Master of Science in Energy Management

Institutional perspective:

The battle between increased profitability and risk, with technology in the leading role.

Erik Nordanger

Bodø, May 2010

Kurskode: EN310E 003

Preface

This master thesis is my final task of my master program Energy Management at Bodø Graduate School of Business. This final semester has been a busy semester filled with good experiences and frustration. My semester in Russia has given me a unique experience and has taught me a lot about adapting to other cultures.

I would like to give thanks to everybody who has helped me during the process of writing this thesis. A special thanks goes to my supervisor Anatoli Bourmistrov. Your constructive and helpful feedbacks throughout the entire process, is a major reason why I am sitting here and putting the final touches on my thesis. Without your help, I would have been lost in a jungle of information.

Finally, I would use this opportunity to say thank you to my informants for good and informative interviews.

Erik Nordanger

Bodø, May 19, 2010.

Abstract

In this thesis, I am investigating what the drivers and barriers for development of new technology on the NCS are. My theoretical foundations for this thesis are based upon theory that explains different factors that will affect an organizations willingness to change. Drivers in this context can be defined as an incentive to develop new technology. Barriers on the other hand can be defined as something that hampers or prevents the companies to develop new technology. In addition, the word technology can be described as the machinery that makes it possible to explore and extract oil. The empirical foundation of this thesis is based upon interviews with Johan Petter Barlindhaug, Lars Kullerud and Cato Wille. Based on this I will give an answer to my problem statement, which is:

"What are the drivers and barriers for technological development at the Norwegian Continental Shelf?"

My empirical data consist of interviews from three different people with background from the oil and gas industry and secondary data.

In short my findings can be summarized like this:

Drivers:

- Hunt for increased profitability
- New and demanding fields
- Governmental legislations forcing the companies to change
- The desire to prolong the lifetime of a field

Barriers:

- The companies conservatism and fear of change
- Lack of incentives from the government

Sammendrag

Hovedformålet med denne oppgaven har vært å kartlegge hva de ulike barrierene og driverne er for teknologisk utvikling på norsk sokkel. Oppgaven bygger på teorier som beskriver hvordan ulike krefter kan ha en påvirkning på en bedrifts vilje til å satse på ny teknologi. Videre bygger den på mine empiriske funn gjort fra mine intervjuer med Johan Petter Barlindhaug, Lars Kullerud og Cato Wille. Jeg har delt oppgaven inn i drivere og barrierer da disse må holde adskilt.

Hovedkonklusjonen for oppgaven er at bransjen stadig søker etter måter å øke lønnsomheten på og dette kan da gjøres ved implementering av ny teknologi. Noen ganger blir bransjen stimulert i form av nye og utfordrende felt eller lovgivninger fra staten som tvinger bedriftene til å endre deres nåværende måte å operere på.

Samtidig er bransjen stadig konservatisme og frykt for ny teknologi et problem når det kommer til ny teknologi. Statens manglende vilje til å belønne ny teknologi er et annet problem for bransjen, noe som også har vist seg i Lofoten/Vesterålen debatten.

List of pictures, tables and figures:

Abbreviations

NCS – Norwegian Continental Shelf

IOC – International Oil Company

NOC- National Oil Company

ConDeep – Concrete Deepwater Structure

EM – Electro Magnetic

R&D – Research and Development

SPBM – Single Point Buoy Mooring

TOGI – Troll Oseberg Gass Injection

Innholdsfortegnelse

1. Introduction and problem statement

1.1 Actualization

Technology, the very heart of the oil and gas industry. What is mend by technology? Why is this interesting for the oil and gas business? In order to answer these questions I will start at the beginning of Norwegian oil and gas production.

During the evolution of the oil and gas industry, there has been an increasing focus on technological solutions and Norwegian oil production is no exception. In order to extract Norwegian petroleum the industry has had to use advanced technology. Technology is the core in oil and gas production, by having the right type of technology one can drill places where one previously could not drill before. Nobody speaks about the technology when it works, it is like a silent worker who is just serving its purpose. However when the industry faces problems, new technology is often the solution. Even in the discussion of the disputed areas outside Lofoten/Vesterålen, is technology been given a central role. During the short period of oil drilling at the NCS, compared with how long oil production has existed, there has been a technological development unlike anything else. The NCS has brought along many new and demanding situations and in order for the oil and gas companies so solve this they have had to develop new and revolutionizing technology. Among these, one can mention the enormous ConDeep platforms, horizontal drilling, multi phase transport and not least, sub-sea installations. These technologies can be seen as different eras in the oil and gas production, where each new technology represents its own era. For an era to exist there have to be a driver that drives forward the new technological era. At the same time there have to be a barrier that prevents technological eras to take place. If this were not so, then there would be technological eras all the time.

Norwegian oil and gas compete against the rest of the world's supply of oil and gas. In order for our petroleum to be competitive, it is important that the costs are kept as low as possible. Compared too many other fields, Norwegian fields are first of all offshore, which automatically makes it more expensive to extract. Second, many of the fields are located at big depths, which at the point of discovery was a big technological challenge. In order for the NCS to be competitive concerning profitability and efficiency, it was important to have good technology. Basically there were several factors that worked as a disadvantage for Norwegian

petroleum, compared to other fields in the world. These new and revolutionizing fields have helped the NCS become one of the leading offshore areas in the world and technology developed here has set the standards at other fields in the world.

Technology has also played an important role in prolonging the lifetime of our fields. In the early stages of the Ekkofisk, the initial calculations were that the field would last for 30 years. Predictions today is that the field will still produce oil for 50 years more. This is a perfect example of how increased efficiency through new technology and increased understanding of the fields has made it possible to extract a bigger percentage of the field. When discovering a field today, it will not be possible to extract 100% of the reservoir. The reason for this is that the oil is pumped up with the help of the pressure in the reservoir. As the oil decreases so will the pressure, the companies use water to create artificial pressure in order to continue the production. Again, technology is the very core in oil and gas production.

I think it would be interesting for other people to get an understanding of the constant battle a company has between different factors that affects them. The reason for this is that the oil and gas industry is an important part of Norwegian economy, it generates tax money and employment. Based on this it is an industry that gets much attention from the public and many people has an opinion about the industry. I think that this thesis would help generating understanding for why the companies have the attitude they have towards new technology.

The oil and gas business is a sector that involves a lot of money, both in form of earnings, but also expenses. For example, building a new platform is very costly, but then again when the oil and gas prices are high and so are the earnings. Does this mean that it could be a correlation between high oil prices and technological development? I mentioned earlier the Lofoten and Vesterålen case, maybe it is discovery of new fields that makes the businesses develop new technology. However, is it too expensive to make new technology? Maybe they are satisfied with the technology that exist and give them an x-income each year.

1.2 Personal motivation

Since technology plays such an important role in the oil and gas production one could be lead to think that it would be important for the oil and gas companies to use the newest and best technology. However, my impression is that the rate of innovation in the oil and gas sector is not very high, opposed to what one normally would think. This has made me wonder what

causes innovation in the oil and gas sector, what are the factors that need to be in place for the companies to choose new technology. In addition, is it possible to explain why the companies are reserved against keeping a high activity of R&D and implementations of new technology?

Based on what I have written above my problem statement for this thesis is as following:

"What are the drivers and barriers for developing new technology in the oil and gas business on the Norwegian Continental Shelf?"

Personally, I think it is a very interesting topic based on the role technology has played through the development of the NCS. When reading and hearing about the oil and gas industry today one usually just speaks about political issues or the prize of barrel of oil etc. However, rarely does one hear anything about the technology that lies behind each existing field. This is something that is also reflected by the course Energy Management. It is very important to understand the role oil and gas has today, and what controls the oil and gas prices and all that. However, for me it is also very important to understand the technological challenges that the NCS has brought along and to understand how these have been solved. Everybody expects the oil and gas production to be as clean as possible and to supply the world with oil and gas in a raging speed, but rarely do one hear about people saying that this and this technology used at that and that field is an engineering art. By writing this thesis it has given me the opportunity to gain a better insight of how it has been technological possible to extract the oil and gas the NCS has to offer. For me, one of the symbols of the very technological golden age is the pictures of the Troll A platform as it is being towed to the field. Imagine creating something that huge, I have heard each leg is as high as the Eiffel tower, and the platform has four of these made in concrete.

1.3 Limitations and structure of the thesis

In this thesis, I have chosen to limit myself to only discussing the technological choices on the NCS. The reason for this is to narrow it down and to be able to go into deep on this subject rather than looking only on the surface of a bigger subject. Another thing is that it is easier to get in contact with informants that have experience from the Norwegian oil industry, rather than speaking to people who have knowledge about the entire industry as so. When that is said, the result in this thesis will make it easier to understand and give a pointer of why IOCs across the world chose the way they chose. Furthermore, this thesis will only focus on

technology used in the exploration and production phase, this is in order to narrow down the thesis and make it possible for me to in depth on some selected themes.

Further, this thesis will not cover all aspects involving new technology. I have limited myself to the information gained through interviews with representatives from the oil and gas sector in Norway, and secondary data. The purpose of this thesis is not to generalize but to provide for a better understanding of the different internal and external factors that affects the technological innovation on the NCS.

My thesis will start with an introduction that will be followed by the theoretical basis. In this chapter, I will discuss different theories that deals with innovation. The purpose of the chosen theories is to give the reader a better understanding of what the theoretical background for technological development is. The theories will help to explain what drives and hampers technological development in general. However, during this chapter I will try to compare this with the oil and gas industry. After this, there will be a method chapter, where there will be a presentation of how my information have been collected and which design my research is. Then, I will present my empirical findings, which will be based on interviews with representatives from the oil and gas sector and secondary data from books and articles. This chapter will start with a brief history of the discovery and development of the NCA. The reader will then be presented with some different technological breakthroughs made during the years of Norwegian oil production. After that, there will be a presentation of what my informants believe to be the different drivers and barriers for technological development in the oil and gas industry. In chapter 5, there will be an analysis, where theory will be compared with empirical data. The purpose of the analysis, it to show how the empirical findings can be related to the theory. The analysis will also be the backbone for the conclusion. In chapter 6, I will make a conclusion based on my analysis were there will be an answer to my problem statement. The thesis will finish with a presentation of the contribution it will make, the limitations and a suggestion to future research on this field.

My thesis will end with some reflections over further research and which contributions my thesis has made and to whom.

For each main chapter there will be a brief presentation of the theory and an explanation for why it is included. The reason for doing so is to make it more readable and to maintain a thread throughout the thesis.

2.0 Theoretical frame of the thesis

The purpose of this chapter is to give a theoretical description of the different forces that surrounds a company and affects their ability to innovate. It will further give a description of how these forces can act both as a driver and as a barrier towards developing new technology.

In this chapter, I have chosen to go in depth into four different theories and present a more understanding picture of how these theories affect the innovation. The first theory will be institutional theory. Further, the chapter will describe the tug of war between exploration and exploitation of technology. After that, there will be a presentation of technology's influence on a company's strategy. The last theory presented is technology transfer.. An overview of the theories mentioned in this thesis can be seen in figure 1. The beginning of each sub-chapter will contain a discussion of the relevance for my problem statement.

Some of the key words in this chapter are drivers, barriers and actors. In order for the theoretical part of this thesis to be more understandable, a brief definition of these words will follow.

Drivers can be seen as forces or incentives to perform a change, actors that stimulate the organization to change. An example of a driver would be to create new technology in order to become more competitive. Barriers however, are a discouragement that prevents change from happening, or in this case prevents a new technology to be developed. For example, the cost of implementing a new technology, if the cost of implementation will be higher than the reward, then a company would consider another solution. A third word is actors. Actors are the organizations involved in the changing process; for example, the suppliers whom provide the oil and gas companies with new technology or the government that passes new laws.

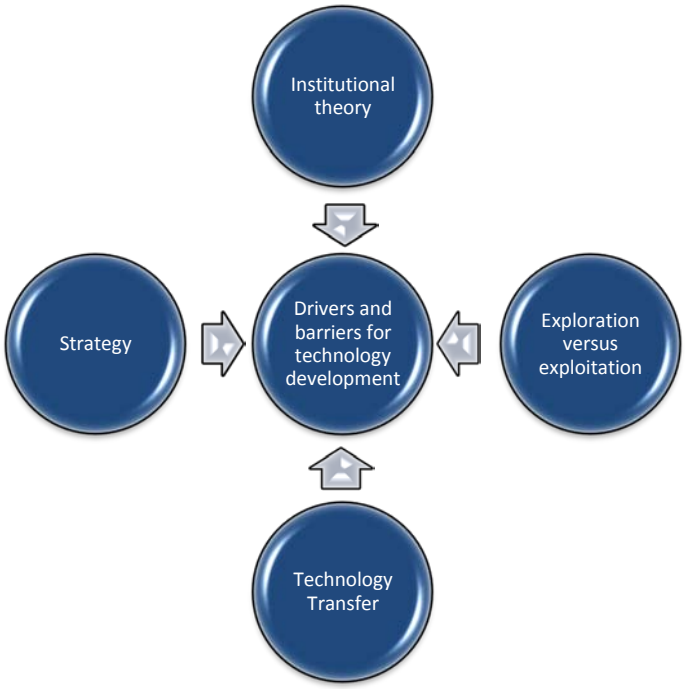

Figure 1: Model over my theory chapter

The purpose of this model is to give an illustration of which theories I will use in this thesis. By placing the theories around the core, which are the drivers and barriers for technological development, I will show how the theories in their own way can help understand what affects a business decision regarding new technology. The model will make the base for the sum-up of the theoretical frame chapter, where it will be made clearer how these different theories can be related to drivers and barriers.

2.1. Institutional theory

When explaining or understanding change in an organizations formal structures, considerable emphasis have to be placed on the organizations surroundings, that is the environment they exist around (Slack and Hinings1994). In this chapter, I will discuss how different actors can influence an organization and act as drivers or barriers for change. Isomorphism refers to the process that forces an organization to resemble other organizations that face the same set of environmental conditions in order to meet the challenges and demands from the environment around them. The reason for using this theory is that it will put in better perspective the different ways a company can experience pressure or incentives to change technology.

Institutional theory also describes why a company can be reserved to implement new technology. According to Hannan and Freeman (1977) in (Slack and Hinings1994) isomorphism and change can be occurs because the competitive pressure that surrounds the organizations eliminates non-competitive organizations. Based on this one can say that the organizations that are left are isomorphic, either with each other or with the environment surrounding them. Companies make changes as a search for legitimacy in the environment that surrounds them, in my case these changes would be creation of new technology. I feel it would be interesting to see if this could be transferred over to the oil and gas business.

DiMaggio and Powell separate between three different drivers for implementation of something new, these are coercive mimetic and normative. Below I will go further into what characterizes each of these three isomorphic processes.

2.1.1 Coercive

Coercive isomorphism is a result of both formal and informal pressure exerted on an organization by other organizations (DiMaggio and Powell 1983). This pressure may take form as force or persuasion. It may also take form as an invitation to join in collusion, working together in order to change technology, products etc. The pressure can come from governmental institutions as well as private actors. How is this in the oil and gas sector? Is it the governmental pressure or pressure from private actors that are the most influence? An example of a direct pressure from the government would be new regulations towards pollution from oil and gas drilling. This regulation could force the industry to do changes in current technology or drilling procedures. Another and more simple example that DiMaggio and Powell (1983) uses are organizations that hires accountants in order to meet new directives from tax-law requirements.

It is important to understand that the pressure do not necessarily have to come from the governmental, it can also come from stakeholders. With stakeholders I here mean people who are affected by an organizations actions. They can pressure an organization to change their structure or way of doing things by sanctions towards their products. A good example of such stakeholders is the fishermen’s that can get affected by the oil and companies actions. If one try to draw a parallel with the Norwegian oil and gas industry, would an example of this be that if the gas exported from Norway was not as clean as it is, the European market would look towards other alternatives?

To put this in perspective one could say that companies experience a pressure, a pressure that takes different forms, to create something new or to make changes.

A question that is important to ask is why does this work? One way of looking at this is to look at the power or level of influence the environment can have on an organization. Governmental organizations make this work through implementing new laws that the organization needs to follow to prevent sanctions. As I mentioned earlier the customers could also perform coercive pressure towards an organization, and the fear for boycott could lead the company to change. It would become a question about the cost of change versus the cost of not changing and also the increase or loss in goodwill in the market.

2.1.2 Mimetic isomorphism

Mimetic isomorphism occurs when an organization is faced with uncertainty model themselves on another organization which they perceive to be successful.

Unlike coercive the driving force for imitation is here uncertainty (DiMaggio and Powell 1983). While coercive processes are external, mimetic processes are driven from within. Uncertainty can be seen as an external threat, but at the same time it is also an internal threat. The company can react to the uncertainty by copying or looking towards other successful organizations. Unlike the coercive where the company is pressured to change. A link between these two could be that uncertainty can come because of coercive pressure. The advantages of mimetic behavior in the economy are considerable, for instance, when a company faces problems that seem difficult to solve a solution could be to look around in the market and find out what other possibilities exist. The reasons why organizations do this are to reduce the level of uncertainty, keep costs down and getting a better response to the uncertainty. For example: Let us say that Statoil is the leading oil and gas company when it comes to sub-sea installations and are having a great success with this and at the same time other companies are struggling with high costs associated with their technological solutions. This scenario created uncertainty among the leaders in the other company and they could solve this by looking at what Statoil are doing and copy their way of solving the technological aspect with drilling under water.

By looking towards their competitors and imitate their way of meeting uncertainty, they go through a mimetic process. However, it is not always the template organization has a desire to

be template. This is understandable when looking at the amount of money that may have been used on research and development to create new technology or money spent on getting increased knowledge about the market they operate in. according to Alchian (1950) in DiMaggio and Powell (1983) there are companies that continuously lie in the forefront on the technology side. On the other side, there are also companies that continuously look to copy from others, through innovation fairs and other ways necessary to cut costs and keep track in the market.

How would this work in the real life? Would this be same as when Norway copied from the Americans in the beginning of our oil adventure? Can an organization change and become in the forefront instead of being the one that try to template a competing organization? Norway has developed to become one of the leading countries on offshore drilling, on the technology front, maybe that is an example of that type of change?

Mimetic processes does not necessarily have to be about new technology or ways of doing business, it can also involve CSR or benefits for their employees (DiMaggio and Powell 1983). In order to keep their employees happy they can look towards their competitors and see what they are doing for their employees, do they offer health benefits or free kindergarten, etc. In addition, they can see look at what type of dialogue their competitors have with their customers, what guarantees are they giving for their product do, they offer something special to keep their customers happy? In general, it is common to say that the bigger an organization is and the more people they have to relate to, employees, customers etc the more they have to offer the same service and programs their competitors do.

The imitation of a successful or acknowledged organization will not necessary secure profit or an economic benefit, what it will do is to secure legitimacy (Radaelli 1997). However, this is also the case with coercive and normative, an organization is always trying to achieve legitimacy from its surroundings. In any given business it is important with legitimacy and by imitating for instance an organizational structure they will secure this.

2.1.3 Normative isomorphism

Normative isomorphism is mainly due to professionalism (Radaelli 1997). Through institutions like universities, formal education and recruitment of people with a higher education will produce a common cognitive base and a shared legitimacy that will affect the

similarities of different organizations. Does this mean that for instance students learn the same things independent of which institutions they have gotten their education at, will contribute to similarities in organizations? Actually a report from Hirsch and Whisler 1982 in (DiMaggio and Powell 1983) claims that there are minimal variations between the Fortune 500 board members. If I understand this correctly then the answer to my question would be that yes, professionalism through formal education systems contributes to minimizing the differences between organizational structures. Why is this interesting for my thesis? This is because it shows that creativity and the ability to think outside the box is hampered at these institutions and can affect a company's willingness to try something new in time of uncertainty and rather imitate models that are safe and accepted. The organizations are searching for legitimacy, and they find this by being similar to all the others. Do we see some of these tendencies in the oil and gas business? Are the companies afraid of trying something new and more comfortable with the existing technological solutions?

According to DiMaggio and Powell (1983) it does not necessarily have to be just an organization as a whole who will experience normative pressure. Professions can also experience this pressure. In an oil and gas company, one of the leading drivers for new ideas would be the engineers, but with a standardization of the engineering education, the companies risk getting similar engineers, which again can be a barrier for new technology. How is this possible? What the theory say, is that with a standardization of the profession, you risk losing the differentiation of the students, they are not creatively stimulated and thereby there will be no difference between them. The incentive for this standardization is to achieve legitimacy for the profession. If the engineers are similar and are thought to think similar, they are less likely to think of something new and revolutionizing, which would be barrier for creation of new technology. This is stressed out by Perrow (1974) in DiMaggio and Powell (1983:229), where he say: *"Such mechanisms create a pool of almost interchangeable individuals who occupy similar positions across a range of orientation and disposition that may override variations in tradition and control that might otherwise shape organizational behavior."* In other words, as long as the leaders of tomorrow are filtered on the same background and drawn from the same universities and have the same attributes, they will continue to look at a situation in the same matter as their predecessors. They implement the same policies, procedures and have the same view upon change. In the oil and gas business, this means having the same attitude towards implementation of new technology and the same conservative attitude as always. Should the organization hire people who have escaped this

filtering process, these individuals will experience less socialization at work and less encouragement from the environment around them, which again might hinder them from opening their creative side (DiMaggio and Powell 1983).

2.2 Exploration versus Exploitation

In this chapter, there will be a discussion of the theory of exploration versus exploitation. First, I will clarify the meaning of the terms in this context. Exploration includes terms like search, variation, risk taking, experimentation, discovery, flexibility and innovation (March 1991). Exploitation on the other hand, is covered by terms such as refinement, choice, production, efficiency, selection, implementation and execution. So why is this relevant for my problem statement? The reason for this is that it affects the level of innovation in an organization, if they choose to use the money on exploitation it will act as a barrier for new technology. It describes the choice a company has between using familiar technology versus using technology they have not tested before.

According to March (1991) it is important for a company not only to choose one strategy. For instance, a company that focuses too much on exploration and neglects exploitation might find themselves using much money on exploration without gaining from its benefits. The reason for this is that they will have too many underdeveloped ideas and gaining too little competence about the sector. On the other side, a company that has their focus only on exploitation will experience being trapped in suboptimal stable equilibrium (March, 1991). Basically, they will end up in a dead-end without being able to be creative and lose their adaptability and risk losing to companies who are more creative and design new technology. As a result, one can say that it with regards to prosperity and survival it is important with a balanced combination of these two.

The challenge with balancing exploration and exploitation is that they compete for scarce resources (March 1991). A company only has a certain amount of money to use. If they choose to use much on research and development this will happen on the expense of money spent on production with known technology. This means that the companies have to make explicit and implicit choices between the two. The explicit choices are calculated decisions between alternative investments and competitive strategies. The implicit choices are buried in many features like organizational forms and customs, for example, in the way targets are set

and changed, and in incentives systems. Understanding the choices and improving the balance between them are important but also difficult. It is complicated because the return from them varies not only with their expected value, but also with respect to their variability, their timing, and their distribution within and beyond the organization. The trade-off between exploration and exploitation in mutual learning involves conflicts between short and long run concerns and the gaining of individual knowledge and gaining of collective knowledge.

According to March (1991) who refers to Winter (1971) a problem with exploration of new alternatives is that it reduces the speed as with the skills at existing alternatives are improved. On the other hand, when the skills in existing alternatives are improved this affects the interest in learning new things. Finding the equilibrium is made difficult by the fact that the same issues occur at levels of a nested system-at the individual level, the organizational level and at the social system level. In evolutionary models of technologies and organizational forms, the choice between exploration and exploitation is presented as balancing the process of variation and selection. In order for an organization to survive, they are dependent on an effective selection of forms, routines or practices. However, it is also essential to keep track of the ever-changing world and adapting to this by focusing on the future. Due to the rapid speed of the change it is important to focus on the future before it appears, an organization will then be able to meet new requirements to for example environmental friendly practice.

Unlike exploitation, the results from exploration is uncertain, there are no guarantees as to what results will come in return for the effort put into the research (March 1991). With exploitation, an organization has something solid to hold on too and they know that the results it will give them will be satisfactory at the moment. As the organization learns how to divide between exploration and exploitation, based on experience, the results they get with affect the lessons learned. Another problem is that the search for new ideas or technological solutions has a bigger time range, more uncertainty as to the result and less certain outcome than improving existing solutions. Due to this, organizations are more likely to focus more on exploitation rather than exploration, and thereby rapidly improving current technology rather than creating new technology. But, can this be related to the “real life”? Do the oil and gas companies focus more on improving the existing technology rather than creating something new and untested? If that is the case, then this uncertainty is clearly acting as a barrier for innovation in the sector. With lack of gambling on exploration follows another problem, the more an organization engage in a certain type of activity and get rewarded, the more knowledge they will get from this activity. Because of this, the bigger the likelihood is for that

type of activity repeating itself, due to the increase in knowledge and the rewards (Argyris and Schön 1978; David 1985 in March 1991). This means that the more an organization choose to go for exploitation rather than exploration, the bigger is the chance that exploration will not be chosen as the area of priority. Since an organization, on a long time perspective, is depended on sustaining a reasonable level of exploration activity, this increasing tendency to focus on exploitation rather than exploration will be self-destructive.

As part of making the decision of exploration of new technology or exploitation of old technology, it is important that the companies have been able to take learning from previous experiences. This will give a higher stimulation towards new technology because increasing learning will make a company able to base new technology on previous experiences (Argyris & Schön 1996). If an organization does not learn from previous experiences the lack of knowledge might prevent them from successfully integrate new technology, this again can become a barrier for future technological implementations.

What is meant by learning? Learning can be understood as either a “product” (something learned) or the process that leads to such a product (Argyris & Schön 1996). In the initial process we can ask ourselves, “What have we learned?” referring to the reflection over what new information we have gained. The second process is when we ask ourselves, “How do we learn?” This is the reflection where one are able to think through how we are learning, is the ability to learn good or bad. When speaking about “drawing lessons from experience”, one implicitly treat the lessons as the “product” and the learning process as the “lessons drawings”. Generally, one can say an organization is learning when they obtain information (knowledge, understanding, know how, techniques etc) of any kind. With this as a background, there is room to say that every company learns, either for good or for ill, whenever they gain more knowledge.

The general schema of organization learning includes a learning product; a learning process that involves getting the hold of information, processing it and storing it; and a learner whom this entire process involves around (Argyris & Schön 1996). An important aspect of organizational learning is an organizations ability to improve its tasks based on the new learning.

According to Sagar & Zwaan (2005), still much is yet to be understood about how to achieve learning and what is really meant by learning. Further, they describe several different factors that will contribute to affect the gains of learning. Within a firm or an industry, improvements

can take place due to learning by manufacturing, which is experience gained trough production process. This also includes learning by operating, which among other things, is about implicit skills that are gained by the workers, knowledge that will allow for a safer and more efficient operation of a given technology. Learning also covers another term; learning-by -implementing. This is when learning is achieved by implementing a given technology and take learning from the experiences of this action (Sagar & Zwaan 2005). Learning-through-implementation can also lead to modification and refinement of institutional structures, structures that frequently play an important role when it comes to uptake of new technologies.

An example of such a structure might be innovative institutional functions for getting finance and maintenance of technologies. These factors might also help with making the deployment processes more effective and by that reducing the cost connected to the execution of a project. Another important aspect to take into consideration is that all the knowledge gained from the learning processes are transferred back into R&D, which again might lead to improved technologies and products in the future.

In order to sum up this chapter one can say; *"The essence of exploitation is the refinement and extension of existing competences, technologies, and paradigms."*(March 1991; 85). Its gains are positive, proximate and predictable. According to March (1991; 85): "*The essence of exploration is experimentation with new alternative."* Its results are often uncertain, distant and often negative. The success of an organization depends on a delicate balance of exploration and exploitation. However, if a company is able to learn from previous experiences it can give them an incentive to choose exploration rather than exploitation. This could give them different benefits, one of the most important one will be increasing profitability by lowering costs on manufacturing, but also the cost associated with installing, operating and maintaining the technology (Sagar & Zwaan 2005).

2.3 Strategic processes

The purpose of this chapter is to look at how the companies can use new technology as part of their strategy. I will discuss different strategies and highlight the challenge of being a first mover. Further, there will follow a discussion of different strategies a company can choose to increase their chances of success as a first mover. For the oil and gas business, this is very relevant because they are skeptic to change and prefer to be a follower rather than a first

mover. The chapter discusses the advantages innovative technology can give, and I believe that new and pioneering technology can give oil and gas company a competitive advantage. An alternative is to use new technology as a mean to get a competitive advantage. Why involve technology into strategic processes? Estimates suggest that of total economic activity in the United States, around 15 percent comes from information technology industries (Hill & Jones 2004). Moreover, this figure actually underestimates the importance of technology, because it does not include other businesses like energy and aerospace. The fact is that an increasing amount of the businesses today are shaped by technology and the circle of high-technology businesses are expanding. Even though the businesses are different they all face the same situation, technology is becoming an even more important part of their strategy plans. They might have different strategies; however, in the end they all want the same result, a competitive advantage. This chapter will discuss different strategies and means of getting this competitive advantage.

2.3.1 Costs in high technology industries

In many industries, the fixed cost associated with production is very high, however the cost for manufacturing one extra unit is relatively low (Hill & Jones 2004). They exemplify this by using Microsoft and their Windows XP as an example. It cost $1 billion for them to develop Windows XP, but the cost of producing one extra edition of the XP is close to zero. Is the situation the same in the oil and gas business? The cost of finding and start production of a reservoir is very expensive, but when all the equipment is in place, the cost of producing one more barrel is virtually zero. This means that the initial cost is high, but the marginal cost of producing one more is low.

To understand why this cost structure is important when laying the strategy one need tounderstand that in many industries the marginal cost increases when they want to expand production (Hill & Jones 2004). In order to produce more goods a company needs to hire more labor, they will have to invest in more machinery and other types of equipment. Usually the extra resources used are not as effective and thereby leads to a higher marginal cost. However, in the high tech industry this is not necessarily the case. An example is the cost of sending an additional bit of information through the telecommunication network.

2.3.2 Intellectual property

New technology based on the effort of intelligent and creative people is referred to as intellectual property (Hill & Jones 2004). The term refers to products made by intelligent and creative people and stretches beyond just new technology, it also includes other creations such as music, art books etc. In our society today we value these types of creations and it is seen as an important economic driver for progress and social wealth. Take for example the creation of a new drug. Only a few percent of all the drugs tested on humans make it to the market. Developments of new drugs are a costly thing and unless a drug company would be sure that their drug would make a lot of money if successful, nobody would want to use the money on creating it. If a company created a successful drug to prevent cancer, it would be a profitable drug, but also give them a monopoly on the market. The last point there is very important, a company would not be willing to use several million dollars on creating a drug that could be imitated by other companies as soon as it entered the market. To prevent this from happening, the law protects their creations by copyright, which means that others cannot copy the product for a number of years.

Intellectual property has gained an increasing role in high technology companies' strategy (Hill & Jones 2004). Creating strategies to protect and enforce intellectual property rights can be an important part of gaining a competitive advantage. In most cases, this means making sure that their patents and copyrights are followed and threatening with law-suits if they are not respected. Law suits have two effects; one, it can sanction those companies that violate the copyright, and two, it can send out strong signals that they will strike hard down upon those who does not respect the copyright and by that prevent future violations.

2.3.3 First mover advantage

In the high-technology industry, companies usually "fight" to be the fight to be the first creator of new products, which is to be the first mover (Hill & Jones 2004). In theory, the first mover whom creates a revolutionary product will be in a monopoly situation. If the product becomes a hit and the demand increases the first mover would gain a lot of profit for their monopoly situation. A situation like this, signals to other rivals that imitating the first mover can be lucrative and save them R&D costs. If the product is easy to imitate a rush of imitators will enter the market and eat up the first mover's profit and leaving all the participants with a lower profit. Regardless of imitation, some first movers have the ability to reap substantial

first mover benefits, for example gaining the advantage of being a pioneer and promoting new products and technologies can give them a competitive advantage. Take for example Intel, they were the first to introduce microprocessor in 1971 and are today leading in this segment. Some pioneers are able to reap advantage of being a pioneer and gain long lasting advantages, in other words, slow down the speed of imitation. However, this is not always the case, sometimes it is not as easy to catch the first mover advantage, and actually sometimes, it can be a disadvantage to be a first mover. An example of this is Apple's effort to create and launch a hand held computer, the Apple Newton, it failed and Palm was able to conquer this market. Based on this, one can say that being a first mover is not necessarily a success formula. The level of success will depend on the first mover's strategy.

What are the first mover advantages then? Usually the advantages can be separated into five categories. First, they have the possibility to exploit network effects and positive feedback loop, locking the consumer into their technology. The second advantage is, establishing a significant brand loyalty. Should the company be successful in this then the market would associate their brand to the product. Two companies who have accomplished this is Xerox and FedEx, these brands has given root to expressions like "Xeroxing" and "FedExing". First mover might be able to ramp up sales before imitators enter the market, and reap cost advantages connected to realization of scale economics and learning effects. When a first mover gains these cost advantages it can be used as a defense against imitators, for example reduce prices and by that maintain their market share. Fourth, by creating so called switch costs they can secure loyalty from the market. An example used by Hill & Jones (2004) is a provider of wireless routers who offered a free phone included in the package, however should the user terminate the contract before a given date, they would have to pay for the phone. By doing this, the first mover makes the imitators offer less attractive. Finally, the first mover can gain knowledge about what the market wants based on the feedback they get from the market. This makes it possible to upgrade the innovation into meeting the markets needs.

It is also important to mention the disadvantages of being a first mover. The first mover would have to bear the pioneering costs that imitators do not have to (Hill & Jones). In addition comes pioneering the technology, develop distribution channels and educate the market about the technology. This is activities that is time consuming and costly and is something that later entrants would not have to do, because the first mover have already done it. First movers are more likely to make mistakes since they are entering the market with a new product, on the

other side, late entrants might be able to learn from the first movers mistake, as Palm did from Apple's effort with hand held computers.

2.3.4 Technological paradigm shift

A technological paradigm shift occurs when a significant new technology enters the market and change the industry (Hill & Jones 2004). It alters the nature of competition, it changes the structure of the market and it forces the existing companies to make changes or else they risk running out of business. A good example of a paradigm shift is the transition from chemical to digital photography. Kodak and Fuji film were one of those who had build up a big market share on the chemical photography market, but now they were facing a new threat, digital photo. This meant that people no longer had to go to a photo shop to get their pictures, but could print them out at home. One of many questions that rise when speaking about paradigm shifts is, can these changes be foreseen? Richard Foster has developed something he calls the S-curve, which is a formalization of the relationship between the performance of a technology and time.

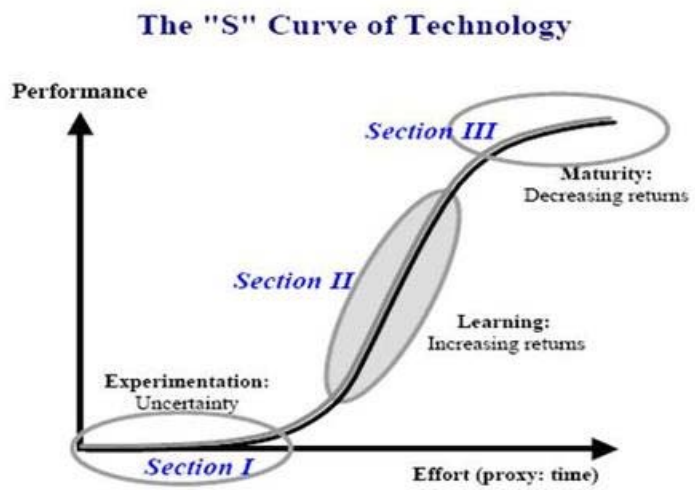

Figure 2: The S-curve showing the different stages for a product (gotoknow.org)

As seen above the S-curve shows the development and maturing of a new technology. When a technology reaches section 3, the maturing phase, new technology will most likely enter the market and take over. In the beginning the company will invest a lot of money into R&D but as the technology matures less and less are used and the company's focus will be on new and better technology. According to Hill & Jones (2004) who refers to Foster, the natural cycles of

a technology is that when the technology reaches its natural limit, research attention turns to other technologies that might be commercialized and replace the existing technology.

This section has described how high-technological companies can use technology in order to gain a competitive advantage. It has described the situation of being the first mover, the advantages and disadvantages of this. Further, I have through this section described how a technological paradigm shift can cause new challenges for companies who are not able to adapt. It also covered the cost structure of this type of businesses, usually the innovation and creation cost is very high, while the production costs in itself are low.

2.4. Technology transfer

My next theory deals with technology transfer. The reason for this is that it describes a way where the companies can move beyond their own fields of competence in order to find new technology. If done successfully a company would be able to use technology familiar in other business areas and adapt them into their own. A successful system of this type would definitely be an incentive for a company to implement new technology. I have just discussed the issues related to exploration versus exploitation, and the importance of combining old with new to achieve success. If the companies can acquire the right type of information, it would make it easier for them to go for new ideas.

In order to understand technology transfer, it is important to understand what technology in this context is. "*Technology is a tool for accomplishing some functions. The tool might be a mental model or a machine." (Rogers & Valente 1991 in Agmon et.,al 1991:104).*Technology transfer in the high technology industry is different from technology transfer in other industries such as manufacturing, service etc. Technology transfer might also consist of persuading an organization to use a certain technology instead of another. The technology process consists of the exchange or movement of technological innovations.

Rogers & Valente (1991) in Agmon et.al (1991) who refers to Larsen et al., (1986) explains technology transfer as the process were technological innovations are exchanged between individuals and organizations who are involved in R&D on one hand, an involved in putting the technological innovation into use on the other hand. Traditionally technology transfer involved the transfer of physical goods, today however, it involves information. Since technology is information, then technology transfer is communication of that specific

information. Put into the context of this thesis, technology transfer is the communication of the information that makes the oil and gas companies create new technology to accomplish a certain goal. The effectiveness of the transfer can be measured by the discrepancy between information transmitted and the information received. However, according to Camp & Sexton (1992) effectiveness should be less about the accuracy in the information exchange, and an increased focus on return on investment.

Technology transfer is usually a two way process (Rogers and Valente 1991 in Agmon et., al 1991). We can define technology process as a type of information exchange. Instead of seeing technology transfer as one certain event, it should be regarded as a continuous process. For example, a private firm might develop a close relationship with university researchers, maintain it over several years, and exchange knowledge. For a technology transfer to occur, there has to be a technology to exchange, or transfer from one organization to another. One major actor in the technology transfer process is research universities, or institutions of higher education, which main purpose is to conduct research or train students into doing research. It is not a coincident that each of the major high-technological centers in the USA is located close to a research university.

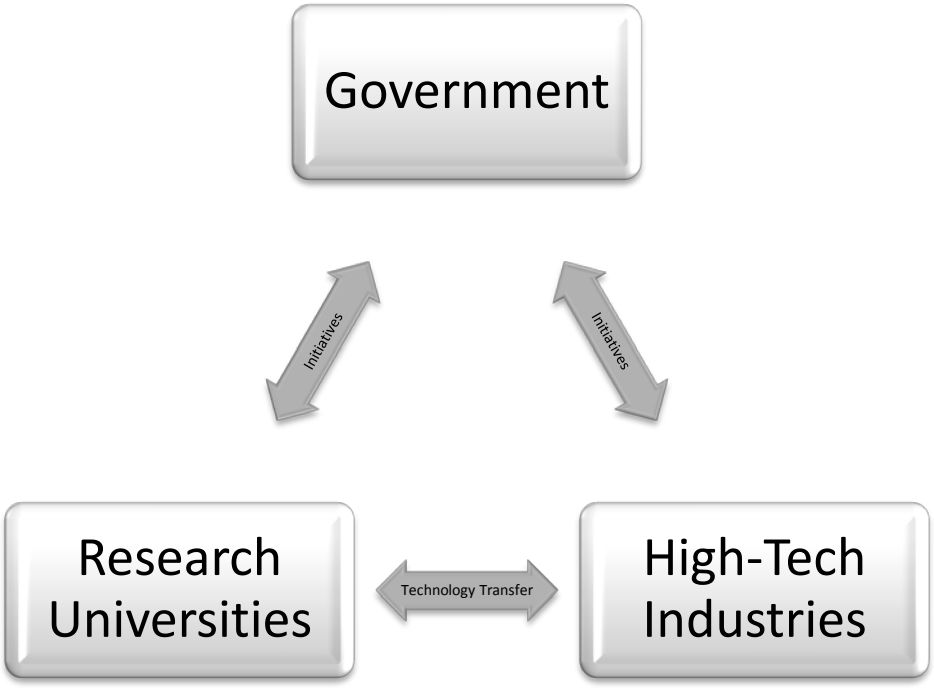

Figure 3: The Technology Process (Rogers & Valente 1991 in Agmon et., al 1991)

The purpose of this model is to give a better picture of how technology transfer can work in the private industry. On the top, you have the government who stimulate to technology transfer through giving money to the research universities. The government gets money from the industry through taxes. Research Universities have researchers who help the industries with knowledge and research, which leads to new technology. This type of technology transfer is typically a transfer of knowledge from one organization to another.

For organizations pursuing a competitive advantage with implementation of new technology, technology transfer and product development are not exclusively mutual processes (Camp & Sexton 1992). In order for an organization to benefit from technology transfer process, they are dependent on having the possibility to treat the knowledge in way that will give them this competitive edge. If this knowledge or ability is not present it will be difficult for them to create the new technology, however if the right conditions are present, technology transfer can give them the little extra edge.

The transfer can be divided into three different stages; the first stage is the obtaining of new knowledge or information (Camp and Sexton 1992). The second stage can be described as the process of taking the obtained information and transfer it into a new product or technology. The third and last stage, is recognized as the steps needed in order to introduce or position the

product to the market. Is it also like this in the oil and gas industry to? The company gain knowledge about how to develop new technology and convert it into the specific technology and then launches it at the fields or to governments?

The conventional model for development of new technology, consist of five stages. (1) basic research, (2) applied research, (3) development, (4) commercialization, and (5) marketing (Rogers & Valente 1991 in Agmon et., al 1991). The Universities mainly conduct basic research while private companies do the rest. Below I have made a model illustrating the different stages in the technology transfer process.

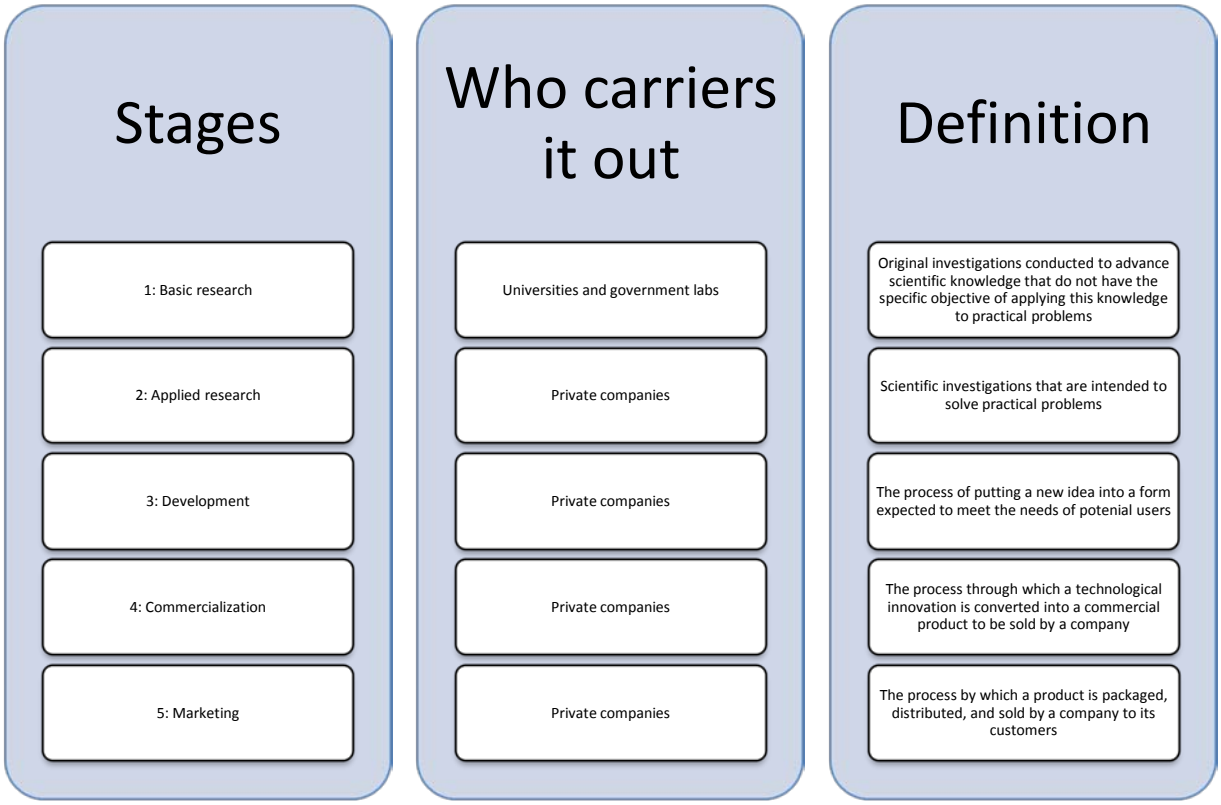

Figure 4: The Model of Conventional Stages in The Technology Transfer Process (Rogers & Valente 1991 in Agmon et., al 1991).

To sum up, technology transfer can be described as the process of gaining knowledge from other scientific fields in order to develop new technology. An important part of technology transfer is cooperation with other research universities. Technology transfer deals also with transfer of technology across different industries.

2.5 Sum up of the theoretical frames used

I will now give a sum up of the different theories used in for this thesis. The theoretical frame chapter, started with a model describing the different theories and how they affect the technological development, I will use this model as a basis for my sum-up to link everything together.

In institutional theory, I spoke about how the environment around the business can affect them as a driver or barrier towards developing new technology. It separates itself from the different ways it affects the company. We separate between coercive, mimetic and normative isomorphism. One of the keywords for this theory is legislation through isomorphism. The companies always search for legislation, a sort of acceptance for their business. However, it takes form in different ways. With coercive isomorphism, the company feels forced to do change so that they achieve legislation. In mimetic isomorphism, a company is faced with uncertainty and as a response to this, they look towards other companies and model their strategy or way of doing things. The last one is normative isomorphism, this when the network around the company affects their technological choice. Engineers who have the same education might make them less innovative. It may also be the case with the top leaders in a firm; many of them recruited from the same environment and by the same criteria's and have been thought to lead in a certain way. This might work as a barrier for developing new technology in the sense that the leaders become conservative and afraid of separating themselves from others. Institutional theory can work as both an external driver for new technology and an internal barrier for developing new technology.

Furthermore, this chapter has discussed other theories such as exploration versus exploitation theories, strategy and technology transfer. Exploration versus exploitation deals with a company's choice between using new technology or old technology. This choice is something that will always be a challenge and the results can be either very good or very bad. However, we learned in the chapter that in order for a company to survive it has to find a perfect balance between using old and new technology. The driver for exploring new technology can be external and internal. An example of external driving force would be if they were to discover new fields that would require a new technology. An example of an internal barrier would be if it was possible, they would use the current technology, which would act as a barrier towards new technology. An important factor for this choice will be the company's ability to learn from previously experiences. The reason for this is that the improved knowledge will make it

easier to develop new technology rather than using current technology. In learning theory, we saw that by taking learning from previous experiences, it can work as an internal driver to develop new and better technology. This reason for this is that the learning will come from within and by that be the internal competence that will drive the new technology forward. At the same time, it might act as an internal driver to, if the companies are not able to take learning from a project or use the learning in a wrong way it will hamper the willingness to develop something new. For example, if developing a new technology has caused tem big losses, they might not be able to look at what the problem was and avoid doing it again.

I then discussed strategy, which deals with using technology as a strategic "weapon" to gain a competitive advantage. This sub-chapter discussed different issues like making the market dependent on your product, and gaining the first mover advantage. I would characterize this as both an internal and external driver for new technology. If a company have employees with good technological knowledge they might be able to design technology that others will be dependent on. This can typically be for the supply industry, they manage to create a technological solution they can sell further to other oil and gas companies and create a competitive advantage. But, the market, an oil company for instance, might also search for a new product and might assign a sub-supplier with the task of creating a technology that would be suited for this and this. Another external driver might be that they see the competitors launch a new technology, however this has some obvious flaws that make the market reject the technology. A second mover might then use this advantage and create a new technology that covers these needs.

My final section dealt with technology transfer, which deals with how companies can develop new technology based on knowledge from other scientific fields. The theory explained that one of the major actors in technology transfer is research universities. Technology transfer does not have to be about the physical technology, but also the transfer of knowledge from one organization to another. It can act as an external and internal driver, based on that technology will come from outside the organization, by in the same way there have to be someone taking imitative to adapt from other scientific fields.

To make this more readable I will present these results in a model, with the different functions it has.

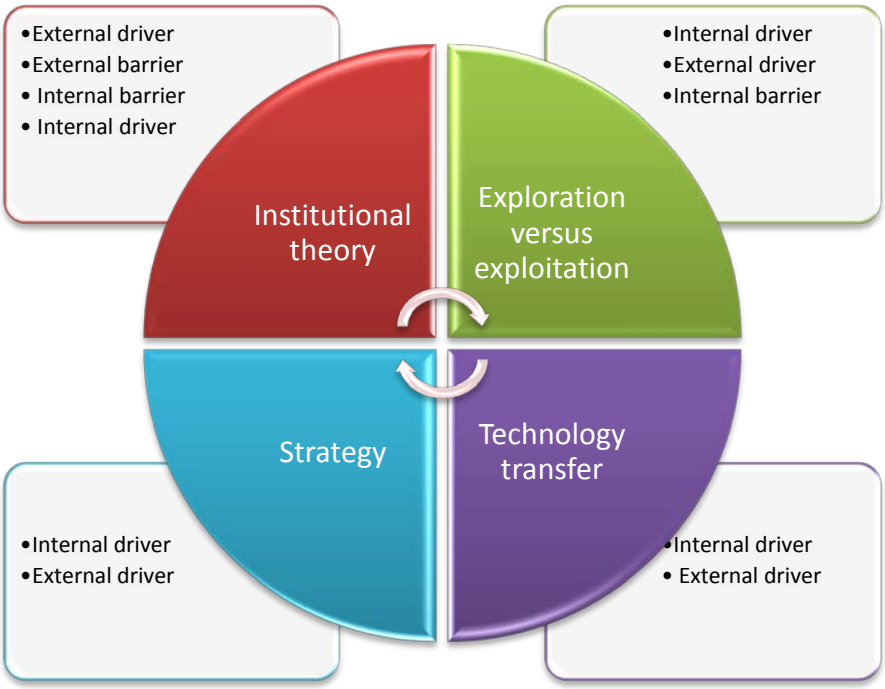

Figure 5: Sum up of theory chapter

The purpose of this model is to show how the different theories fit in with drivers and barriers. Each "piece" of the cake represents a theory and the boxes around them shows how they work as either driver or barrier. I have separated between internal and external because it gives a better image of which forces affects the technological development in the oil and gas industry.

3.0 Methodological reflections

In this chapter, there will be a discussion of my approaches for data collection and an argumentation for choice of methodology and research design. The chapter will then continue with a description of how the analysis will be done before ending with a discussion of validity reliability and the ethical considerations I need to take as a researcher.

3.1 Qualitative Method

When performing a research there are two different approaches the researcher can choose from, either qualitative method or quantitative method (Johannessen et,al., 2005). Which one

is the right one to use will depend upon what the purpose of the research is. Qualitative approach is very good if one would like to study a phenomenon and get a better understanding of it. It is especially suited for research where the researcher does not have a great deal of pre-knowledge about the phenomenon that he is studying, and there has not been much previous research on it. In order to understand the phenomenon, the researcher needs to be out in the field and get involved, talk to people and see how the society is acting. Quantitative data is better when the purpose is to measure something specifically. It can also provide a wide coverage of a range of situations; however, quantitative data are not as useful in understanding the reasons behind the situation. It is worth mentioning that the researcher is not locked into one specific method, if he wants to he can mix qualitative with quantitative.

The purpose for my thesis is to get a better understanding of the forces that affects the decision makers in oil and gas companies concerning development of new technology. In a quantitative approach, I could measure the amount of times an oil and gas company creates new technology, however it would not give a description of the underlying reasons and incentives for doing so. By doing a qualitative study, it would be possible to go in depth with the challenges that faces an oil and gas company when considering new technology. In addition, I would like to find out what hinders such a company from developing new technology. A survey could give me an idea and understanding of what factors might be the most important one, but it would not explain how they work. The goal of this thesis is to create a general understanding of what affects an oil and gas company's choice between new and old technology. At the same time, I want to make a description of the different incentives to use unproven technology. Based on this, the best thing for my thesis would be a qualitative approach. It would give me an opportunity to gather more information about the reasons behind decisions, and better understand what the important drivers and barriers towards new technology are. Due to the complexity of the thesis, it would be best for me to gather as much information on the area as possible rather than performing surveys. A survey would not be able to capture the mindset of the decision takers, which I believe is important if one wishes to gain a better understanding for why they make their choices.

According to Johannessen et., al (2005) qualitative research is best suited on three different types of research questions. The first is when the researcher wants to describe something specific connected to specific actions or happenings. The second one if when research questions that has the purpose of seeing how the informants interpret specific actions or events. The last one is when the research question is theoretical and has the purpose of finding

out what lies behind certain actions. Johannessen et., al (2005) who refers to Kvale (1997) say that a qualitative research has the purpose of bringing to light the informants everyday in order to interpret the meaning of the phenomenon's described.

3.2 Design

In short, case comes from the Latin word *"casus"* which means case (Johannessen et., al 2005). Case design is suitable when the purpose is to study one or more cases over a period of time through detailed data collection. There are two major characteristics with case design, which is a limited focus on the case and a thorough description of the case. This is done in order to generate as much information as possible about the phenomenon that is being studied. Case design is well suited for research that are explorative, descriptive, explanatory, understanding and evaluative. This is suitable for my thesis since it is trying to generate an understanding of why change occurs and what drives these changes forward.

For this thesis, I have chosen an explorative case design. The reason for this is that I want to study a case over a certain period of time, which is the oil and gas industry and what affects their choice of new over old technology. Case design is suitable when the purpose of the study is to describe and create an understanding of why phenomenon x occurs (Johannessen et., al 2005). The purpose of this thesis is not to develop a new theory but to create an understanding based on existing theory. A key word here is meaning, through my research the reader will gain a better understanding of technological drivers and barriers in the oil and gas industry. Case design is well suited for in-depth interviews, which is something that I will do for this thesis.

3.3 Data collection

In order to make a good thesis the researcher needs to gather good data to build upon. For this thesis, data collection will happen mainly through in- depth interviews. In order to do a good interview it is important to possess some knowledge about the theme you are going to discuss with your informant. I have therefore chosen to read books and articles that will give me a better understanding of what affects a company's willingness to change. By doing this, it gives me a better understanding of the environmental forces surrounding a company, both

internal and external. Based on the knowledge gained, I created an interview guide that would be best suited for my interviews.

In addition to the primary data, the thesis will also be build upon secondary data. The secondary data helps to give a background for my topic and consist of books written by people with experience and knowledge from the oil and gas industry and articles written about the topic.

3.4 Interview guide

As opposed to when using a quantitative approach, the interview guide for qualitative is not a questionnaire with locked answers, they can be semi or partly structured interview guide with themes covering the research question (Johannessen et al., 2005). However, it is important that the interview guide works as a guidance through the interview and helps the researcher guide the informant into the right path, which is the things you are trying to find out.

For my thesis I felt it was best to use a semi-structured interview guide, the reason for this is that allows me as a researcher to have an open approach to the interview and at the same time, as far as possible, similar questions to each of the informants. The advantage of using this type of interview guide is that it makes it easier to analyze the answers I get and compare them to each other.

I have divided the interview guide into two different stages, the exploration phase and the production phase. The reason for this is that these phases include very different technology and cost levels. In addition, it could be interesting to see if there are different forces that affect the exploration phase than what affects the production phase. My interview guide is included in appendix (1). The informants have been asked what they believe are the different drivers and barriers for innovation in the industry. In addition, the guide included some alternatives, which was included to help me during the interview.

Each section ends with a question of what they believe have been the most significant technological innovation for that specific phase. This is done in order for me to get a better picture and understanding of how the technologies have evolved during the lifetime of the Norwegian oil and gas adventure. The final question offers the informants a possibility to give

some predictions of what will come in the future, and what needs to be in place in order for these technologies to be developed.

3.5 Interviewing

My choice of data collection is through in-depth interviews with people who have experience from the industry. My informants have a varied background, which is an advantage because it will give me different viewpoints. Johan Petter Barlindhaug has experience from a small oil and gas company, being one of the founders of NorthEnergy. Lars Kullerud has worked on numerous projects regarding exploration technology in oil and gas companies. Cato Wille works at Statoil in Trondheim and is the chief of research. During the interviews, I used the questions from my interview guide, which helped me to keep the interviews structured and lead the informants into the topics that were of interest to me. Since my guide was based on a semi-structured base, it was possible to add questions during the course of the interview. The best way to perform an interview is face-to-face because it makes it easier to get a connection with the informant, which again will make it easier for the informant to relax and lower his shoulders. However, this is not always an option, which is something that I experienced for my interviews. Luckily, there are other options to carry out an interview, for example by phone or through mail. For this thesis I have had three interviews and just one of them has been face-to-face, this was my interview with Johan Petter Barlindhaug. My interview with Lars Kullerud was carried out through Skype, which is a tool for communicating over the internet where one uses the internet as a telephone. This worked surprisingly well and the sound was very good. My last interview, which was with Cato Wille, was done over phone, which also worked very well and the sound quality was good. Common for all three interviews was that I used a recorder to tape the interview in addition to taking notes in case the tape recorder would malfunction. By doing so, it was easier to get a hold of all the information.

3.6 Analysis

Before starting any analysis, the interviews would need transcribing. Since they have been taped, it would be best to transcribe it word by word, in order to make sure that everything is mentioned. This is a tedious process and takes time. The normal rate is a 4:1 ratio that means four hours of transcribing one hour of interview (Smith et al., 2008).

My empirical findings will be linked up with the described theory. In other words, my empirical data will be explained by the theory. The theory chapter describes what a can act as drivers and barriers for new technology. Take for instance institutional theory, which describes that a company might be forced to change their technology. For the analysis part, I try to find out how this works in practice. During the interviews' the informants have not been asked "theoretical" questions because this would not have any purpose. Therefore, it will be my task as researcher to connect it with the theory. For example, when the government creates new regulations concerning the environment, this could force the companies into creating new technology, it can be described as a coercive isomorphism. Another example is technology transfer; Statoil uses technology that is known in other industries, but not in their own sector, for example CT-scanning. When this has been linked up too each other, I would further need to find out how it acts as a driver or barrier.

3.7 Validity and Reliability

This chapter will discuss the validity of my findings, based on the data I have gathered and how this has been treated. The term reliability deals with which data that have been used, how they have been collected and how they are handled. Reliability is an important part of quantitative research, and there exist different ways of measuring the data's reliability (Johannessen et al., 2005). However, since my data have been collected by doing interviews, measuring reliability is not very practical. Duplicating an interview situation is not possible since there are many variables that come into play, the atmosphere that generated the specific answers', the way the researcher asked the questions etc. Another reason is that in the interpretation process, the researcher uses himself as the background. Since nobody besides the researcher will have the experience and background, another person will not be able to put themselves in the interpreter's shoes. In order to make my research more reliable I have described the process of getting the information and the processing of my findings.

Another thing I have done in order to improve the reliability of my paper is to get an approval from my informants to use everything said during the interviews and refer to them. The reason for me to do so is to show where my information is coming from and to show that it is not information made up to fit into the rest of the thesis. By making the interview guide open, the informants have not been asked question in way that their answers would fit my understanding of drivers and barriers. They have been asked about their views and opinions on the matter and have been given the opportunity to think for themselves. This improves my reliability because it shows that my results come from the informants and not me.

With a quantitative research, the purpose is to end up with a result that is possible to generalize and quantify (Johannessen et., al 2005). However, this is not the case with a qualitative research study, and not the case with my study. The purpose of this study has been to gather views from people in the industry in order to build further on a theoretical model and gain a better understanding of the topic.

Validity is another way of measuring the reliability of a study (Johannessen et al., 2005). A common understanding of validity of quantitative cases is done through the question: "Are we measuring what we think we are measuring?" according to this definition, qualitative research cannot be measured because it is not possible to measure the result. Nevertheless, what one can do is to check to what extent the observations reflects the phenomenon that really was of interest. In other words, are the findings reflecting the purpose of the study? This is an important aspect of a research and for this thesis as so. This is something that has been of importance for my thesis. By increasing my knowledge within the field of this research, it has been possible to dig deeper into the informants' statements. Gaining a better understanding of the topic as a researcher sends a positive signal to the informants and makes it easier to know which information is important and get the informants to speak more about this. When doing this the informants will be more amenable to give a better and more detailed interview. I believe by doing so it has strengthen the validity of my thesis and it has been possible for me to use follow up question to get more in depth of interesting sides of the phenomena. Another thing that strengthens my thesis is that the information obtained, comes from people with different backgrounds, which have provided the thesis with more than one perspective.

Another measuring method is through transferability, or so called external validity. The idea here is that the result reached, should be possible to transfer back to other cases (Johannessen et al., 2005). Research is more than just gathering the observations and presenting them, they

need to be analyzed and coded. All research has the purpose of being able to draw conclusions beyond the immediate information gathered. This situation is also current for my thesis, I am studying what drives and hinders innovation in the oil and gas sector on the NCS. However, this does not mean that the result from this thesis will only be relevant for the oil and gas sector. The oil and gas sector is an industry where skilled people and good technology is important; however, this is also the case with other types of high technology industries. This thesis could be used as a tool to better understand the effects the companies' environment will have on their willingness to promote new technology. In qualitative research, one speaks of transfer of knowledge instead of generality (Johannessen et al., 2005). As mentioned earlier this is the case with my thesis too, it gives a better understanding of why the companies sometimes choose to change their technology, while other times stick to old and reliable technology.

3.8 Ethical consideration

As a researcher it is important that the research follows the ethical guidelines, which means the rules and the guidelines for considering if something is right or wrong (Johannessen et al., 2005). Ethics is primarily about the interaction with other humans, that is what we can and cannot do to each other. An ethical consideration is important when collecting data for example through interviews.

In my research, this has been an important topic, and I have tried to make sure that the ethical standards have been present during my data collection. For example, when using the recorder I made sure that this was not any problem for the informants. Actually, it would prevent any wrong quotations since a complete transcription was done, word by word. It was important for me as a researcher to make sure that the informants were aware of their rights. They were informed that they could quit the interview if they should feel like this. My informants have been given the option of anonymity and any use of their names in the thesis has been clarified with them in advance. In order to secure this, a complete transcription of the interviews has been sent to each of the informants asking for their permission to use their names in the thesis. All my informants have given their approval for the usage of their names in this thesis.

During my role as a researcher, I could come across sensitive information that is useful for my thesis but at the same time should be kept away from the public. If this type of situation were

to occur, it would be important for me as a researcher to have guidelines for how to treat this sort of information. By having these guidelines, the information gained from my informants would be protected and the valuable information could be used in my thesis. An option then would be to sign a contract stating that the thesis should be withheld from the public due to the content of the paper. At the end of the research process, any sensitive information would be destroyed to maintain the anonymity of the informant.

My personal experience as a researcher was that it was an advantage to come prepared for any situation like this. In my case, none of the informants have given any specific requirements regarding the information from the interviews, accept for approval of any quotations.

4.0 Findings and empirical data

In this chapter, I will present the findings made through my interviews and secondary data. The purpose of the chapter is to see what representative from the oil and gas business see as drivers and barriers for new technology and how the environment around the businesses have affected them to change. To make this chapter readable I will divide between drivers and barriers. First, there will be a presentation of the historical technological development on the NCS, this is done to highlight the most revolutionizing technologies and to give a better basis to understand how Norway and Norwegian companies managed to gain the necessary competence to participate in the technological development on a later basis.

4.1. Historical technological development

This chapter will present a timeline for important technological innovations on the NCS. The purpose of this is to get a better picture of how the development has been and then give a description of each of them and present some underlying reasons for why they were developed.

Before oil was discovered in Norway, Norwegian geologists had concluded that it would be no chance of discovering oil in the North Sea (www.regjeringen.no). However, findings in Netherland gave optimism among the oil and gas companies and in 1962, Phillips Petroleum sent a letter to the Norwegian government asking for a license for the part of the North Sea located on Norwegian territory. The offer was lucrative, according to the standards of that time, 160 000$ each month. Luckily, for Norway, the government at that time saw the offer as

an attempt to gain monopoly on the entire NCS, which they could not accept. A year after this, Norway passed a new law claiming their sovereignty over the NCS, saying that it is the property of Norway and only the government could give licenses. In 1969, Phillips Petroleum found the Ekkofisk field, which was given the description and elephant field based on the amount oil present. This discovery was the beginning of the oil and gas adventure at the NCS.

When the American oil companies first came to Norway, they brought with them new technology that worked in other offshore fields, for example the Mexico gulf (http://www.norskolje.museum.no/). This technology was the best in the world at that time and the companies felt sure that it would be good. It soon turned out that the existing technology could not cope with the conditions in the North Sea. Because of this, they had to create new technology because of the weather conditions and depths were the petroleum was. At this time, Norway did not have any petroleum industry and processed no knowledge about oil and gas production. However, what we did have knowledge about was other types of industry, for example, concrete and aluminum and this knowledge came to use when creating the different platforms used in the NCS. Esso used a semi-submersible platform to drill for oil in 1966, which turned out to be well adapted to drilling in the North Sea; however, they soon experienced that the construction was too weak. The solution was then to use Norway's competence on shipbuilding, and a new platform was build with the help of Norwegian shipyard.

Figure 6: The Technological timeline

The different technological breakthroughs are shown in the timeline above. During the lifetime of the oil and gas industry in Norway, there have been many different inventions. I believe the technologies mentioned in the timeline are the ones that have had the biggest impact on the Norwegian economy, and represent the biggest technological breakthroughs. The era for sub-sea installations started in 1981, however its breakthrough was in 1991with its role in the TOGI project. Each route is fitted with a picture of the technology, while the question mark represents the uncertainty of the future.

4.1.1. Steel Constructions

In the start of the Norwegian petroleum adventure, the first platform jackets were constructed of steel. At this time, this was the leading technology and was first used in the Mexico gulf, and then transferred to the NCS (http://www.norskolje.museum.no/). In total 63 platforms have been build of steel on the NCS. The technology was effective and well adapted for the North Sea, however it was best suited for shallow sea level. Aker constructed a steel rig that should withstand 30 meter waves, increased strength even with reduced steel use and improve the rigs mobility. This new platform received the designation Aker H3 and was such a success

that other companies around the world started building similar rigs on license from Aker. The first steel platform used was the Gulftide platform used at the Ekkofisk field. However, this installation was very simple and thereby removed and replaced in 1974. The big advantage with the steel platforms was the cost. Building the platforms was not very expensive and therefore it was possible to build many and place them around the different fields discovered in the wake of the Ekkofisk discovery.

4.1.2 ConDeep

ConDeep has its roots in the "Ekkofisktanken" (http://www.norskolje.museum.no/). In the 1970's, when the oil and gas companies first started production at the Ekkofisk field, there were no infrastructure to transport the oil and gas to the market. This meant that the only alternative was to use SPBM solutions. However, for this to work the weather conditions had to be good and in the North Sea it can be harsh winter storms. In order for the companies to keep production up they needed something to store the oil in, the solution was to build a concrete tank which they could store it in. Based on its success, it was developed further with the result being the ConDeep platforms. The construction is, a platform stored on top of huge tanks made out of concrete. Statfjord A was the first ConDeep platform on the NCS and the building of it was the turning point for Norwegian companies and Norwegian solutions on platform design. ConDeep platforms were more expensive to build than the steel constructions, however the advantage was that the platforms could be assembled prior to transport to the designated field. This removed costs connected to lifting and assembling the platforms later. In addition, the concrete structures could carry more equipment, which was necessary for big production. The platforms were constructed as integrated platforms with drilling facilities, living facilities and process equipment on the same platform. ConDeep platforms were being build almost as serial production and were almost supreme from the end of the 70's and through much of the 80's. However, in the beginning of the 90's the period was over. Decreasing oil prices meant new solutions that would make the production more profitable by reducing costs.

4.1.3 Horizontal drilling

The most important leap to make more effective production wells came with horizontal drilling (http://www.norskolje.museum.no/). This technology has made it possible to extract more oil from the fields with a minimum of wells and platforms. By creating and implementing the horizontal drilling, it has made fields not normally seen as profitable, profitable. A good example of this is Troll Olje. While the Troll field is most known for its huge amounts of gas, it also contained areas of oil which at the point of discovery not seen upon as profitable. The oil is located in a thin layer but stretches over a large area. By using normal vertical drilling, it would be unprofitable due to the number of wells needed to extract the oil. In 1989, Hydro drilled the first horizontal well. Due to advanced horizontal drilling and new technological solutions, a field first described as only a gas field had become one of the largest oil producing fields on the NCS with a top production of over 400 000 barrels a day. Actually, the Troll field has been an important field for the development of new technology on the NCS. With almost half of the advanced wells in the world drilled at the Troll field. Nevertheless, how does horizontal drilling actually work? First, the oil companies drill what they refer to as a production well, this goes straight down and is the well that will bring the oil up to the surface, or the platform (www.statoil.com). After that, they insert a flexible drill into the production well that will drill out to the side and into pockets that might lay 2000 meters away from the initial drilling well. The industry refers to this technology as Through Tubing Drilling and Completion technology. It will save the companies approximately 4 million USD per operation.

4.1.4 Multiphase transport

Normal oil and gas production consist of separation of oil and gas on a platform near the wellhead before further transport (http://www.norskolje.museum.no/). Dried gas is send through pipelines to the market while the oil is shipped by boats or in a different pipeline. For this to work each field needs to have a platform with process equipment. There have since the 1980's been a continuous research going on in order to find solutions that opens up for transport of unprocessed well flow to a platform further away or a process plant on land. Multiphase technology got its break through with the Troll field. Due to the weight of the platform, it would not be possible to construct a processing plant on the platform because it would simply make the platform to heavy for transport and lay to deep in the sea. The solution to the problem was to build a plant for process of gas on land. In order for this

solution to work, a further development of the multiphase technology was necessary. Multiphase technology has been crucial for projects like Ormen Lange and the Snøhvit field.

4.1.5 Sub-sea installations

The first sub-sea installation in the North Sea was the Nordøst Frigg field. In addition, TOGI, which was installed in 1991 on the Troll field, was a technological new step (http://www.norskolje.museum.no/). The depth was now 300 meters, unlike the Frigg field that was on 102 meters and was 48 kilometers from the Oseberg platform. This situation demanded new technology that would withstand the pressure and transport of unprocessed gas over the big distance. Since then, the technology has moved on with processing plants on the seabed on a numerous fields and with sub-sea installations on depths between 300 and 1100 meters. When the first installations came 1986 it revolutionized the industry, how was it possible to move an entire production facility from the platforms and down to the seabed (www.Statoil.com). When the second generation came, they were put to use on already existing fields, around the Statfjord field there were several small fields that were not economical profitable to defend having their own platform. However, by putting these sub-sea installations to use they could connect them with the production facility at Statfjord. The NCS soon became the pioneer for sub-sea installations, and Statoil explored the possibility to use the technology on other international fields too. Soon the systems became smaller and more effective and the cost of production dropped. As new fields became increasingly tougher the demands to the technology grew, and with the help of new generations of sub-sea installations fields that previously had been regarded as impossible, were put into production. The last generation of sub-sea installations deals with a known problem with sub-sea installations, their inability to produce as much oil as would be possible with a platform. These systems are referred to as smart wells.

4.2 Drivers for new technology

I will now present my findings from my interviews. My informants pointed several drivers for developing new technology. As seen in the model below, my informants emphasized several factors that act as a driver for new technology.

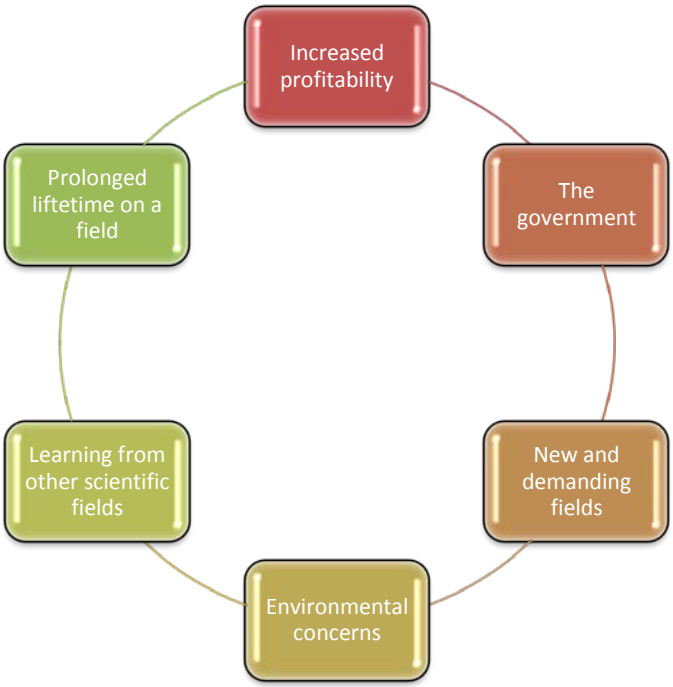

Figure 7: Drivers for new technology

4.2.1 Increased Profitability

According to my informants, the number one driving factor for new technology is increased profitability. The companies always think about how maximize their profit. New technology can reduce the costs connected to drilling. For example by implementation of horizontal drilling, a solution that made it much easier for the oil companies to drill for oil. It saved them for a lot of time, and time is money. The time versus money aspect can be seen in correlation with the costs of renting a rig. Renting a rig can cost everything from 170 000$ a day and up to 500 000$ a day (www.offshore.no). The companies always seek to reduce their costs connected to production. The lower production costs they have the more competitive they are. It is not a big challenge to be profitable when the oil price is 130$ a barrel, but when the price drops it is important to have cost optimizing production.

The conditions at the NCS is not necessarily the most optimal compared to other places in the world, for instance in the Middle East where they have light crude. Kullerud (2010) mentions the oil price as a big player when speaking about drivers; when the price is high, the exploration activity is high and the production is as high as possible (without affecting the oil price). For him this is a strange and very short-minded strategy because the rates are higher at this moment since they are competing with everybody else. So instead of using the oil price of today as the basis for exploration activity, the companies should think ahead. However, when speaking about production it would without doubt be good for the oil companies to have as high production activity as possible due to the potential high profit they would receive from it.

When discussing exploration technology, the rig is mainly used to drill straight down to see if there are deposits of oil or gas in the area. This is the most expensive part of the exploration process, and therefore the incentives would be present to make some changes in the way they do exploration. Drilling is expensive and a company would want to drill as few drilling holes as possible to keep cost down. By using a different approach, they could reduce the costs associated with test drilling, for example use horizontal drilling and drill more wells without having to move the rig.

In addition, it would be desirable for a company to increase their production ratio, the more oil they sell the more money will they get. Technology that will make the production be more effective will cause the companies to earn more money. When the companies discover small fields that are not big enough to defend a new platform, new technology has made it possible to connect them with existing fields located in the area of the discovery.

The companies might be conservative with regards to new technology, however when it comes to exploration technology that might decrease the chance of drilling dry wells the companies have a low threshold to implement (Wille 2010). As mentioned previously, when doing exploration work, drilling is the most expensive part. If the companies could, together with good technology and increased knowledge among the employees, reduce the risk of drilling dry wells it would mean a cost cut. EM-technology, Electro Magnetic waves, is a good example of a technology driven forward by a wish of better exploration results. When the companies use normal 3D seismic it gives a reflection of what lies beneath the seabed by using pressure with the result being a measurement of the density of the measuring unit. This means that oil and gas will have a different density, and it makes it possible to separate between those two. When using EM technology you will measure the characteristics of the

measuring unit, oil and gas will have the same characteristics while water will have different. This makes it possible to separate between petroleum and water. If this information combined with ordinary seismic, it will be possible to be surer when drilling as to whether or not it will be petroleum deposits at the drilling place.

4.2.2 The government

Another important reason for change is regulations from the government. These regulations may not always be welcomed by the industry but they do lead to change.

Take for instance the tax-regime Norway have for operating costs connected to exploration. The Norwegian government gives refund to 78% of the money spent on exploration, which acts as an incentive for the companies to create new technology. If the technology does not work properly, they will still get as much as 78% of the money back. There are no other places in the world were the companies can get this offer, and it is good example of how the government try to stimulate to new technology. The idea behind this is that the companies pay 78% tax on their profit, but they will also get 78% refund for expenses associated with exploration. However, according to Wille (2010) this in itself cannot act as an incentive for the companies to develop new exploration technology. He emphasize that the 78% is the income tax that every oil company has to pay. If a company was depended on this money in order to conduct exploration than their livelihood would not be present. Wille (2010) explains that this system has its background from the government trying to stimulate the foreign oil companies to continue exploration on the NCS.

Barlindhaug (2010) also feels that this alone is not an incentive to develop new technology. His point is that, yes, you will get this money back, but still you will have to cover 22% of the expenses yourself and also the time used on it, time that could have been used on something else. Therefore, the companies will not invest in technology unless they are sure that it will give results. They have to know or at least believe that this new technology will give results in form of increased production or safer drilling etc. If this is not present then they will not invest in new technology just because they will get 78% of the expenses refunded. Nevertheless, should the companies see the target the tax-would act as a driver to make the development process faster.

In the 80's the government launched something called "Goodwill deals" for the industry (Barlindhaug 2010). The purpose of this deal was to promote innovation and new technological solutions to the NCS. By using money on research and development, the companies would be given a favorable position when it was time for new licenses to be announced. This system was something Norway had through the 70's and 80's, however they ended it in the 90's. It was a powerful incentive for the companies to contribute with new technology and was the reason why Agip (today Eni) introduced their ideas to subsea installations which would not be in the way for the fishermen's.

Barlindhaug (2010) believed this has probably been the biggest motivation the government has given to the oil and gas companies to develop new technology. In no other type of business in Norway will companies experience this kind of support for developing new technology. I think this shows how valued the industry is in the Norwegian economy and the importance for both parties that technology is renewed as often as possible.

Wille (2010) feels that pressure from the government is an indirect driving force. However, he mentions a good example of how governmental legislation has worked as a good technology driver. In 1991, the government implemented a CO2 tax, which meant that the companies would have to pay 82 øre per cubic meter of CO2 they released into the atmosphere. This new tax made the companies look for solutions that would reduce their emissions. At this point, the main source to CO2 emissions was the flares that each platform had. This flame was part of the security on the platform. As mentioned earlier, each platform had a processing plant which separated gas from oil and should a critical situation occur in the processing plant they could send it through the plant and up to the flame and flare it. This solution had existed for a long time and the industry had grown custom to the situation being like this. When the additional tax came they asked themselves if the flame really needed to be lit all the time. They then developed a new technology that would automatically light the flare if something critical would happen in the processing plant. Today, this technology is used on every platform on the NCS, and is increasingly being adopted in the rest of the world.

Another example is the invention of re-injection into the fields. Before any gas can be send to the gas market in Europe, Statoil had to remove the CO2, it had to be under 2,5%. Normally this removed CO2 would have been sent into the air or flared, but due to the new CO2 tax, they came up with idea of re-injecting the gas back into the field. By doing this, they saved the money and could export the gas according to the requirements.

4.2.3 New and demanding fields

As mentioned earlier in my thesis, the NCS is not the easiest place to operate. The harsh weather conditions in the North Sea meant that the industry could not use the technology they had used at other fields. Because of this, new technology had to be created and this was done in cooperation with Norwegian contractors and the companies. One of the most famous constructions that came from this cooperation is the concrete platforms or ConDeep as they were called, which were created to handle the rough weather conditions that were present on the NCS.

"The fact that existing technology has not been good enough has been one of the biggest drivers on the Norwegian Continental Shelf" (Wille 2010). He feels that because the existing technology has not been good enough the companies have not had any real choice between using known technology or untested technology. This was the fact when the Americans came to Norway and was also the case when developing the Troll oil and Snøhvit. In the oil industry's history in Norway there has been a powerful and ripping development on the NCS. The result of this has led the NCS to become one of the leading in the world and the competence gained here is used all over the world. For 30 years ago, the situation was different, at that time, the Americans came to Norway to learn the industry and now it is much the other way around. However, he do not believe that this would have been the situation if the industry had a real choice between using old and well tested technology or new technology.

A good example of a demanding field is the Snøhvit field, which are located just outside Hammerfest. When this field was first discovered nobody in the oil and gas business were able to celebrate over the big gas deposits that the field contained (www.ntnu.no). The reason for this was that the potential market had never been so far away as in this case. Normally the chosen solution would have been pipeline systems, like the ones used at Ormen Lange, but the distance would not make it profitable. Another factor was that at this time the LNG technology was not widespread. At this time, there was only one American company that had knowledge and technology to produce LNG and to but the technology from them would be too expensive for Statoil. What they did was to work together with a professor from NTNU, Einar Brendeng, who was an expert on cooling systems. Together they managed to create the technology needed to develop a LNG plant at Melkøya. So due to the geographical conditions

of the field they were forced to develop a new technology in order to put the field into use. Even to this day, they have not been able to get the plant running 100%, but for every technological challenge the field brings they have to deal with it.

The Snøhvit field is not the only example of technological challenges that have helped the technology to be driven forward. When discovering the Snorre field the engineers were faced with new challenges. Never before had somebody drilled this deep before, offshore, and so many small fields located this close together. The depth was 320 meters something that may not seem so much today, but at that time the deepest field on the NCS was Gullfaks with 140 meters. In addition, they had to re-think their first ideas because the oil price collapsed and it was stricter demands to living age and costs of development. Nevertheless, through cooperation with suppliers, they managed to solve it and it got build, one year later then first planed.

Based on the technological challenges the industry have coped with them and gained valuable experience that will help them deal with similar challenges in the future. By gaining learning the industry will gain the willingness to explore new technologies other times, rather than making a safe choice.

Barlindhaug (2010) mentions the role of the NOC's and the IOC's when speaking about technological development. During the last 20 years the oil and gas industry have gone through big changes. An increasing nationalization in the southern parts of the world, have led the IOC's to get fewer and fewer drilling licenses which then again have made them look for oil other places. This has then again led the companies to put more focus on countries like for instance Norway. It has been in the interest of Norwegian technological development that these nationalizations have forced the big and knowledgeable IOC's offshore. Now they are faced with a decrease of new fields and is forced further north. The amounts of easy fields are disappearing. When they established their business here in Norway, they had to develop new and improved technology suitable for the conditions up here. This increasing experienced pressure will force the companies further and further north were the conditions will be tougher and tougher and it will probably force them to change some of their mentality. Even though the need for "proven technology" always will be present, they will experience a need to change the current way of thinking. Distances will increase, temperatures will decrease and it will make the drilling conditions that much harder than for instance in the North Sea. This in itself can be a technology driver, at least for the big companies. In the next section I have

provided a good example of how this situation is about to occur again, IOC's are currently moving towards extracting shale gas, and as result of this they are taking current technology and developing it further. What seems to be the trend is that due to the company's lack of risk willingness, they wait for smaller companies to develop new technology and when this is developed at an early stage the big companies come and copy the technology and bring it one-step further (Barlindhaug 2010).

Big companies depend on having huge incomes to be profitable and please the shareholders (Kullerud 2010). They will have to make new discoveries in order to continue the money flow and these will be made further north. In order to make these areas economic attractive they will have to change their focus when it comes to technology. They will probably use a lot of the knowledge gained from previous experiences both offshore and onshore to develop the necessary technology. Barlindhaug (2010) mentions horizontal drilling as a good alternative because it will make it possible to reach more areas from one platform. An example of this is the Gulltop reservoir that they drilled from the Gullfaks platform, a project that I will mention later in my thesis.

A big incentive for the oil companies to renew themselves it to show to the government that they have technology needed to operate accordingly to regulations in a safe way. This is something that will be more and more important at the NCS, because the reservoirs in the southern parts of Norway are running out and in order for the companies to get access to new areas they have to use different type of technology. Take for instance NorthEnergy, they suggested using the knowledge we have in Norway when it comes to making tunnels through mountains and combine that with oil drilling offshore. The result of this fusion would be a sub-sea tunnel that the operators could drill from. This is something that they have suggested for the Lofoten and Vesterålen areas, an area that is not open for oil drilling. People from the oil sector have the "give us demands, and we will meet those" attitude.

Environmental concerns are closely correlated to this point. Take for instance the Lofoten/Vesterålen area; to get access to the area they have to prove that they are able to follow the environmental concerns the government have for this area. In order to do this they would have to have the proper technology to show too. The impression I got though, is that it is important for the companies to maintain a good environment profile in order to keep the government off their backs and also maintain a good image. The oil and gas business is not

the most environmental friendly industry and the product they sell do contribute to increasing CO2 emissions which is something Norway are trying to reduce.

4.2.4 Shale gas

This section will give a description of a new market that is in great request, the shale gas market. I mention this market because it is a good example of how a new market can contribute to developing new technology. The purpose of this is to present a modern case where many different factors are affecting new technology. Shale gas is a new market that is growing and in the wake of this, new and improved technology is created.

What is shale gas? According to API (www.api.org) shale gas can be defined as natural gas from shale formations. The shale acts both as the source and as the reservoir for the gas. Unlike conventional gas, shale gas does not exist in a "pocket" where drilling into this "pocket" pocket would be enough to extract the gas. As a result, it is much more difficult and demanding to extract shale gas than normal gas. Shale gas is developed in fine-grained shale stone. Previously this gas has been non-profitable because the existing technology at that time has not been good enough to extract it in a profitable matter. Emerge of shale gas production can be compared with the position offshore fields once had. The IOC's moved offshore and further north because of a perception of a closing world. At that point, offshore petroleum was considered as unconventional resources. As the offshore fields are being increasingly nationalized, the petroleum companies are looking to other types of resources, in this case shale gas. In other words, it is about breaking new barriers in order to find new opportunities.

Shale gas is not the only opportunity for the petroleum companies; they are already involved in oil shale, super deep waters and more. However, shale gas has gotten the attention now because of the potential big payoff versus the small costs, compared to other alternatives such as arctic drilling or extraction of oil shale's.

A key element in the growth of shale gas production has been the improvement of cost-effective horizontal drilling and hydraulic fracturing (Ground Water Protection Council & All Consulting 2009). These technologies combined have contributed to making it possible to access areas previously seen as impossible. By using horizontal drilling, it is possible to open up more of the area and make the gas easier accessible. To give a better understanding of the advantage of horizontal drilling I will give an example. If using horizontal drilling, it would

be enough to drill six to eight wells drilled from only one pad to open the reservoir. To achieve the same result with vertical drilling it would be necessary with sixteen vertical wells. A solution like this would save the company for money and spare the environment. Hydraulic fracturing, which is a technology where high-pressured water is shot down in the shale's. The purpose of this is to fracture the shale's and free the gas from the shale's and thereby making it easier to access the gas.

There have previously been speculations about a peak in the worlds gas storage, however the ability to extract shale gas has proven the theory wrong. Even though shale gas is most widespread in USA, Europe also has big deposits of shale gas. According to an estimation done by IEA Europe could supply itself with gas for over 40 years based only on the shale deposits known today. After the gas crisis with Russia last winter this could be of big interest for the EU.

The downside of shale gas production is that it is not environmental friendly (www.aftenposten.no). According to its critics, it pollutes the sub soil water. One of the success factors for shale gas production will be the balance of production and damage of sub-soil water. The problem is all the water used with hydraulic fracturing, which is mixed with chemicals. Environmentalists want a clearer handling method for the wastewater, instead of letting it be absorbed by the nature or pollute the ground water. However, the industry is in the start of its era and like offshore production time is needed to map out all the potential environmental affects and create regulations. What the environmentalists do agree with is that the production of shale gas is much better than for example oil sand, which demands more energy and water to produce.

Seen from a technological perspective shale gas production has had a huge impact on technological development. Although the technology developed are not as revolutionizing as experienced through offshore drilling in the North Sea, the impact of the new technology is important to acknowledge. In the case of the shale gas, many different factors have driven the technology forward. First of all, the companies have felt "forced" to search for other alternative since the control over offshore oil fields have been decreasing due a nationalization. Money is another important factor, the amount of potential profit that lies in shale gas is big since it would not be difficult to find the market and some shale gas is actually cheaper to produce than conventional gas. USA can supply themselves with gas from shale stone instead of having to import.

4.2.5 Environmental concerns

Another force for the oil and gas companies to create new technology is the consideration to the environment. As the industry has gotten increasingly attention from media and environmental organizations they have sort of been forced to be more environmental friendly. As of today, the world is dependent upon oil and so the industry cannot close down either, the solution then is to try and be less harmful to the environment. Also an increase in knowledge about the damages emissions can have on the environment has made the company's focus more on environmental technology. The companies are not "heartless capitalists" whom only have money as a target, they know their CSR responsibility and also voluntarily change into environmental solutions.

Environmental technology can sometimes also be profitable, which is the case with horizontal drilling. This has made it possible to get access to sensitive areas by having the platforms away from the area and using horizontal drilling to reach the fields. It is also a cost effective method for the industry since it makes it possible to have small fields become economical attractive.

Barlindhaug (2010) believes that the environmental technology that will come in the future is to generate electricity on land and transport it out to the fields. Today, electricity is mainly produced from generators, which is one of the biggest contributors to CO2 emissions today. If the companies are able to get power delivered from land they it would be beneficial for the environment and give the companies a better profile.

I asked my informants about how the environmental organizations affected the oil and gas industry. They said that one can divide the environmental organizations into two categories, once they were very technology focused and had an approach to the oil business that were more like; how can we reduce the amount of harmful discharges and have a zero discharge policy? At this time, they were very constructive in their pressure. Later they have changed their focus and now they are more like; we do not want this industry, it is harmful it is non-environmental and we should limit their production as much as possible. At this time, when they changed perspective you can say that they had played their role.

After this, it was the fishermen's who took over the role the environmentalists had previously had. However, also here will one experience differences in this group. Some groups of

fishermen's are more polarized, meaning that they are less balanced, and fail to focus on cooperation and co-existence and there is more politics that rule. Then you have those who say that we are a genuine fishing organization and we are interested in meeting and together come up with a solution. Organizations with this approach it the ones that contributes to driving new technology forward. By raising demands to the oil and gas companies they can help drive the technology forward. A specific example of this is the sub-sea installations. Previously the structures were installed at the sea bottom with the result being that areas in a certain radius around the platforms were closed for the fishermen's. The oil companies were favored over the fishing industry and could not get near the drilling area because they could destroy something. This situation has now changed and the roles are almost switched around, today the fishermen's demand that they will not have any of their fishing areas removed due to oil activity. This is probably one of the biggest "victories" for them and shows how they have been part of change in technology used at the Norwegian Continental Shelf.

Their role is central in the discussion of the Norland IV and IIV and Troms II areas and whether or not it should be opened up for exploration. One of the main things that are debated here is that the technology present now cannot guarantee for a safe drilling. If the fishermen's go together and as a unit presents their demands they could have an effect on the technological development of the fields. With the right type of pressure, they can force the companies to think new and drive the development further.

4.2.6 Learning from other scientific fields

Technology transfer is about the companies using knowledge from other sectors and implementing them into their own industry.

Wille (2010) mentions that for Statoil technology transfer has been an important technology driver. He believes that in the future we will see more technology that is not known in the oil and gas business but in other types of industries. This is something that is already taking place, however he believes that the extent of it will increase. He mentions that a great deal of the technology Statoil use today, deals with visualizing reservoirs, where these are found and interpretation of these. That is that they manage to create a model that people can talk together about and manage to understand the mechanisms that are going on down in the reservoirs.

Much of this technology can be found in the medical industry today. Wille (2010) believes that it has been a technology transfer both ways in relation to visualization, because the problem situation is in many ways similar. In the oil and gas industry, visualization is about seeing and understanding the reservoirs, while in the medical industry it is about seeing into the human body. In both cases, a physical visualization is very difficult and limited. An option then is to use CT scanning, which will give a better impression of how things look like inside.

Another example Wille (2010) uses is Statoil's work with preventing hydrate formation, which is when small particles of gas and water freezes inside a pipe, under certain pressure and temperatures. When this happens, it causes a blockage inside the pipe, which is not desirable. To prevent this from happening they pump a sort of antifreeze liquid into the pipes, often methanol, to prevent the formation of hydrates. What Statoil did was to look to the biology, are there a any insects or other type of animals that can survive under these conditions? If yes, then maybe they have some type of living mechanisms inside them that prevents them from freezing under this temperature and pressure. Maybe biological research can find out that this and this type of animal can expose some substances that could be produced industrially for use in a mix that would prevent the making of hydrates. This is an example of where the competence is elsewhere but can still be used in the oil and gas business.

In addition, at previous occasions the oil industry has learned from others. For example, have the industry harvested from cooperation with NTNU, which is the technological university in Norway. Close cooperation with the University have given access to young and talented people and professors with a lot of knowledge that have been contributing. Wille (2010) mentioned that Statoil are currently working on a project with NTNU for a new type of well drilling.

4.2.7 Prolonged lifetime of a field

New technology have played a big role when it comes to increasing the recovery rate. An increase in the recovery rate means that the amount of money gained from a field will increase. A very good example of this is the Ekkofisk field, which was discovered in 1969, this field was first estimated to last 30 years, but due to better technology the field is now estimated to last for another 50 years. This gives the field a total living age of 80 years. This has been important for the companies operating at the field and for the NCS. It is self-

explaining that this big increase in production time will give great benefits, economically, to the operator and inspire them to keep working towards new and even better technology. When speaking about increased recovery rate, the ability to understand the reservoirs and "manipulate" them has played a significant role. By pumping water into the fields, they are able to keep the pressure up in the reservoir and prolong the life time of the field.

What is interesting with the prolonging of a fields lifetime due to technology is that according to Kullerud (2010) the economic benefit a company would get from just increasing the extraction rate with 1% is not enough for a big company to drive them to new technology. Based on a business case, they would get return on their money based on the increase in production and the prolonged lifetime of the fields. The problem for these big companies is that they are not valued, on the stock market that is, by the amount of production they have, but accordingly to how big their reserves are. This means that they are sort of forced to keep searching for new fields to increase or maintain their amount of proven reserves in order to keep their stock value. Personally, I think this can be seen both as a driver and as a barrier. A driver in the sense that they create new technology that will fit the conditions and requirements they face there. On the other side the barrier part of this is that the situation will prevent them from creating new and more efficient technology for small fields.

4.3 Barriers

In this section, there will be a presentation of the different barriers for implementation of new technology. According to my informants, there are two major barriers for developing new technology.

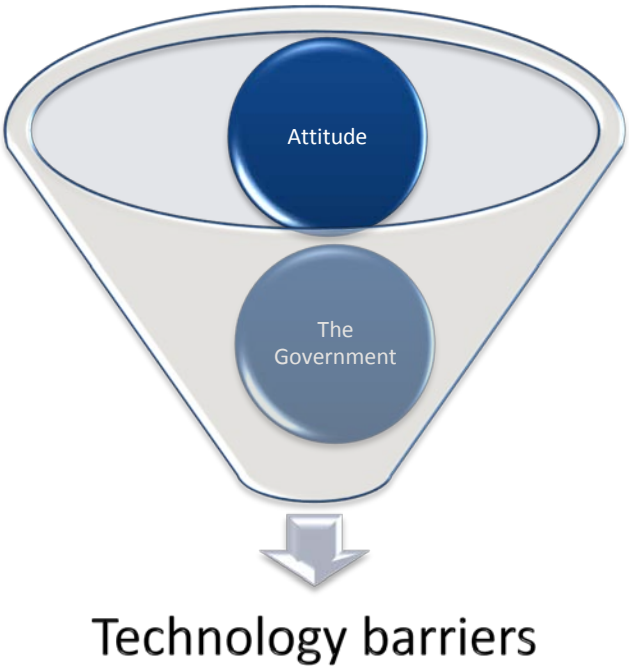

Figure 8: Barriers for new technology

4.3.1. Attitude

The general attitude in the oil and gas sector towards new technology can act as a barrier for implementing good ideas. To create and develop a new technology is often a big and costly process and is something the companies are skeptic to do unless it is necessary. This has to do with the fear of something not working properly. Wille (2010) explains that this will lead to increased costs associated with repair of the technology. Further, the problem might cause a reduction in production capacity or in worst case a halt in production, which means reduced income. For a field that might produce 200 000 barrels a day, a halt would mean big losses. The big numbers makes the companies less willing to accept the risk. In order to deal with the risk, Statoil uses a form for business case, which means that they weigh the risk against the potential profit. If the risk is something they can accept then they will go ahead with the technology.

A company's willingness to invest in new technology is very different. Kullerud (2010) explains that some companies' lies in the forefront on technology while others lie more in the back and wait until the market develops something new they can imitate. The solution to this problem is often for them to go into sort of partnerships with sub-suppliers or other

companies. By doing this they will reduce their costs and also get advantage of the technology.

At a field there will be one company that has the role as operator but the field will be developed together with other companies as a partnership (Wille 2010). The operating company might have knowledge about a new technology that they believe in and are eager to try out for this specific field because they believe it will give the best result. The challenge in a situation like this is get the other partners to agree with this idea. If they have no knowledge about the technology, they will be negative to use it. Therefore, it is important that everybody have the same knowledge about the suggested technology and that the risk associated with using it is something that is acceptable. The keyword here is technology communication, the operating company need to present the technology to its partners and share their knowledge about the technology in matter that convinces the partners.

On the other hand you have companies that do not want to be part of this game and refuse to use money on something they do not know if will work or not. Kullerud (2010) points out that often it is more a psychological barrier among the top managers to try something new, rather then it being the financial aspect that is the deciding factor. Wille (2010) describes this phenomenon a sociological phenomenon, which is an internal counter force. In order to give a better description of this, I will use a hypothetical situation. A company wants to change the technology at an installation because it has been experiencing a decrease in production and thereby profit, by changing the technology it might turn the situation around. The technology used at this installation has existed for 10 years and the managers working there have gotten used to the technology, they know how it works and it has given good results. By changing this technology and implementing the new one, some people might feel that their position in the organization is threatened and work against the new technology. The current technology being used might be very special in the sense that only a few people understand it, which gives them a “status” in the company. When removing the technology these experts might feel like their identity is removed, because their knowledge is what gives them prestige in their workplace. For a technology to work it is very important that the company get their employees with them on the team. It is therefore important with employees who are able to adapt to changes quickly. It would be easier to implement new technology on a new field rather than changing it on an existing field.

Barlindhaug (2010) mentions the conservativeness as an important factor for barriers in new technology. He believes that the oil and gas business is a conservative business and that this will affect the companies' willingness to try new technology. From good ideas and up to testing and actually implementing new technology it is a long way ahead. He uses NorthEnergy as an example. They have been working with Sintef and other big research organizations in order to use tunnel technology to get out to the disputed area in Lofoten and Vesterålen. This is not something new but just combining two technologies into one, tunnel technology and offshore technology, is a long path. Documentation shows that a solution like this could be very profitable, but to move beyond theory and research is something else. Just to think like this, is seen as crazy among the other industries. They will not take the suggestion seriously and have no believe in this actually working. Oil companies are used to using floaters (drilling ships) or templates at the seabed, and thinking offshore. When a company then suggests using land technology and combines this with offshore technology, it is something the big companies will not even consider, it is a big step to take.

He feels one of the biggest barriers for new technology is the structures of the companies and their way of thinking. To implement new technology is a tedious business, and the companies are very bureaucratic, meaning suggestions have to go through many links before reaching the decision makers. The companies want what they refer to as "proven technology", they want evidence that shows that the technology works before wanting to implement it. Therefore, they lean towards proven technology that will guarantee results and meet governmental requirements like environmental concerns.

A business case might look perfect on the sheet, however in the end it is all about the decision makers, and they might not always think rational.

Instead of using a lot of money on new technology, they use a lot of money on research, hire scientist and engineers that do research and by that try to gather a lot of information before putting the money into new technology (Barlindhaug 2010). However, this is not research in the front end, in that area, it is the little companies that are in the front. They gather information and get ideas in order to get a competitive advantage and when their research has come far enough the big companies come with their capital and take the research further.

Kullerud (2010) was part of a research team where they wanted to find out if there was a big difference in the success rate if a company used advanced technology or skilled people. During their research, they found that a lot of people were very determined on using

technology and that this would give the best results. On the other hand some companies had a different approach which was to invest in people with knowledge and understanding about how a reservoir looks like and what geological conditions needs to be present for finding oil. The result showed that those who used the solution with skilled manpower had just as high success rate as the other companies who swore to advanced technology. The reason why I mention this is that it shows that it does not necessarily help with good technology, one need skilled people to operate them and to read the results given by the computers. This can act as barrier for certain companies as to creating new technology. Technology can only do so much, but in order for it to work, it has to be operated by skilled people. Both Wille (2010) and Kullerud (2010) highlight the fact that technology combined with the right type of skills is important to get the best result.

4.3.2. The government

The government can also act as a barrier for new technology. As mentioned, the companies have a tendency to be afraid of trying new technology and do not feel like creating new technology unless they have a target or a clear incentive to do so. This is something the Norwegian government could do something about. Barlindhaug (2010) uses Lofoten and Vesterålen again as an example. Right now, the government and the fishermen's are skeptic as to how good the current technology the industry posses is and if it would be good enough to drill in this area without doing damage to the rich fishing life there. What Barlindhaug feels is that the governments constant indecisiveness as to whether or not to open up this area makes the companies hold back any development of new technology suitable for that area. If the government could give the industry some perspectives they could relate to it would be easier. If they for example where to say: We will open this area by 2015 if this particular technology is present. He feels that if the politicians were better at giving these perspectives the companies would have something solid to hold on to and take into consideration.

According to Wille (2010), Statoil prefers to be ahead of the government, in order to avoid any directives that they would not be comfortable with. Therefore, they would rather present solutions that they will comfortable with and that the government accepts. For Statoil's part, it is important with a constant dialog with the government about environmental concerns, for them the best solutions come from this.

An example on this is North Energy's suggestion to use tunnel technology in the disputed areas outside Lofoten and Vesterålen. This technology has been known for a while, however, the companies are uncertain as to how to make it work and the cost of this solution. The strategy of the big companies is therefore to wait with presenting this solution in fear of the government demanding a similar solution, a solution they would not be comfortable with. On the other hand, you have the smaller firms who feel that presenting new and innovative solutions is the best way of gaining a competitive advantage. The big companies' response is that a process like that would be too complicated and expensive.

4.4 Sum up

In this chapter, there will be sum up of the different drivers and barriers mentioned by my informants. My impression from the interviews is that it is easier to point out what the barriers for new technology in the industry are. The oil and gas industry show signs of being a very conservative business. They prefer to be "second users" of technology and tend to lean towards proven technology. Barlindhaug (2010) mentioned that the big oil companies do a lot of research; however, it is not research in the front end. On this area, it is the smaller companies who dominate, and when they have come far enough the bigger companies enter the market and use money. The result of this trend is that resources on new technology are not used before somebody else has done the job. Another internal barrier is seen at the employees and managers working in these companies. In fear of being replaced by the new technology, they might work against the implementation of it. For example if technology would replace the need for geophysicists, this group would feel that their prestige and status as experts in for example interpreting seismic data or drilling cores would disappear. It is therefore important that the top-managers have a clear profile towards technological innovations and also communicate the technological solution to their employees.

In relation to governmental legislations, the big companies prefer to be in the driver seat and make suggestions to technological solutions, rather than having the government dictating solutions. However, unclear governmental incentives can also act as a barrier. Instead of closing an area for drilling, they could reward the innovative companies. If they were clearer on which criteria's that needs to be in place before considering an opening of this area, it could speed up technological development in some areas. Lofoten/Vesterålen is a good

example of this. Today the technology is not good enough to defend an opening. In this case it is the government who have the role as an external barrier for new technology.

The final discovery I made was that it is not always up to the company to decide to implement a new technology. Often on big projects, a company is working together with other actors and therefore has to present the business case to them and convince them that the intended technology is the right one. This can be characterized as an external barrier.

The most important drivers mentioned by my informants are, increased profitability, new legislations, new and more demanding fields, environmental considerations, learning from other scientific fields and prolonging of a fields lifetime. The cost driver is very important for this business, it are a lot of money involved in this type of industry. If implementing new technology might bring the costs down then this is very interesting. Take for instance the transition from the ConDeep platforms to the templates standing on the seabed. Going from gigantic projects and to installing templates have made it possible to reduce their costs. Like business in general, they are always looking to increase their income in the best possible matter. The best way to do this is often by new technology, if they can increase the production or the living age on a reservoir, it would mean extra earnings. This has been the case for the Ekkofisk field where the living age has been increased as the extraction techniques have improved. I would consider these drivers as both internal and external since it is the company's goal, but they also have to please the shareholders.

Furthermore, I have spoken about learning from other scientific fields and environmental considerations. It is not uncommon for the oil and gas industry to use technology that are known in other types of industry and transform it into suiting their own needs. The companies acknowledge the importance of a good environmental profile, and use technology that will make production environmental. However, it can be discussed if the environmental considerations can in itself be considered a driver. Environmental drivers are both internal and external drivers. The companies seek legislation from the society and adapt to the "demands" from there, while some companies choose to focus more on environmental issues. Learning from other scientific fields is driven forward internally. For example, the potential tunnel technology North Energy has mentioned for the Lofoten areas.

Governmental legislations also work as an external driver towards new technology. When they for example implement new environmental laws, it means that the companies have to figure out how to produce the petroleum in a satisfactory way. Another external driver is the

discovery of new fields where the existing technology is not good enough. In order for the companies to extract the oil and gas from the field, they have to figure out a new way of producing. The Troll oil field is a good example of this, where multi phase technology got its breakthrough.

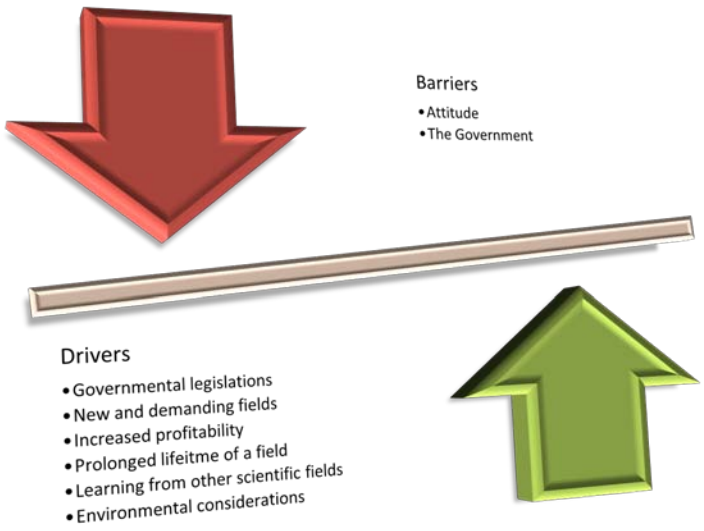

Figure 9: The relationship between barriers and drivers for developing new technology

In the model above, I have shown how barriers drive the technological development down, while the green arrow symbolizes the drivers that push the technological development up.

5.0 Analysis

The purpose of this chapter is to pick up the different threads in this thesis and saw them together. So far, I have presented the theoretical frame of this thesis, my gathering of information and my empirical findings. In this chapter I will show the relation between my theory and my empirical findings, and argue for how the theory fits in with my findings

In order to give a better understanding of the complexity related to technological development I will use a mosaic picture as a metaphor. When going close you see all the small stones of the picture and it is difficult to see how the big picture will look like. However, when you look at the picture from distance and all the stones are on place you see the motive. It is the same with technological development. This complicated process consists of many small factors that

either drives or hampers the development. When looking at each factor separately it is difficult to see how they will influence the innovation process. Put together they make out the pieces needed to see the picture. This is where the analysis come into place, in the analysis all the different pieces that has been laid out throughout the thesis, will be put into place and form a picture.

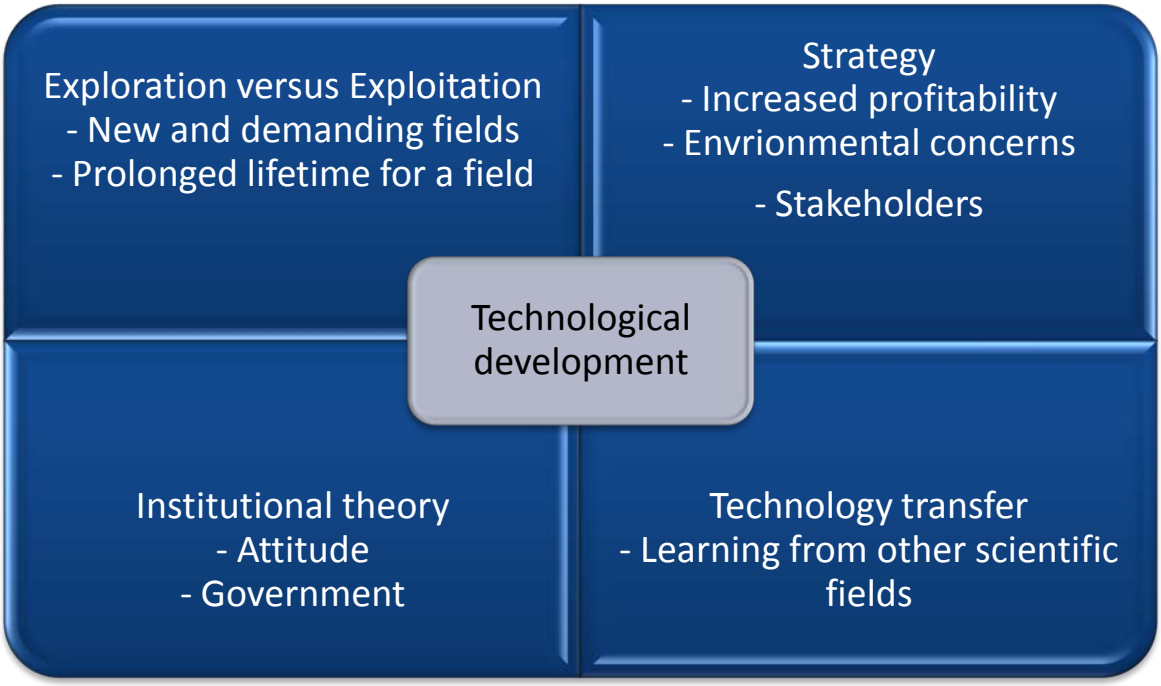

Figure: 10 The Mosaic picture of the analysis

As shown in the figure above, my findings can be transferred back to my chosen theories.

5.1. Institutional processes

The institutional theory describes institutionalization as a big disadvantage for technological development. The constant fear of moving away from the comfort zone prevents the creation of new and improved technology. Based on a theoretical perspective this phenomenon can be described as isomorphism and it acts as a clear barrier for new technology. However, as I will show in my analysis, there are examples of external actors that contribute to deinstitutionalize the industry. It has mainly taken form as new laws and has forced the companies to think different and open up to new ideas. Institutional isomorphism deals with the challenge the companies have between stability and creativity.

In my empirical part, I have been speaking about how companies might be reserved to new technology. Resistance to use new technology can be seen in context with institutional theory. As part of an institutionalization, a company will show more signs of routine and stop asking questions of why things are done and if these things can be done in a different way. This can act as a hamper for new technology, because innovation needs creativity as nutrition.

In my empirical findings, I told the history about how the oil and gas companies moved on from constant flaring to only doing so when necessary. This history is a perfect example of institutionalization in the oil and gas business and how governmental legislation can contribute to deinstitutionalization. Not even once did the industry stop and think, hey maybe we do not need to have this flame burning all the time. In other words, the industry was institutionalized, they were stagnating in their own routines and leaning towards the safe and certain way of doing things. When the new CO2 tax law came, all of a sudden, the industry stopped and started thinking: do we really need to have the flame burning all the time? The result was a new technology that made it possible to have the safety option of burning the gas if this should be necessary, without having the flame burning all the time. In this case, it was the government who acted as a driver by deinstitutionalizing the industry. The same tax law led the companies to start with re-injection of CO2 into the reservoirs. This type of change, which happens through a new law, is what the institutional theory describes as coercive change. The essence in coercive change is that the companies somehow feel forced to change. Coercive change is not necessarily a negative thing for the company, it forces them to look at things from a new perspective and make them realize that change is a good thing. The story I just mentioned is a perfect example of what I like to refer to as “positive” change.

This is not the only example of the government contributing to technological innovation. The goodwill deals they designed in the 80’s, is also a perfect example of the government trying to remove the psychological barrier the oil and gas companies have towards renewal and being dynamic. It is their way of stimulating the industry to new ideas. With the launch of the deals, the government wanted to promote innovation on the NCS, by giving a competitive advantage to those who were willing to leave old routines and be new. According to Barlindhaug (2010), this is one of the best and most successful initiatives taken by the government when it comes to motivating the industry to take an innovative role.

Companies who become isomorphistic have a tendency to not being innovative and not open to change, which has been a characterization of the oil and gas businesses too. According to

my informants the oil and gas sector are very skeptic to implementing new technology that they have not tried yet. The reason for this is the cost associated with something not working the way it is supposed to. In other words, if they implement the new technology and it does not work properly they will lose revenue and experience increased costs due to repair of the technology. In my empirical chapter, this situation is described as the companies' attitude. It is an internal barrier that occurs because of the decision takers attitude.

As the theory mentions a problem is that the companies pick their leaders by the same criteria's and want the same type of people, which again hampers the engagement in the company. All the way from the universities and up to the day they become leaders, they have been thought not to take risk and to use familiar technology rather than unproven technology as far as possible. Because of this, many new and exciting ideas are "killed" already in the start- up phase, because the leaders prefer the familiar technology. This barrier occurs because the companies want legitimacy and as part of this, they try to be similar to everybody else. This explains some of the tendencies seen in the oil and gas businesses. Barlindhaug (2010) mentioned that from suggesting a new technology, and to actually developing it, is a long and tedious process. The institutional isomorphism can also explain the industries bureaucracy. In order for the companies to make sure everything is treated properly and according to regulation, every suggestion to change has to go through a numerous people before being accepted. To explain this attitude one can look at institutional theory, specifically normative isomorphism. It describes how the companies adapt to the network around itself in order to achieve legitimacy and feel safer. However, the process of gaining legitimacy makes the companies less willing to separate themselves from similar companies and also risk averse.

Another found that can be related back to normative isomorphism is how the other partners on a field can affect the operator who is the licensee. Wille (2010), explained that during a decision process, it is not only the company in itself that has the final word. On a project it is often several companies working together to get a field in production and designing the right technology for this. Basically, it is the environment around the company that will have an effect on their choice of technology.

My informants told me that the oil and gas companies are skeptic to new technology and as far as possible want to lean towards proven technology because it gives more safety and less potential complications. This happens because the companies get stuck in their own routines and get satisfied with it. By using the proven technology, they can be sure that everything

works according to plan and gives the desirable profit. However, by stopping and thinking to themselves that if they took a chance on something new then maybe the profit would be higher and the production more effective. Since the decision makers are thought to not separate themselves from anybody they do not think in this matter.

Kullerud (2010) explained that there are companies that refuse to use money on technologies that they are not familiar with, and that have no guarantees as to if they will work. A reason for this is often due to a psychological barrier among the management, they will not use money on untested technology. He calls this a sociological phenomenon, which can be translated back to institutional theory. The company's leaders are institutionalized and this act as barrier for them to be open minded. When they face new challenges or uncertainty in the market, they would rather look towards similar companies and try to model their way of doing things. Modeling is something that are described by mimetic isomorphism, and is a strategy a company use as a response to uncertainty. They tend to look towards successful companies and try to model them in order to reduce the uncertainty. However, if everybody is modeling each other who will be the first mover then? If everybody has this approach then nobody will develop new technology.

Sociological barriers do not necessarily have to lie at the top managers. Sometimes the workers are afraid of changes. Employees might fear that the technology will replace them and therefore work against the technology. They might have worked in the company for 10 years and gained a reputation or status, should they feel that the new technology would deprive them of this, they would not welcome the new technology. If the companies are not able to communicate the effect of a new technology, they might have people working against it, an internal barrier. This phenomenon is again described in institutional theory, the workers have grown custom to a certain way of doing things. They fear that if this new technology will come they will not be able to go on with the same working pattern. In other words, the employees are afraid of change because they have grown custom to the way things work and fear the new technology will change this. In the theory, this is referred to as the individuals being isomorphistic.

The government has also tried to stimulate the industry to use money on R&D by giving a 78% return on expenses. An initiative of this kind is typically an effort to deinstitutionalize the industry. Although the thought is good, it can be discussed if it has worked in the way the government had hoped for. Both Barlindhaug and Wille (2010) believe that this initiative is

not a driver in itself. The industry is too institutionalized to look upon this as an incentive in itself to use new technology rather than old. They regard the return as money they have already paid in taxes and so it can therefore not be considered a good initiative.

I have mentioned the government as a possible actor to deinstitutionalize companies, however they can also contribute to institutionalization. By not sending out clear signals that change will be rewarded the companies do not grasp the potential award they might be given by developing new technology. Wille (2010) referred to this as technology communication, and it means that the government needs to be clearer when sending out signals. Barlindhaug (2010) used the Lofoten/Vesterålen field as a good example. He felt that due to the governments indecisiveness they acted as a barrier towards new technology. In other words the government is also to some extent isomporphisitc. They value change on the NCS but they are not able to figure out new ways to stimulate to this change. Again, this means that the governmental officials are not capable of seeing things in a different way. Governmental processes are tedious processes and can often be described as bureaucratic. Some politicians say that one should give them this incentive, however others are more skeptic and do not see the value of the new technology. However, when the government does impose new laws the companies may not want these changes. The reason is that they feel uncomfortable with it and prefer to be in control and suggest new technology they feel at ease with.

By having too many rules the companies see that the employees grow custom to following these and performing their work tasks in a satisfactory way. However, the challenge is that it hampers the employees' ability to challenge the routines and promote new ideas. On the other hand if the company gives too much slack their might be a failure in routines that are necessary to operate in a safe and profitable matter. It is a constant process, but as my informants points out, the industry are leaning towards safe solutions and limited wiggle room.

5.2 Exploration versus exploitation

The main issue with exploration versus exploitation is as I have mentioned in the theoretical part the balance between using old and new technology. Should they gamble on unproven technology or exploit the safer choice, proven and tested technology? The theory about exploration versus exploitation states that it is important for a company to balance this in a

healthy matter. At the NCS, the use of new technology has been brought forward by new and demanding fields. When the big oil and gas companies came to Norway they did not have any choice as to use new or old technology. The technology that existed in the world at that time was not good enough to cope with the conditions in the North Sea. In the beginning, they could use the steel platforms, but only on shallow water and many new fields that were discovered lay on deeper water. One could therefore say that the driver in itself was that the companies had no choice, if they wanted the oil they would have to create new technology. In this case, an external driver drove forth the development.

In connection with new fields, the companies have been given the incentive for developing new technology. Normally a company would prefer to exploit the known technology since it would minimize any risk associated with new technology. When the companies see new opportunities and are "motivated" they will use new technology. This motivation can be in form of being granted access to a new field, where they have to look at the production in a different matter. New fields are often a good way of implementing new technology. It happened with the Troll field, Snøhvit, and probably it will happen with Lofoten/Vesterålen if the industry are allowed to drill there. It seems like it is easier to explore new technology at this point rather than implementing an untested technology on an existing field.

Wille (2010) refers to the use of so called business cases when deciding for new technology. As the theory about exploration versus exploitation mentions, new and old technology compete for scarce resources. One of the ways Statoil solves this, is through the use of business cases. They put down the cost, look at the potential advantage of developing the technology and then calculates the risk. If the potential advantage surpasses the risk then they will consider a development. However, the risk needs to be at a level the companies can accept.

By exploring new technology, the companies have been able to prolong the life age on a field. Barlindhaug (2010) points out Ekkofisk as good example, a field that has lasted much longer than first estimated due to improved technology. However, this goes back to the business case Wille (2010) mentioned. If new technology can contribute to prolonging a field with 20 years or more, it will be of interest for the companies. Balancing the R&D resources is demanding, but when the results are like with the Ekkofisk field, maybe it could work as an initiative to focus more on exploration rather than exploitation.

From the process of creating new technology, they have been able to use that and build further on from that experience. In other words, they have learned from the projects that again have made them become better in their way of doing things. The theory speaks about learning as a necessity in order for change to happen. Sagar & Zwaan (2005), mentions that one of the ways of learning is through implementation of new technology. Again, this was the case in the early ages of Norway's oil industry. By being involved in the process of technology development, the industry was able to gain the knowledge necessary to create new technology in the future. Argyris & Schön (1996) emphasize the importance of using the learning to improve upcoming tasks. The evolution of oil production has showed that the industry is able to use the experience in a good way. Increasingly difficult fields have forced them to develop new technology, but for them to manage these challenges they have had to use previous experience. This process can be characterized as learning through production, which means that the industry has had a constant learning process.

Success in this area will increase their knowledge and understanding of how things work. I mentioned Statoil's effort with the Snøhvit project. If they had chosen to acquire the technological knowledge from the Americans, the knowledge gained would have been much less than what happened to be the case. By creating their own technology, they have managed to get increased knowledge and understanding for how the LNG technology works. It was expensive and they have had trouble, but if they have been able to learn from the process, the knowledge can be a base for future projects. Although learning is difficult to quantify as a driver in itself it certainly is one of the necessities that need to be in place as a foundation for technological development. If they have not been able to gain knowledge, they will not have the right type of knowledge to be innovative in the future. As mentioned one of the major driving forces through the years has been the lack of sufficient equipment. By implementing new technology, the companies have been through what the theory describes as learning by doing process.

However, learning does not necessarily have to be about gaining knowledge about how to develop a new technology. Learning is also an important factor to gain trust and respect by other groups. During the years of oil production, the industry has been able to learn how to cope with other interests. The increasing focus on co-existence has made them aware of the importance of dialogue and good routines in case of emergency. This again can give them an advantage when it comes to gaining access to new areas.

Based on the learning process the Norwegian petroleum industry has been through, they have been able to build up a world leading offshore industry. This increase in knowledge is a basis that need to be present in order for a company to create new technology. The learning has also helped them open up new areas that previously would not have been possible to open up. Wille (2010) mentioned Troll as a good example. If Statoil had not had the experience and knowledge gained previously with using horizontal drilling the oil fields in Troll would not have been economical responsible to open up.

5.3 Technology transfer

The theory about technology transfer describes how information or knowledge transferred from one organization to another one can act as a driver for change. Technology transfer can be seen in relation with what my empirical chapter describes as learning from other scientific fields. Wille (2010) mentioned that Statoil sometimes gather technology across of the industry, which means that they look towards other industries and gather knowledge to create new technology. In other words, they take learning from other scientific fields. It means that a company sometimes use known technology from other industries and then develops it so it will fit with their own needs.

Technology transfer can also involve a nutritious cooperation between different unions. In the Norwegian oil and gas business, Statoil sometimes cooperate with NTNU in order to create new technology. For example, they are currently working on a new way of drilling, by using electro pulses instead of having a rotating bit. The theory describes cooperation with research universities as an important part of a technological company's existence. In the theory about technology transfer, it was described how it is common with research universities close to the high-tech companies. Statoil have their head office in Stavanger, however their research center is located in Trondheim, which is the same city as NTNU is located. By doing so, it is easier for Statoil to keep a good relationship between the technological university and themselves. Figure 4 shows that normally it is the research university that conducts the majority of the research in the beginning and then afterward the private companies take over. By nursing a close cooperation with NTNU, Statoil are able to conduct researches like new ways of drilling, where NTNU do the initial research and then Statoil's engineers take over and develop the project further.

Barlindhaug (2010) mentioned that technology transfer can be used to solve problems the industry is facing. He believes that for example by adapting knowledge that Norwegians are skilled in, specifically tunnel technology. By adapting the knowledge and technological solutions used in other industries, he believes it will be possible to solve many of the technological challenges the oil and gas industry will face, it will just be a question about willingness to experiment. Transfer of knowledge is one of the main essences of technology transfer theory, more specifically communication of information that leads to new technology.

A good example of this type of transfer is what Wille (2010) mentioned about Statoil using technology from the medical industry. This technology has made it easier to understand and visualize the reservoir, because there is not any other way of seeing into the reservoir.

Normally the industry has had more of a, "silo thinking" as Wille (2010) calls it. It means that the industry has been focusing on their areas of expertise instead of enabling themselves to look across this and towards other types of knowledge. He believes this is something that will become an increasingly important part of how the companies will work in the future. This is part of what technology transfer means, gaining the competence from other areas of expertise.

5.4 Strategy

My final theory described how a company's strategy would affect their willingness to develop new technology. It tells us that in high-technology companies, the costs are very high, something which also is the case with the oil and gas industry. My informants told me that one of the main driving forces for new fields is increased profitability. Producing oil is a quite expensive thing and the companies are therefore always looking too decreasing these costs. They can not affect the oil price, so it is therefore of much bigger interest to get the production cost down. By reducing costs, they will save money, money that can be used on other investments. Hence, the companies become more profitable.

The theory describes how it is common with a high fixed cost, and after that, it is not as expensive to produce on extra unit. To illuminate this they used the development of Windows XP as an example. Expensive to create but the cost of producing one extra unit is close to zero. There are many similarities between this and the oil and gas sector. Doing seismic surveys, test drillings and not least producing the production equipment is an expensive process. However, once the reservoir is located and the production equipment is out there, it is

not expensive to produce one extra barrel of oil. It is therefore a natural process among the companies to find out how to make those fixed costs lower. This can be done by creating new technology. One of the things my informants mentioned that revolutionized the production for the companies was horizontal drilling. Drilling is one of the most expensive processes associated with the oil and gas production; by using horizontal drilling, they were now able to drill one whole where they normally would have to drill four holes.

Further, the theory tells us about how intellectual technology can help them create a competitive advantage. Imagine the competitive advantage a company would have if they were the first to develop horizontal drilling. It would give them a production advantage over all the other industries. As Wille (2010) pointed out, the companies do not compete on price because this is set by the market. Therefore, they will have to compete on production techniques that will make their product more desirable than their competitors' product. It can also give them a competitive advantage in a different way. The heated discussion about the Lofoten and Vesterålen area is a typical situation where a company with a unique technology could get an advantage. If a company can show to their technology solving the problem, they might be able to gain a drilling license at the expense of a competitor.

Hill & Jones (2004) refers to something they call a first mover advantage. They describe a situation where companies in the high-technology industry "fight" to be first on the market with a new technology. In the oil and gas industry the situation is opposite, they would much rather prefer to be a second user of technology. By waiting, they will eliminate the risk associated with using an untested technological solution. However, this is not always the case. According to Barlindhaug (2010), the smaller companies are often in the front line when it comes to gambling on new technology. The reason for this is that they hope it will give them a competitive advantage. This is actually an interesting situation, because as I mentioned the companies do not compete on price, which is normally a common competitive strategy. What type of advantage is this then? It is driving the costs down so they will become more profitable, but also that gaining access to new fields by having a unique technology is a major factor and making their product more desirable. Another thing he mentioned is that it is usually the small companies that deals with research in the front. This can again explains why they often are those who take initiative to new technology, which is the case with NorthEnergy and their tunnel solution for the Lofoten/Vesterålen areas.

In my strategy chapter, I have mentioned something called technological paradigm shifts. Paradigm shifts occur when a new technology is introduced to the market and revolutionizes it. If a company can quickly adapt to this shift they will gain a competitive advantage, if not they will in worst case be out of business. In the oil and gas industry there have been several major changes, a technology my informants mentioned is multiphase transport. By implementing this, it made production of offshore platforms cheaper and more effective. It made it possible to use sub-sea installations and reduce the drilling costs. According to the S-curve (see figure 2) it is important to invest much into R&D in the beginning to make the technology better. The oil and gas companies did this, and the technology kept on improving and becoming more advanced and today it is standard for new fields.

As the theory mentions, it is not always an advantage to be the first mover. When Apple launched their hand held computer it ended up failing, while the second user Palm used Apple's failure to make a better version. In the oil and gas business one can see the same tendency. In order to prevent high cost with gambling on untested technology they prefer to wait for others to implement the technology. This is a deliberate strategy from the companies. According to Wille (2010), one of the reasons for this is the high cost of developing new technology. Should the technology fail and production be delayed it would be even more expensive for the companies to be first mover. In addition, any repair of the technology would be very expensive.

As part of a company's strategy, they cooperate with other companies on a field, this way they will not bear all the costs and risks themselves. However, there is a challenge with this, which is to get the companies to agree on the same type of technological solution. If one company prefer to be innovative and use new technology they will have to get the other companies along with this. The success rate of this will be dependent on the other company's attitude towards new technology. If being innovative is not part of their strategy then it will be difficult.

It might also be in a company's strategy to have a good environmental profile. By obtaining this, they will reduce the focus on the fact that their product contributes to pollution. This might also be a driver for new technology. If a company implements a new technology, they will be able to reduce pollution and gain a better environmental profile. An example which Barlindhaug (2010) talked about, was replacement of the generators used at the fields to produce electricity. These generators are one of the biggest CO2 polluters at a field. He talked

about developing small generators on the seabed that would be supplied with electricity from land. This solution would not only replace the polluting diesel generators but also open up new possibilities.

5.5. Sum up

In my analysis chapter, I have tried to put together all the different pieces and make a beautiful mosaic picture. The purpose of the chapter was to show the connection between my theoretical chapter and my empirical findings. One of the most important barriers for new technology in the oil and gas business is their conservatism and attitude towards change. Ore put in a more theoretical way, the industry are institutionalized, they are stuck in their own routines and are pleased with their current situation and see no reason to ask questions about it. A company's willingness is according to the institutional theory affected by three different variables, coercive, normative and mimetic isomorphism. All of these three forces are represented in my findings. The government contributes to change through coercive, or force in form of new laws. Normative isomorphism is recognized through the leaders background and the standardization of the engineer education. Mimetic isomorphism, which deals with modeling other companies is also present. The companies prefer to wait for others to make a move or test a certain technology before they want to use it themselves.

Further, my empirical data showed signs of the companies working together with other institutions in order to develop new technology. In the theoretical part of this thesis, this process is described as technology transfer. It also involves learning from other scientific fields, such as the medical industry, as Statoil did when working with the medical industry or the biology industry. Statoil did so in order to gain a technology that will help visualize the reservoir in a better way. They have also worked closely together with NTNU in Trondheim, which happens to be the city where they have their research center.

Exploration versus exploitation is another theory that is reflected in my empirical findings. The theory describes the battle of resources between exploring new technology and exploiting the old. My informants told me that as far as possible the industry prefer to use the old technology, however sometimes they have to use new technology. This is often the case with new and demanding fields were existing technology is not good enough. A company can also be motivated to use new technology if granted access to a new field. Another issue that

involves around exploration versus exploitation is learning processes. If a company is able to learn from previous experiences they can gain new and important knowledge which could motivate them to explore new possibilities. Stakeholders might also affect the choice of new versus old, which we for example can see in the Lofoten/Vesterålen area.

The description from the theory regarding strategy is also represented in my empirical findings. Some of the most important things there are first mover advantage, technological paradigm shifts and increased profitability. The core is about gaining a competitive advantage through technology. The most important strategic finding is increased profitability based on new technology. Implementation of horizontal drilling and multiphase transport has been a result of this and can also be characterized as technological paradigm shifts. Maintaining their environmental commitments is another important reason. According to my informants, the companies are always looking for increased profitability and new technology can often be the answer to this.

One can also clearly see that the companies value technology transfer. Statoil looks towards other industries and use the technology there to solve problems or challenges they might experience. As the theory mentioned an important part of the technology transfer, is cooperation with research universities, something that is reflected in Statoil's close cooperation with NTNU.

6.0 Conclusion

In this chapter, I will put all the mosaic pieces on place and present a picture of the different forces a company battles against when it comes to implementing new technology. The purpose of this chapter is to give an answer to my question, which is:

"*What are the drivers and barriers for development of new technology on the Norwegian Continental Shelf?"*

There are many different forces surrounding the companies, which affect their degree of innovation. It is a constant balance between the safe and the uncertain. The first part of this chapter will deal with the divers for new technology, while the second part will involve barriers.

6.1 Drivers

As my findings show, there is not only one driver that makes the oil and gas companies invest in new technology. In order to understand what drives the innovation forward today, it is important to look at what happened in the years after discovery of oil and gas in Norway. From a historical perspective the most important driver for the technology that exist today is, according to Wille (2010): *"The fact that existing technology has not been good enough has been one of the biggest drivers on the Norwegian Continental Shelf"*. In other words, the industry had to develop new technology. With stimulation from Norwegian government, Norwegian industry was involved in the process of developing new technology. This and the creation of Statoil helped Norway to gain the competence needed to develop new technology.

Based on the information gained from my informants the most important driver for new technology is to increase their profitability. By developing new technology, they will be able to increase their profitability and prolong the lifetime of a field. Oil and gas companies are always trying to make their business more productive and effective, which also was the end of the ConDeep platforms and the beginning of smaller installations.

Another major driver is new fields that are located in increasingly difficult areas, which demands a new way of thinking. As the industry has set their heart towards new and exciting fields further north, the conditions get tougher and the demand to the technology gets even tougher. This means that they have to develop new technology in order to drill in these areas. From a historical perspective, this has given birth too many revolutionizing technologies that have become standard in today's oil and gas production. My informants believe that in the future there will be new technologies that will be suited to drilling for example in the arctic. Working together with other scientific fields is something that has driven the development forward and will become even more important in the future in order to meet the awaiting challenges.

However, governmental legislation is another important driver for new technology. By demands of more environmental production, they have forced the companies to make new technology in order to match the demands given from the state. It happened in the beginning of the 90's with the new CO2 law and it will happen in relation with new fields.

Lofoten/Vesterålen is an area they want to drill but the technology is not good enough to meet the demands from the government. This also falls under the new and exciting field driver.

Based on previously experiences the industry has gained knowledge that they are able to use for further development of new technology. Learning from previous experiences is an important foundation that needs to be in place in order for the industry to develop new technology.

6.2. Barriers

The biggest barrier for new technology in the oil and gas business is the companies' attitude. As my findings show, the oil and gas business is a very conservative industry and they are skeptic towards using new technology over old. The reason for this is that the companies have to invest a lot of money in R&D without knowing if the result will be satisfying. Look at the Snøhvit field, Statoil chose to develop their own LNG technology rather than buying it, but it has not worked as expected and they are still having problems with the technology, even 8 years after production start.

The companies prefer to be second users of technology rather than lying in the front of the technological scale. As Barlindhaug (2010) mentioned, the companies feel safer with proven technology because this will reduce the chances of any unexpected and unwanted surprises. After my interviews, my impression is that the bigger the companies are the more conservative they get. The reason for this is that they have many big shareholders they have to answer to, who want yield on their shares. Creating new technologies that will not increase the value of the company is not of interest for them. The smaller the companies are the fewer the shareholders are and they often think about increasing the size of the company and gaining competitive advantage with new technology.

Another barrier for new technology can be explained by a sociological phenomenon, and can be seen as an internal barrier. A company's employees might not feel comfortable with change. The current technology might have given them a sort of status in the company, a status that will disappear when a new technology is presented. Some employees might feel their position threatened by the new technology. Sometimes a company's partners on a project can act as a barrier; if they are skeptic to use new technology then it would be difficult to implement it.

7.0 Contribution, Limitations and Further Research

The purpose of this chapter is to present what my research has contributed with and also give a clarification of the limits and my personal suggestion for further research.

7.1 Practical Contribution

In this thesis, I have dealt with a topic that is very interesting for people with interest in the oil and gas business. By finding what drives and hampers the technological development in the oil and gas industry, I have contributed to a better understanding of why these companies act as they do. Normally in an industry where the technology is so important, the companies would usually try to be in the front when it comes to presenting new technology. However, this is not the case with the oil and gas industry. My thesis have dealt with this issue and my findings would be very interesting for other companies involved in the oil and gas sector, either as suppliers or even governmental officials. My thesis explains how the government can contribute to stimulate the industry to develop new technology. Considering how important the oil and gas industry is to Norwegian economy, it would be interesting for them to understand how they can contribute to a further technological development. By understanding what are the major driving forces for new technology it would be possible for other industries with connection to the oil and gas industry to adapt to this. I would also claim that this thesis would be of value for the oil and gas industry to, by understanding the psychological barrier towards new technology they would maybe be able to deal with it. Another important factor for the oil and gas companies is technology communication. The internal fear some of their employees might feel towards new technology is something that the companies could prevent by communicating better the impact of implementing a certain technology. This can ease the transition from old technology to new and prevent internal obstruction.

7.2 Limitations

This thesis is only focused on making a general description of the oil and gas industries attitude towards new technology. By interviewing different representatives from both big and small companies, I have managed to give a general understanding of which factors act as a driver and barrier. The purpose of this thesis has never been to generalize the result but just increase the understanding. This thesis only deals with technology related to the exploration and production face. Another limitation is that the technology mentioned is only the big and high profiled technologies.

Because of limited time, I have only interviewed three informants instead of interviewing a representative from each of the big oil companies on the NCS. The result of this is that this thesis is based upon limited information, however the interviews performed has given me a good impression of what is typical for this industry. Two of my informants are people with high ranking positions in the companies they represent, something which have given me a good deal of information. However, if I had also interviewed other groups of these companies, for example engineers who actually designs the technology, it could have given me an even better understanding of how the management deals with internal barriers towards new technology.

7.3 Further Research

One of the things I would suggest for further research is to interview representatives from other companies on the NCS. However, instead of using the same questions as used for this thesis, I will suggest making a new interview guide based upon the findings made here.

It would also be interesting to go more in depth on some of the barriers discovered, for example speaking to engineers, and hearing how they experience the search for new technology. Do they agree with the conservatism or do they have a higher willingness to explore new technology.

This thesis has described the drivers and barriers for new technology; however, what would be interesting is to turn it around a bit and find out what the most important drivers and barriers are by performing a quantitative study.

8.0 List of references

8.1 Reference books

Agmon, T, & Glinow, A. V.,M. (1991): *Technology Transfer in International Business.* Oxford University Press Incorporated, United States of America.

Argyris, C., & Schön D.A (1996): *Organizational Learning 2: Theory, Method and Practice.* Addison-Wesley Publishing Company, United Stated of America.

DiMaggio, P.J., & Powell, W. W., (1982): *The New Institutionalism in Organizational Analysis.* The University of Chicago Press, United Stated of America.

Garud, R., Nayyar, R.P., & Shapira, B,Z. (1997): *Technological Innovation. Oversights and Forseights.* Cambridge University Press, United States of America.

Hill, W.L.,C & Jones, R., G. (2004): *Strategic Management Theory. An Integrated Approach.* Houghton Mifflin Company (Sixth Edition), United States of America.

Johannessen, A., Kristoffersen, L., & Tufte, P, A.(2005): *Forskningsmetode for økonomisk-administrative fag*. Abstrakt forlag,(2 utgave, Oslo).

March, J.G. (1991): *Exploration and Exploitation in organizational learning*. The Institute of Management Sciences, USA.

Smith, M, E., Thorpe, R., & Jackson, P, R. (2008): *Management Research*, SAGE Publications, (Third Edition, London).

8.2 Reference reports and internet

American Petroleum Institute (2010, February 1): *Facts About Shale Gas*. Downloaded (2010, May 2) from: http://www.api.org/policy/exploration/hydraulicfracturing/shale_gas.cfm

Camp, M., S & Sexton, L., D (1992): *Technology Transfer and Value Creation: Extending the Theory Beyond Information Exchange*. Downloaded (2010, April 15) from: http://www.springerlink.com/content/313k50q63471x135/fulltext.pdf

Goto Know: *The "S" Curve of Technology:* Downloaded (2010, April 24) from: http://gotoknow.org/file/poramez/preview/1.JPG

Ground Water Protection Council & All Consulting(2009, April): *Modern Shale Gas. Development in the United States. A Primer*. United States of America.

Harbo,H (2010, January 09): *Klondyke for Skifergass*. Downloaded (2010, May 1) from: http://www.aftenposten.no/okonomi/utland/article3456279.ece

Norsk Oljemuseum: *Utvikling på Norsk Sokkel. Politiske Føringer og Teknologiske Valg.* Downloaded (2010, May 2) from: http://www.norskolje.museum.no/stream_file.asp?iEntityId=701

NTNU: *Har gjort Norge søkkrikt. Downloaded (April 20, 2010) from: http://www.ntnu.no/skapende/oljegass*

Næring og Handelsdepartementet (2007): *Ny giv for nyskapning.* Downloaded from: http://www.regjeringen.no/nb/dep/nhd/dok/nou-er/2000/nou-2000-7/5/2.html?id=376099

Olje- og Energidepartementet (June 20, 2008): *Norsk Oljehistorie på 5 minutter. Downloaded from:* http://www.regjeringen.no/nb/dep/oed/tema/olje_og_gass/norsk-oljehistorie-pa-5-minutter.html?id=440538

Radaelli, M., C. (1997): *Policy Transfer in The European Union: Institutional Isomorphism as a Source of Legitimacy.* Downloaded (2010, April 05) from: http://aei.pitt.edu/391/01/jmwp10.htm

Sagar, D, Ambuj., & Zwaan, V, D, B. (June 3, 2005). *Technoloigcal innovation in the energy sector: R&D, deployment and learning-by-doing.* Downloaded (2010, April 5) from: http://www.eoearth.org/article/Technological_innovation

Slack, T & Hinings, B. (1994). *Institutional pressures and isomorphic change. an empirical test-includes appendix*. Downloaded (2010, April 5) from: http://findarticles.com/p/articles/mi_m4339/is_n6_v15/ai_16736633/

Statoil (2010): *The subsea story*. Downloaded (2010, May 8) from: http://www.statoil.com/en/TechnologyInnovation/FieldDevelopment/AboutSubsea/SubseaPresentation/Pages/SubseaAnimation.aspx

Statoil (2009, October 12): *Through-tubing drilling.* Downloaded (2010, May 8) from: http://www.statoil.com/en/TechnologyInnovation/OptimizingReservoirRecovery/AdvancedDrilling/Through%20tubing%20drilling/Pages/ThroughTubingDrilling.aspx

Økland, J. (2010, March 24): *Setter ny standard for riggrater*. Downloaded (2010, April 12) from: http://www.offshore.no/nyheter/sak.aspx?Id=28692

9.0 Appendix

Appendix 1: Interview guide

Letefasen:

Dette blir definert som den fasen hvor et selskap undersøker og det finnes forekomster av olje og gass i et område og hvilken teknologi de da bruker under denne fasen:

Teknologiske nyvinninger:

Hva har skjedd på denne fronten med tanke på teknologi som brukes?

Lete stadiet:

Drivkrefter:

Hva har drevet denne utviklingen fremover?

- kostnadskutt

- effektivisering

- miljøhensyn (om ja, utdyp)

Det at staten subsidierer 78% av letekostnader, er dette en driver i seg selv?

Er det interne eller eksterne drivere?

Barrierer:

Hva er barrieren for implementering av teknologiske løsninger?

- Penger

- Frykt for omstrukturering

- Fornøyd med dagens teknologi

- Risiko/konservativt

Hva har vært de største teknologiske fremskrittende når det kommer til lete teknologi?

Produksjonsstadiet:

Hva er de største teknologiske nyvinningene på den norske kontinental sokkelen:

- Condeep plattformene

- Undersjøiske installasjoner

- LNG anlegget på Hammerfest

Hvilke drivkrefter ligger bak forandring av eksisterende teknologi:

- borreforhold (dypt vann, vanskelige forhold etc)
- økonomiske hensyn (oljepris f.eks)
- konkurransefortrinn
- inspirert av andre foregangsbedrifter
- miljøhensyn (pålegg fra staten)
- lærdom fra andre prosjekter

Opplevere bransjen at de må fokusere på stadig mer kostnads og teknologikrevende felt som krever nytenkning?

Kan fokus på nye satsningsområder bringe frem ny teknologi?

- f.eks. skifergass hvor horisontal boring er viktig?

Er det noen spesielle aktører i bedriftenes omgivelser som kan påvirke dens utvikling av ny teknologi?

- miljøvernorganisasjoner
- konkurrenter
- staten(nye krav til miljøhensyn etc)

Hvordan påvirker disse bransjen?

- reguleringer (staten)
- ny og forbedret teknologi (konkurrenter)

Hva er barrierene til innovative teknologiske løsninger i et selskap:

- lite omstillingsdyktig organisasjon
- manglende satsning på FOU
- frykt for å prøve noe nytt (eksisterende teknologi fungerer tilfredsstilende)

- risiko

Fra et historisk perspektiv hva har gjort Norge til ledende innenfor dyp vanns boring?

- samarbeid mellom selskaper

- samarbeid mellom petroleum industri og universiteter/høgskoler

- Til hvilke grad balanserer bransjen mellom å utnytte eksisterende og kjent teknologi versus det å prøve ut ny og uprøvd teknologi som kan gi dere et ledende konkurransefortrinn?

Hvilke fremtidige løsninger kommer mht O&G og hvilke faktorer/aktører som skal være avgjørende at den teknologien tas i bruk fortest mulig?