shown to be unsustainable and have not been efficient enough in eliciting mass diffusion of solar technology. To examine the challenge of low solar adoption in Norway, the researcher set out to assess the performance of the firms in the solar energy industry in relation to how long they have been in the solar business (experience).

The study examined the relationship between firms' experience in the solar business and their performance as it relates to the cost of PV installations, efficiency, patents, and speed. It was found that experience of the firms did not seem to lower the cost incurred in setting up PV installations. The experience also did not seem to affect the yield of the solar panels either because the modules cannot be improved beyond the manufactured efficiency (Thorud April 2016). However, the efficiency of the processes and installation routines was more a result of the actions of the firms. The study suggests that experience enhanced the speed at which solar systems were installed as well as the technological know-how.

The second objective of the study was to examine how learning was likely to enhance performance in the firms. This was approached through the framework that organizations interact with the environmental context to create knowledge which improves performance (Argote and Miron-Spektor 2011).

Firms' active interaction within the internal borders of the organization and the external environment should produce knowledge that is likely to enhance their performance and sustainability. The researcher, therefore, suggests that:

- Cost-effective goals that are carefully implemented through the use of checklists will facilitate the pace of learning by reducing the error rate and completion time.
- Proprietary knowledge and competencies in areas that complement the core business will provide service differentiation and serves as a potential source of competitive advantage for firms.
- Prior planning will save time, and optimize the solar technology's efficiency.

- Well-trained staff will be better at communicating and educating customers and others about the benefits and mechanisms of solar systems.

- An appropriate business model is likely to facilitate investment profits for the firms and investors.

Knowledge flows in and out of the firms can facilitate learning in the following ways:

- Firms can gain valuable technology and market insights as they participate in associations and network forums that are aimed at sharing and dissemination industry’s best practices.
- Firms can collaborate with other firms to get reduced price for the PV modules.
- Firms who collaborate with R&D are likely to be at the forefront of technology’s best practices.
- Consumers who understand solar technology and benefits are more likely to adopt it. In addition, neighbours of customers can be positively influenced when customers are satisfied and negatively influenced when they are not.
- The use of interactive tools to reach, sustain and retain customers through value added communications has shown to be both cost effective and efficient

In conclusion, the study suggests that learning by the firms will drive down costs and enhance efficiency to an extent but may not be sufficient to drive solar mass adoption. In other words, high performance in the firms needs to be in parallel with knowledge changes by the other external players. High performance in the firms coupled with learning by the external organizational context to mitigate standardizations problems, high cost of investment, and competitions with the conventional electricity prices, will likely lead to solar mass adoption.

6.1 Recommendations

The extent to which firms interact with its environment will determine the extent of learning (knowledge change) that will occur.

The researcher proposes in view of the conclusions, that the following should be done to facilitate a quick mass adoption.

Policymakers

- Policy makers should actively interact with the industry to make informed policies that will promote the knowledge base of firms. Standard operating procedures should be in place for implementing the feed-in tariffs, and securing investment finance. Thus creating an environment for firms to grow their competence in a less hindering environment.
- Policy makers should find other methods to market and promote solar technology in Norway such that the price of grid electricity is not a limiting factor to solar adoption.

Firms

- Firms should collaborate with other firms to make procurements, marketing, and other forms of knowledge sharing activities.
- Industry players and R&D firms: There should be frameworks set to promote innovation, knowledge and competence base of the solar firms in the industry.

Norway's R &D Institutions

- Since 40% of energy are consumed by buildings and households. There should be more research to find how solar can be applied and extended to other 60%.
- Norwegian research firms should increase collaborations with international research firms to develop expertise in ground-breaking technologies.
- Research institutions and entrepreneurial firms should create platforms to promote reference projects so as to facilitate learning by doing. Thus, levelling the knowledge barriers and uncertainties that exists today.

6.2 Implications for Future Work

"We certainly do not get an elephant by adding up its part. An elephant is more than that. Yet to comprehend the whole we also need to understand the parts"(HenryMintzberg, Ahlstrand et al. 1998).

Every problem has different sides to it and should be assessed from various angles to see the different perspectives. That said, extant reports and literature have recognized the impact of R & D on efficiency and cost reduction in solar adoption (IEA, 2007).

This thesis has looked into the limitations and challenges facing Norwegian firms with regards to increased volume outputs. However, the researcher proposes that more research should be conducted from the perspective of the utility and system operators (DSOs). More understanding needs to be gained regarding the challenges and factors they consider before distributions contracts are signed. In the same vein, consumer buying behaviour should be studied to understand the motivations and impediments they perceive in the solar technology. In addition, more research should go into finding more applications and extensions of the solar technology, and efficient ways to store solar electricity.

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Appendix A - Interview Questions

Background of the Firms:

- Why are you in the solar market
- What is your previous knowledge.

Knowledge Source

- What knowledge was crucial to starting the firm?
- Where and from whom do you pull knowledge from?
- On what occasions do you contact external sources of information for firm related problems?
- Are you a member of any business network?
- How do you generate knowledge in the firms?
- Are you involved in any standard setting body?
- How do you acquire knowledge?

Procedures and Criteria

- How do you solve problems in the firms?
- How do you select projects to embark on?
- What factors do you consider before you choose a project?
- Do you have predefined ways of solving problems or is it done on an ad hoc basis?

Second Phase Interviews

- What do you think will happen when the government remove the incentives which acted as a boost for solar adoption and sale.
    a. (is it possible)
    b. How will it affect adoption?
    c. How will it affect market players (big and small, upstream and downstream)

-What are the targets for solar installations for Norway and have they met it so far?

-What are the major challenges in Norway's industry

-If costs begin to rise, what will happen to the current players

- Why do you think Norway is lagging behind
- What percentage of Norway firms operate outside Norway
- How should players in the different value chain position themselves to compete properly?

Appendix B - Survey Questions

What is the name of your company?

1. State the business area of your company.

   a. Solar electricity
   b. Solar heating
   c. Both
   d. Other:

2. Which of these describes your business segment.

   a. Solar component manufacturer
   b. Design / Architect
   c. Construction / Installation
   d. Adviser/ Consultant
   e. Supplier
   f. Turnkey
   g. Electricity production
   h. Other

3. How many years of experience does your company have in this business area.

   a. 1-6
   b. 7-12
   c. 13-18
   d. 19-24
   e. 25-50
   f. 51-99
   g. 100 and above

4. How many employees does your company have?

   a. 0-4
   b. 5-15
   c. 16-30
   d. 31-60
   e. 61-100
   f. 101-499
   g. 500 and above

5. How many of the employees work in the solar related business?

6. What type of business model do you use?

Business Model (BM) is a strategy to grow the business and make profit for the shareholders. Vertical BM controls more than one step in the value chain, Horizontal BM : usually controls a step across different market to reach various audience.

a. Vertically integrated business model
b. Horizontally integrated business model
c. Partially integrated model (mixture of both)
d. Other:

7. Do you have any patented solar products?

a. Yes
b. No

8. Please assess the following statements:

	I strongly agree	I agree	Neutral	I disagree	I strongly disagree
I have other business areas not solar related	○	○	○	○	○
I am a mother company to another company	●	○	○	○	○
I am a subsidiary	○	○	○	○	○
I produce products not directly used in the solar industry	○	○	○	○	○

9. Does your company install Solar panels / Solar collectors?

a. Yes, Solar panels.
b. Yes, Solar collectors.
c. No.

9b. Approximately how long does it take your company to install 5 meter squared solar panels?

9c. On average, how much energy (KWh) does 1meter squared of your installed solar panels produce?

a. Less than 100KWh
b. 100-129KWh
c. 130-150KWh
d. 151- 160 KWh
e. Above 160 KWh
f. Other:

9d. On average, how much energy (KWh) does the installed solar heaters produce per m^2?

a. Less than 300KWh
b. 300-399KWh

c. 400-499KWh
d. 500 - 599KWh
e. 600 and above
f. Other:

10. Is your company a Solar panel Producer/Supplier?

a. Yes
b. No

10b. On average how much energy does 1 square meter of your solar panels produce?

a. less than 100KWh
b. 100- 129KWh
c. 130-150KWh
d. above 150KWh
e. Other:

11. Is your company publicly traded on the stock market?

a. Yes
b. No

11b. On average what percentage of your revenue is cost?

a. Less than 10%
b. 10- 25%
c. 26-50%
d. 51-75%
e. 76-100%