A CONTEXT STRATEGIC ANALYSIS

- OF FOSSIL FUEL SUBSTITUTION BY BIOFUEL

MASTER OF SCIENCE IN STRATEGY ORGANIZATION AND LEADERSHIP – MINOR IN CSR AND SUSTAINABILE BUSINESS

At Copenhagen Business School

MASTER THESIS

HAND IN: 13/12/10

ADVISOR: HENRIK JOHANNSEN DUUS / CENTER OF MARKET ECONOMICS

NUMBER OF CHARACTERS (Including figures, graphs and tables): 181917

Permitted number of characters: 182000

TOTAL NUMBER OF PAGES: 91

COMPOSED BY: RAMI ALI

CPR: XXXXXX-XXXX

EXECUTIVE SUMMARY

This thesis investigates the Danish biofuel industry in 2009-2010. Danish energy policy formulated in 2008, calls for improvements to the energy sector and a greater focus on sustainability. The most ambitious goal stated was the desire to make Denmark completely independent from fossil fuels in a realistic long-term perspective. One of the hardest sectors to convert to sustainable energy is the transport sector. This is because fuel energy used to run vehicles must be portable, able to be stored, and have a high power to volume/weight ratio. What more is that this sector dominates one third of Denmark's gross energy consumption and, 95% of its consumed energy is non-sustainable fossil fuels. The thesis evaluates bioethanol's candidacy as a possible sustainable solution for fossil fuel substitution.

It does so by first stating what the circumstances are, that are calling for such a change in energy policy. This is done in part I and Part II. Otherwise, most of part I acts as an introduction to the topic and illustrates the thesis's framework.

Thereafter in part II, detailed descriptions of what biofuels are, what process they are made by and how the industry looks today is presented. To complete the industry description there is a brief look at the legal framework the industry is to operate by.

In part III a theoretical framework in an empirical context is formulated. This will predominantly look at strategic considerations and scenario planning. Secondarily it looks at governance from a managerial perspective

Part IV is where the strategic analysis comes to fruition and a strategy is formulated. The strategy is formulated based on the industry description in part II and the strategic analysis in part III. Finally, the concluding thoughts on the thesis are presented.

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PART I: INTRODUCTION

1 Introduction

1.1 Setting the scene

The year is 2010 and for the most part, the majority of the world's economies are emerging from the very turbulent market meltdowns of 2008-2009. Organizations, industries and governing bodies alike are now exiting what has been an arduous struggle for their future preservation. (Shah 2010). These are times where many organizations and institutions are looking back on their strategies and choices and reevaluating themselves. "Near death experiences" have a tendency to stir up emotions and the need to reflect. It is however not all so morbid, for within a crisis lies the ability to seek out opportunities.

We find ourselves in a time where the issue of corporate social responsibility (CSR) has come under the corporate magnifying glass more than ever. The actual concept has in fact existed since the 1970's under the term social marketing and responsible management. (Weinreich u.d.) Regardless of how one perceives what CSR is exactly defined as, its recently growing popularity has had effect on matters that were long underestimated. Sustainability and green business strategy have started to make major headway and are being looked at as strategic solutions rather than external problems.

It is an inevitability, and a well known fact that fossil fuels are going to near depletion as a natural resource within the next several decades.[1] As demand grows and the resource depletes price will rise drastically reaching an estimated 210$ per barrel by 2035 (in 2008 prices). For a comparison, the cost of a barrel of oil reached 147$ in the summer of 2008. The same barrel of oil only cost around 20$ in the 90's. The EU imports 85% of its oil and 60% of its natural gases.

[1] This can be argued, due to estimates regarding depletion dates are based on the current amount of "proven reserves". (Conger 2010). This will be elaborated on in chapter 1.5.1 Delimitations.

The biggest reserves of these two fossil fuels are generally located in the Middle East and Russia. When the source is so centralized the supply guarantee is theoretically insecure since it is exposed to instability by issues of politics or conflict. (Danish Commission on Climate Change Policy 2010, 13-14).

In light of this there has been a growing tendency to explore alternative methods for energy production for industry, society and transport. There are forecasts that the future holds a biotechnological revolution, where biofuels will play a large role and farm yields will reach unmatched levels. (Tvede 2010)

To sum up, we are facing the following economic, environmental and technological scenarios. An economy recovering from recession that is ready for new challenges and opportunities. And an environmental appreciation that has governmental and corporate sector ready to act morally, ethically and more sustainable than they previously had been prone to.

In the future we can expect a strong development in fundamental technologies, necessary to mediate the environmental and resource challenges being faced. It is the choices that will be taken these very days that are going to shape our future environments, economies and industries.

1.2 Background and Motivation

I have spent the last two years of my life at Copenhagen Business School (CBS) studying a MSc in Strategy Organization and Leadership with a minor in CSR and Sustainability. Parallel to my studies I have been working at an independent Danish think tank, Danmarks Erhversakademi (DEA). DEA occupies itself with adding value to society by making Denmark as a whole, more productive. It tries to do so by operating with three platforms; innovation, technology and education.

My motivation for writing this thesis has a root in both my professional and academic experiences. I choose to minor in sustainability for several reasons. By casually following the conventional and financial media I could see a growing interest in sustainability and environmental issues. Before my electives semester I was looking for a niche competency to supplement my broad academic study. So when I discovered that CBS was offering courses in CSR and sustainability I grasped the opportunity to broaden my horizon whilst simultaneously specializing my studies. At my work place I would often co-author writing reports of a similar nature to this one, however it was predominantly in fields outside of sustainability. This is therefore an opportunity for me to write a thesis that has a similar purpose as to the type of work I have been doing professionally, yet is utilizes my core and newly acquired competencies from my studies with a sustainable topic.

I was introduced to biofuels while doing during background research on a Danish biotech company called Novozymes, in relation to another project. This gave me the opportunity to host an interview with their senior sustainability advisor. He had some ideas and perspectives on the industry that I found intriguing. It provided me with an incentive to research it further and ultimately evaluate it as a possible solution for future energy demands. Since then I had always had a fascination with biofuels and their ability to be utilized in such a diverse array of solutions.

1.3 Problem Statement

The biggest challenge for the biofuel industry is that it has not yet been fully tested on a full-scale production in the "real" world. It has experienced a lot of technological advancements, but still has a long way to go before processes become completely efficient.

It is not being considered as a serious contender in the sustainable energy race and even less so in regards to the transportation sector. Denmark has subsidized the industry to a degree that will meet minimum legal requirements by the EU and the Kyoto-protocol, but does not show ambition to take it further.

The intention of this thesis is map the biofuel industry and the framework in which it operates. Thereafter the industry will be evaluated as a solution for Denmark, in its aim to achieve fossil fuel independence. A strategy will be formulated on how such an industry can be constructed.

1.3.1 Topic Sentence

What role, if any, can bioenergy assume in the quest for Denmark to achieve fossil fuel independence?

1.3.2 Research Questions

- What are the circumstances and drivers that call for Denmark to aspire for fossil fuel independence?
- What is the current state of the energy sector and the biofuel industry in Denmark?
- How is bioethanol created, what are the processes of the industry and what is the state of the current industry?
- What are the various applications of biofuel, and what commercial markets are they optimally suited for?
- What are the strategically forecasted scenarios for the bioethanol industry?
- How can a bioethanol meso strategy be constructed in a manner that caters to private profit driven market frameworks in a sustainable context?

1.3.3 Significance of problem

The potentially massive positive impact this industry can have on the Denmark and even the world is almost beyond comprehension. If it not only exists but also functions optimally giving off its intended effects. It can solve problems on a wide spectrum of issues ranging from, the environment, depletion of critical resources, consumer cost efficiency, profitability and national competitiveness to name a few. It can open opportunities for fair-trade agriculture production in tertiary countries. Reduce negative environmental impacts on the world. Reduce energy costs for consumers. Perhaps even help maintain employment levels within populations.

Therefore resolving the given problem and topic sentence would have a great deal of significance. This would be regardless of the conclusion being for or against a biofuel energy solution. Either way it would help put a lid on what is fast becoming a heated debate on the matter.

Alternatively, the potentially massive negative impact this industry can have is almost as incomprehensible as the above mentioned. This industry for reasons that will become evident throughout this thesis cannot have the sanction to run ramped. The other side of the medallion will be described later on and will make evident the need to be very strategic regarding this industry and have clear set goals and visions for its application and eventual termination.

It is equally significant to realize that every action has an equal an opposite reaction, and showing acknowledgement of this phenomenon aids in carrying out a proper strategic analysis.

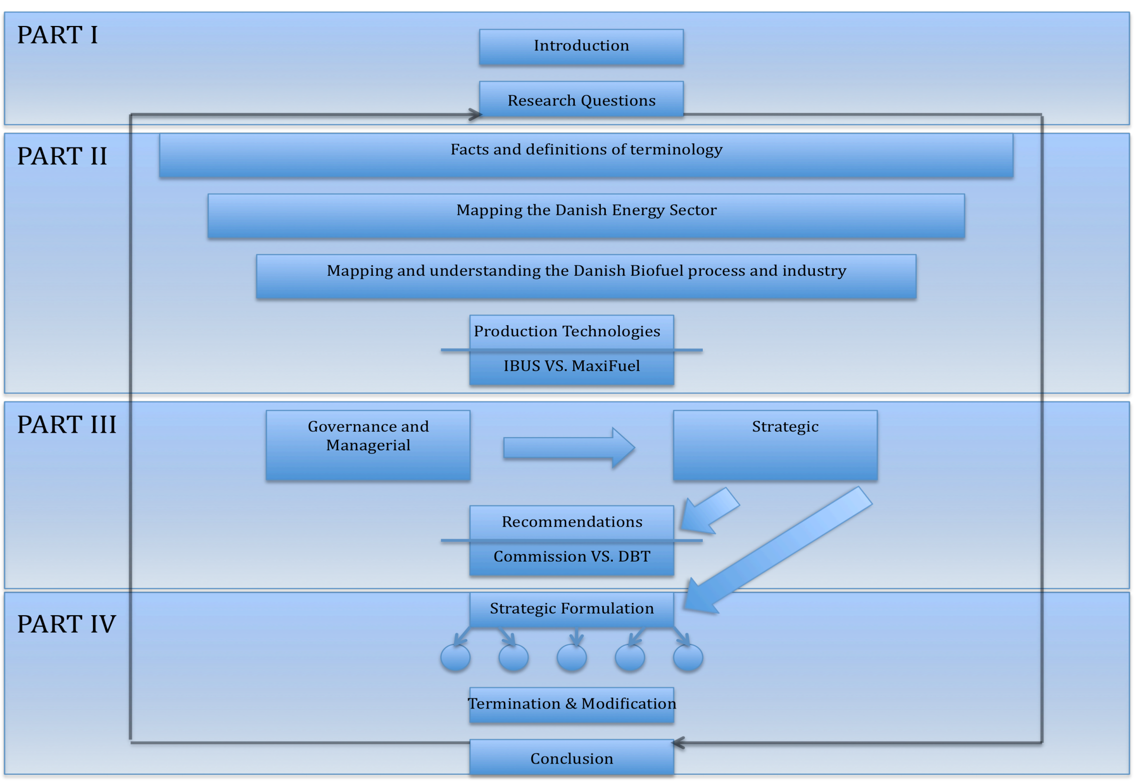
1.4 Methodology, Structures and models

The scope of the research will be based on published reports from active agents/organizations related to the industry. It will then be approached from an academic and theoretical perspective with varied degrees of focus.

The thesis will be implementing Chicago style references. Note that if the reference is inside the paragraph it refers to the particular information/statement given in the preceding sentence-s. Should the reference be located at the end of the paragraph it refers to the information (professional knowledge) generally given throughout the entire paragraph. Bearing in mind that those types of paragraphs still contain original discussions, statements and thoughts of the author. If the reference is found on its own line, it refers to the series of preceding paragraphs.

1.4.1 Flowchart

Below in figure 1 is a flowchart overview of the thesis's framework:



1.4.2 Part and Chapter Description

The thesis will be divided into four interrelated main parts with relevant chapters and sub chapters.

Part 1 Introduction:

- Chapter 1 Introduction: Supplying the beforehand knowledge and framework necessary for understanding and structuring of the thesis.

Part 2 Understanding terminologies, mapping both the Danish energy sector and the biofuel industry:

- Chapter 2 Facts and definitions of terminologies: This Chapter is aimed and giving a fundamental understanding of the main terminologies used within this thesis. It will supplement with relative facts and basic process descriptions.
- Chapter 3 Mapping the Danish Energy Sector: This offers an overview and energy landscape of the general energy sector in Denmark.
- Chapter 4 Mapping and understanding, the Danish Biofuel process and industry: This chapter is particularly long since it covers several elements within this topic, to give a thorough understanding of it. It looks at understanding the general methods for bioethanol creation and describes them in detail. It then serves up two Danish methods for 2gen bioethanol production process.
- Chapter 5 Danish Biofuel production Technologies: Concrete examples of Danish biofuel projects that are underway and emerging. It describes a 1gen project and two 2gen projects.
- Chapter 6 Legal Framework: Legislation and goals regarding energy policy that are relevant to the biofuel industry.

Part 3 Theoretical approaches:

- Chapter 7 Governance and managerial: This chapter looks at how governance techniques are implemented on an organization and industry from a managerial perspective

- Chapter 8 Strategic analysis: Describing how scenarios are constructed and can be planned. It shows the uncertainties related to the biofuel industry and illustrates a series of potential outcomes based on them.

Part 4 Recommendations and Strategy Formulation

- Chapter 9 Recommendations: The Danish Commission On Climate Change Policy and The Danish Board of Technology: This chapter shows two conflicting organizations views on the biofuel industry and presents each of their strategies and recommendations.
- Chapter 10: Strategic Formulation: This is the strategic formulation based on the thesis's own findings and evaluation of the biofuel industry.

Conclusion

- Chapter 11 Conclusion: The concluding thoughts of the author's reflections regarding the topic sentence and research questions.

1.4.3 Theoretical framework

The framework has been segmented into two main themes and sub topics. Sustainable topics and discussions are distributed throughout the entire thesis and are not only designated to the theoretical framework and strategic analysis. The theoretical framework is being introduced after the empirical study, so when theories are presented they can be linked to specific empirical topics and discussions.

Governance and Managerial

- The ecological environment: Understanding ecological arguments and how governments regulate organization based on them.
- Building Scenarios: Understanding the future impact of the external environment

Strategic

- Porters five forces: Competitive analysis
- PESTEL: The external environment
- Balanced Scorecard: Performance measurement systems
- Scenario Analysis: Scenario planning as an approach and tool for the industry

- Scenarios and strategic conversation: Scenario planning from an action perspective
- Option Planning: The decision making consideration to scenario planning
- Beyond Greening: Strategies for a sustainable world: Sustainable specific strategies for managers Focus
- Industry Scenarios and Competitive strategy under uncertainty: Scenario planning at an industry level.

1.4.4 Data Sources

Internet sources: Commissions, Partnerships, NGO's, Theory Models and Corporate organizations

Articles: Various articles written for newspapers, journals, organizations, etc. (may also be internet sources).

Literature: From bachelor, masters and minor programmers (predominantly from the masters). It will be heavily supplemented with specialized literature on strategic analysis and scenario planning.

Interviews: Confidential interview Stefan Mård, Senior Sustainability Advisor, Novozymes (Biotech company that are involved in enzyme creation used in biofuel production). Only non-confidential segments will be referenced. (Controlled online to confirm that Novozymes have gone public with the information Mr. Mård has given in the interview statements).

1.5 Limitations and delimitations

1.5.1 Delimitations

Below is a framework of boundary lines created to preserve the thesis's focus and relevance.

Focused theory selection:

- The scope of theory selection had to be narrowed down and focused into a concentrated theme. Given that the aim of the thesis is to understand an industry, its framework and to strategize based on it. The theories selected have to be reflective of that goal. The main idea is to set up a scenario analysis. Therefore the theories based on industry scenario planning have to be extensive. Governments and regulatory agency are going to be a play a large role in the establishment of this industry. Therefore theories that will illustrate the role and effect of government must also be analyzed. The initial scope looked at a wide array of relevant theories, looking at organization, sense making, market, etc. However, including a wider array of theoretical themes would dilute the concentration of each one. Ultimately the theories that actively and directly aid in creating a well-rounded stratic formulation will be selected. As a result Scenario planning is the central theory applied in this thesis, therefore a detailed and deep understanding of the industry and its processes must be known.

Focused to the Danish market:

- The scope of the industry analysis is focused to Denmark. Attempting a global analysis is too far reaching and provides barriers in regards to culture variations and legislation.

  This does not mean that information from the international scene will not make its way into the thesis. Global conditions, scenarios and facts will be presented and discussed since they will most defiantly determine how the Danish industry can and may be structured. It would not be a valid industry mapping or strategic analysis without taking into account external environment and discussing it.

Fossil fuel depletion dates and proven reserves:

- This topic has been filed under delimitation due to the fact that depletion dates in regards to fossil fuels are relative. These dates are estimated based on the figures of known proven reserves. A proven reserve is when the reserve is accessible, profitable or proven to hold a certain amount of resource for a company to mine. There are a lot more reserves that have been discovered but not mined because they cant be categorized as proven. However technological innovations can help make these reserves proven. New machinery can make inaccessible reserves accessible, or measurable. Increased demand can also turn what were once unprofitable fields to profitable ones. Therefore the depletions dates can keep shifting. (Conger 2010).

  The delimitation is therefore that despite the fact that the dates can shift, this thesis will be operating with statement given in chapter 1.1 setting the scene, regarding the inevitability of fossil fuel depletion being near. This is because logically, unproven reserves will not become proven without the following circumstances. The increase in demand will make a once unprofitable field profitable, supply and demand principles teach us that the commodity price will likely increase due to decreased abundance, hereby securing the necessary profit. Research and development (R&D) of new machinery incur costs that are likely to be passed down to the consumer, hereby once again securing the profit margin. Once costs have risen to a critical level (figures stated previously indicate they will, and will do so within the next several decades), the substitution product will eventually become cheaper alternative for the consumer. So whether the depletion actually occurs tangibly or the costs rise to critical levels creating an intangible depletion, it is essentially the same. The incentive for independence with alacrity from either scenario is preferable.

Perspective of the thesis:

- The thesis will take on a primary perspective at the meso level. Regard its purpose as if it were to investigate if this industry is viable. Similar to the type of investigation a commission or partnership of organizations would perform. Its ultimate aim would be to make Denmark more sustainable and solve a resource depletion problem. The meso perspective is what may be considered the most unbiased since it does not take a specific consideration or outlook of the actors involved in the industry, but rather a holistic viewpoint. In other words, the thesis is not taking a perspective for a specific corporation (or group of corporations). It looks at the industry as a whole with corporations, organizations, government, NGO's, etc. as actors that make the industry exist. Therefore the strategies and discussion are not designated a specific actor, but the entire industry.

  The major challenge with attempting this meso perspective analysis, is that sustainability in a private profit driven market is inherently a paradox. True sustainability puts resources and environment as primary objectives and all other incentives, such as profit, as secondary. In a private profit driven market, a corporate entity would not pursue investments that do not yield a sufficient return on investment. Additionally in a competitive environment, what may truly be the optimal solution for a given scenario could be out competed by rivals based on superior marketing, strategy or lobbying and not the fact that it is the ideal solution. So a creation of a successful biofuel industry must cater to both the profit driven competitive element as well as the sustainable aspect.

CO2 standpoint:

- The thesis is delimited from taking a strong CO2 standpoint. This thesis's aim is not to go green with the demise of other incentives, but to go green and maintain the incentives (i.e. the financial and competitive advantages) for doing so. The environmental benefits should be a positive spill off from an attempt to resource manage (gaining independence from a depleting fossil fuel resource) more efficiently. This delimitation is founded on an impression that most environmental issues are general based on a CO2 argument. The CO2 arguments are currently far to divided, with neither side able to produce conclusive scientific evidence as to the validity of their theories. (Lenntech 2009) This being the current state of the matter, I find that the thesis would stand stronger with the main environmental argument being intelligent and sustainable resource management. In short, CO2 will be covered but plays no significant role in the analysis.

  On a personal standpoint I believe the CO2 argument to be false, based on the following reasoning. CO2 as a molecular element is not inherently toxic or harmful. It first becomes toxic to organic matter when it reaches highly elevated levels. (Lenntech 2009). Then again, the argument is the same for any molecular element reaching drastically heightened levels, even oxygen. If CO2 levels become elevated logic assumes that plant activity should match in growth given that plants in their respiration process consume CO2. (Science Daily 2010). This is not the type of affects one would expect from a compound that is being classified as toxic or harmful. There is then the theory that CO2 is having a greenhouse effect and causing the earth to rise in temperature, this I find is also questionable. I believe that this is caused due to solar activity, cosmic radiation and orbital patterns. A simple reasoning behind this belief is that Mars is also getting warmer, a fact that has been known and proven for over half a decade. (NASA 2005).

  Ice core analysis from the South Pole shows a clear link between temperature and CO2. Yet correlation is not the same as cause. The data presented actually shows that CO2 levels are lagging approximately 800 years behind temperature levels. Meaning that temperature rises, and then CO2 follows. (Brahic og Page 2007)

  Suppose then that the CO2 argument should then be based on the fact that human activity (anthropogenic) is causing an unnatural growth in CO2 levels hereby closing the lag gap.

The question should then become, what is the ratio between natural and anthropogenic CO2 levels? The answer is, anthropogenic CO2 amounts to only 3.2 % of total CO2 levels and naturally occurring CO2 amounts to 96.8%. Additionally and most convincing of all is that CO2 is not the prime green house gas. In reality it is water vapor (including clouds) that accounts as the biggest cause for greenhouse effects. This is due to its superior abundance and ability to retain heat. When you look at water vapor as a factor for heat retention and do the math. It accounts for 95% of the global warming effect and CO2 (anthropogenic and natural together) only account for 3.6%. If you just take the anthropogenic CO2 it only sums up to 0.1% of global greenhouse effect. In short, Man-made CO2 from human activity on this earth only amounts to 0.1% of the total greenhouse effects on this planet. Due to it being dwarfed by the amount of naturally occurring CO2 and that CO2 in general cannot compete with the far more heat retentive characteristics of water vapor. (Broecker 2003)

It seems that more things don't make sense regarding the CO2 argument rather than do, therefore I choose to dismiss its significance in this thesis. I am not claiming that CO2 levels have not escalated, or that they have no effect on the environment, or that it is directly beneficial for plant life for that matter. I am claiming that it does not cause global warming or categorize as pollution. CO2 is therefore an unsuitable flagship issue in regards to climate, environment and sustainability concerns. Intrinsically this also means that I do not believe it should be taxed. Regulation and taxation should be reserved for chemically proven contaminates and toxic materials, such as methane, chlorofluorocarbon and poly-chlorinated biphenyls, that create actual and measurable pollution.

To sum up, acknowledging that CO2 levels have risen and that they can have effect our environment is not the same as agreeing that the effects are significant, that it causes global warming or that it is a pollutant.

Transport Sector:

- Preliminary research for this thesis has indicated certain circumstances regarding the topic sentence. Biofuel as a solution to fossil fuel dependency would most logically only be realistic as a solution in regards to transportation. Hereby meaning that it would be best suited to substitute oil (as liquid biofuel fuel/bioethanol), and not coal or natural gas.

However at this stage it is too early to rule anything out. Therefore the topic sentence refers to biofuel, but the research questions are geared towards bioethanol. The thesis will in general be focusing most on bioethanol. Given that the transport sector consumes over one third of the final energy consumption in Denmark[2], focusing on this sector will have a very significant impact in itself. Additionally, in the event that the preliminary research indications are incorrect, and there are other optimal markets for biofuel than transportation. The scope of the thesis would grow too big and require exceeding the physical limitations of the thesis (describe in the next section).

- In regards to scenario planning there are no actual good or bad scenarios. They are a set of potential situation outcomes that are driven by uncertainties. Due to the physical limitations of the thesis, only the most probable of the scenarios presented will have the strategy formulation based on it.

1.5.2 Limitations

Restrictions that limit the extent of certain aspects of this thesis can be found here.

Interviews:

- Experience has taught me that non-confidential interviews rarely yield practical information I would not have been able to find myself regarding the organization or its standpoints. This is not to say that interviews, even if they are non-confidential, are not beneficial. However, I have a strong desire to keep this thesis un-confidential so it later on may be read and presented in a complete and uncensored state. Additionally, I am seeking to take a meso perspective and maintain an unbiased evaluation. Interviews at this evaluation stage might have an influence on my perspective, given that one individual is better at formulating and arguing for their point than another individual. Furthermore the level of discussion in this thesis does not require me to have any in-depth knowledge as to the inner workings of any specific organization, institution or corporation. Knowing their functions and the information they have already published themselves is more than sufficient at this stage.

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[2] See chapter 3.1 table 2 for source.

The single interview that is referenced in the thesis was the interview that initially fueled my interest in the industry. I therefore, reference to non-confidential statements that were said during the interview, to give credit to the interviewee that inspired my line of thought. The actual interview was confidential so a transcript will not be added in the appendix. It should not be necessary for validation in any case, since the statements do not contain information that has not been published in the public media. Should there for some reason arise a need for documentation of the interview and statements. Such documentation can be presented given the examinator/censor acknowledge its confidentiality. The interview segments I am using are quoted word for word.

Size of the thesis:

- The physical aspect of this thesis is limited by the thesis guideline, in regards to layout and length. (CBS 2110)
    - 2275 characters including spaces, (tables count 800 STUs) account to a standard page
    - 2,5 cm margin on all 4 sides
    - 12 pitch Times New Roman
    - 1,5 spacing
    - 80 standard pages

1.6 Critique of sources

The most comprehensive empirical sources are generally from agents and actors that have a stake in this industry's success. Therefore a scrutinize eye in regards to bias must be applied at all times. Either they are a partnership of organizations that are evaluating the market for profit and trying to create public awareness, or they are a NGO whom are approaching the topic with their environmental concerns as a flagship or they are a commission set up to fulfill government requirements.

Articles and Internet sources as such are great resources for discussions and specific information, however not informative enough in regards to creating a detailed energy sector mapping.

The Danish Energy Agency has produced a conflicting report, energy statistics 2008. After close examination I have come to realize that their figures do not correspond to the figures in Eurostat's energy report of 2008. There is an expected variation when two different agencies carry out the same figure calculations, perhaps utilizing varied methods. However the puzzling aspect is that The Danish Energy Agency present Eurostat figures under its International comparisons chapter. This means that they have conflicting figures regarding Danish energy statistics in the same report. The Renewable Energy chapter of the report claims that 67.2% of renewable energy came from biomass and waste, where under International Comparisons with Eurostat figures it claims this figure, is 80%. There is a substantial difference here, so for the sake of statistical creditability I will be primarily utilizing Eurostat and only referring to the Danish Energy Agency report when I need Danish centered information that can be valid without a mathematically exact calculation. An example of this would be, if I have calculated (based on Eurostat statistics) that Denmark uses more renewable energy than it makes, I would assume they import the rest. Looking at the Danish Energy Agency's report I can confirm that they do import renewable energy, but not state their figures. Eurostat will supply the hard data, and The Danish Energy Agency report will be used to describe situations, circumstances and scenarios to back it up.

PART II: UNDERSTANDING TERMINOLOGIES, MAPPING BOTH THE DANISH ENERGY SECTOR AND THE BIOFUEL INDUSTRY

2 Facts and definitions of Terminology

To understand the terminology used and their context throughout this thesis one must be familiar with the following terms and definitions. Having a deeper understanding of what biomass is, what it consists of and how it is used, helps when devising a strategy regarding its application and potentials.

2.1 Biomass

Biomass is a collective term for organic material consisting of plants, animals and their waste. There are two stages for energy production from these materials. The primary production occurs through photosynthesis where the sun's energy is converted to sustenance as energy for the plant. With animals it occurs with the consumption of plants or other animals that have consumed plants. The secondary production occurs with the decomposition of these organic materials.

The entire Danish biomass production is comprised of:

- Vegetative and animalistic production from forests.
- Farming and fishing.
- Meat and meat production.
- Wood, corn, wheat, straw and produce.
- Algae
- Organic waste from domestic and industrial sources (including slurry and sewage).

(The Danish Board of Technology 2009, 100)

Energy Crops these are crops that have been grown with a designated purpose to be utilized for energy production. They can be segmented into single or multiple year crops and also forestry. (The Danish Board of Technology 2009, 100)

2.2 Energy

Sustainable Energy is energy that is produced from a sustainable source. A sustainable source is characterized by the fact that is non-depletable and regenerative. Such sources are:

- Sun: solar
- Atmosphere: wind
- Ocean: Hydro (tidal)
- Freshwater: Hydro (dams)
- Underground: Geothermal
- Element: Thermodynamic non toxic reactions (Hydrogen and oxygen reacting in a hydrogen fuel cell)
- Earth: Biomass

Biomass is in a sense depletable if it is not replanted/reproduced or naturally restored. This fact gives cause for debate regarding its candidacy as sustainable. However, when considering that crops can be re-sown and animals bred within a relatively short period of time, doing so by being naturally fueled by the sun and atmosphere it then falls under the category of sustainable. The condition is that regeneration times and overconsumption are taken under consideration. (The Danish Board of Technology 2009, 100). The process by which it is restored determines how sustainable it is. It is the amount and type of energy used in its replenishment that is decisive, when it does not occur naturally. One measure of this is CO2 neutrality.

Bioenergy is all energy produced as a result of biomass. This includes solid biofuels used in combined heat and power plants (CHP-plants) and biofuels used in combustion engines. (The Danish Board of Technology 2009, 100).

2.3 CO2

CO2 is the combined element of carbon and two oxygen molecules *O=C=O*. This is typically a byproduct of photosynthesis (opposite of respiration), land clearing or burning carbon-based elements. Fossil fuels are essentially organic material and therefore comprised of carbon. When fossil fuels are combusted they release CO2 and an array of other chemicals. The same thing happens when Biofuel is burnt or biofuels are combusted. The main difference is that the biofuels are chemically cleaner. When something is considered **CO2 neutral** it means that it neither contributes nor reduces CO2 levels. Biofuels are CO2 neutral since the amount combusted releases a certain CO2 amount, which is absorbed by plants, which are being grown for the next production of biofuel. (Gable og Gable u.d.) Fossil fuels do not share that cycle since they are the result of highly compressed organic material that is several millions of years old. In other words it gets used much faster than it is restored, hereby only adding to the CO2 level.

There is little doubt that changing the balance of CO2 in the atmosphere will have its effects. It is the question of the significance of those effects and if they are harmful that make the CO2 discussion controversial (see subchapter 1.5.1 CO2 standpoint).

2.4 Biofuels

Biofuels is the universal term used to describe gas, liquid and solid fuel made from biomass.[3] These fuels can be used to power CHP-plants or combustion engines.

Fibrous biomass can be after sorting be used in CHP-plants as direct **solid biofuel**. This means that without processing it can be incinerated to create heat that boils water, creating steam to power turbines. This is used in substitution for coal. There is generally a high-energy yield from this process. However yield effect is determined by the sorting ratio of the various biomass elements.

Liquid biofuels are segmented into two sub categories called **bioethanol** and **biodiesel**. Bioethanol is based on sugar or starchy biomass that has undergone processing. This is called first generation bioethanol (1gen). Once fibrous biomass has undergone processing it can also

[3] In depth description of these biofuels will be presented in chapter 4 Mapping the Danish biofuel industry

create liquid biofuel, called second-generation bioethanol (2gen / cellulosic ethanol). Fibrous biomass, when referring to 2.gen is also known as **cellulosic biomass**. The process biomass undergoes to make ethanol is called fermentation, and results in an alcohol based fuel that is suited for combustion.

Biodiesel can be produced from any vegetative or animalistic oil. The most common type of biodiesel is Fatty Acid Methyl Ester (FAME), and is created by a chemical reaction called transesterification.

Biogas is created by anaerobic (oxygen-free) decomposition of biomass. Depending on what biomass is used, the gas can be comprised of varied ratios of methane and CO2. The optimal mix is reached when combining several types of biomass into the decomposition phase.

(The Danish Board of Technology 2009, 101).

Enzymes are proteins created by microorganisms that behave as catalysts in a biochemical process to then initiate fermentation. (Martin 2007) They are much the same as the digestive enzymes in our stomachs that help break down and consume food. The enzymes found in cow stomachs for example, are very good at breaking down grass (cellulosic biomass).

3 Mapping the Danish Energy Sector

3.1 Statistical Overview and Energy Landscape

Before attempting to map the biofuel industry is imperative to have an understanding of its dimension in the total energy market. Knowing the position it has in relation to the other energy sources and the roles that each source plays are beneficial. It is also helpful to know the attributes of the entire market and similar markets alike. This holistic point of view is important to gain if a sound strategy is to be formulated later on.

To understand the state of the Danish energy sector one can refer to the four tables illustrated below[4]. Please refer to the appendix to see the tables' calculations, methods and notes.

[4] The tables and calculations are the thesis author's own creation based on Eurostat statistics

Together they show what Danish energy sector looks like by how much is consumed, on what its consumed and how its distributed. This is also known as an "energy landscape". Sweden, Finland, Iceland, Norway and the EU27 have also been included since they, with the obvious exception of EU27, are the countries Denmark can best be related to in regards to energy. They have been included to give an opportunity to benchmark the figures and also give the figures presented relativity. The figures of most interest in this thesis's context are Denmark's.

2008		Share of Gross Energy Consumption, Pct.					
Table 1 (Eurostat, 2010)	Gross Energy Consumption PJ	Oil	Natural gas	Solid fuels	Nuclear energy	Renewable	Deviation from 100 % share of Gross Energy Consumption
Sweden	2093	27.6	1.8	5.3	34.2	30.9	0.3
Finland	1521	29.9	10.6	14.8	16.3	25.2	-3.2
Denmark	832	40.5	20.5	20.2	0.0	18.1	-0.6
Iceland (2006)	182	22.7	0.0	2.3	0.0	74.9	0.0
Norway	1249	39.8	16.3	2.6	0.0	45.2	3.9
EU27	75333	36.5	24.5	17.0	13.4	8.4	-0.2

Table 1 (as seen above) shows the Gross energy consumption of Denmark and the share of the gross energy consumed. Gross energy means the total amount of energy hereby including the energy consumed in the actual energy production. Solid fuels are coal, along with oil and natural gas they fall under the category of fossil fuels.

One can see that only 18% of the gross energy consumed is derived from renewable sources, whilst there is an 81% dependency on fossil fuels.

2008		Share of Final Energy Consumption, Pct.			Share of Final Renewable Energy Consumption within Sector, Pct.		
Table 2 (Eurostat, 2010)	Final Energy Consumption PJ	Final Energy Consumption Industrial sector	Final Energy Consumption Transport sector	Final Energy Consumption Services and Household sector	Final renewable Energy Consumption Industrial sector	Final renewable Energy Consumption Transport sector	Final renewable Energy Consumption Services and Household sector
Sweden	1375	37.4	27.6	35.0	31.4	N/A	9.1
Finland	1083	48.1	19.2	32.7	26.7	N/A	15.5
Denmark	651	17.8	35.3	46.9	6.0	N/A	14.5
Iceland (2006)	100	35.8	20.1	44.1	4.2	N/A	44.4
Norway	791	35.7	27.1	37.2	18.0	N/A	25.8
EU27	48928	27.2	32.0	40.8	6.4	N/A	7.9

Table 2 (as seen above) shows the final energy consumed. This is the energy that has been produced for consumption (excluding the energy used in its production). It is thereafter divided amongst the three sectors of industry, transport and services/households. The final segmentation is the percentage of renewable energy the sector uses. An example is that the Danish industrial sector uses 18% of the final energy consumption. 6% of that 18% is from renewable sources. 18% is 115 PJ and 6 % of that is 70 PJ. The percentage of renewable energy the transport sector utilizes is N/A (not available) due to either that it is non-existent or immeasurable.

This shows us that the Danish transport sector consumes a large percentage (over one third) of the final energy consumed. This is the highest percentage of the benchmarking figures presented and even slightly higher that the European norm.

2008			Production Share in pct.				
Table 3 (Eurostat, 2010)	Gross Consumption of renewable energy + waste, PJ	Primary renewable energy production PJ	Hydro	Wind	Biomass and Waste	Solar	Geothermal
Sweden	672	672	37.0	1.1	61.9	0.1	0.0
Finland	383	384	16.1	0.2	83.9	0.0	0.0
Denmark	151	132	0.1	18.9	80.0	0.4	0.7
Iceland (2006)	136	136	19.2	0.0	0.1	0.0	80.7
Norway	565	560	89.7	0.6	9.8	0.0	0.0
EU27	6324	6202	19.0	6.9	69.1	1.2	3.9

Table 3 (as seen above) shows the renewable energy consumption and primary production. Primary production means the total production of the country (hereby being able to exceed consumption figures). One may quickly notice that Denmark consumes more renewable energy than it produces meaning that it imports the difference. (Danish Energy Agency 2009, 7) Importing, however admirable that may be, it is not an optimal solution. With the array of renewable energy sources available one should in theory be able to produce 100% of energy demands locally, regardless of the country's geosystem. This 100% achievement is strictly theoretical in our current society however the point is that Denmark certainly can reach levels high than 16% of gross energy consumption deriving from domestically produced renewable sources. Another interesting figure is that Denmark retrieves 80% of its renewable energy from Biomass and waste. This may on give the impression that there is a vibrant and active biofuel industry, yet the reality is quite the contrary. The definition of biomass includes straw and wood. This straw and wood is simply burnt to create energy; this is also the case in regards to waste. Waste accounts for 38% Wood/straw account for 55% of renewable biomass and waste energy. This means that under 7 % comes from biofuels, which is 1% of Denmark's gross energy consumption (1% being a generous estimate). (Eurostat 2010, 76).

2008			Share in pct.			
Table 4 (Eurostat, 2010)	Population (Approximately)	Primary energy production PJ	Energy efficiency	Energy Self Sufficiency	Renewable Energy Self Sufficiency	Consumption of energy per capita, PJ
Sweden	9183000	1372	65.7	65.6	100.0	0.000228
Finland	5301000	680	71.3	44.7	100.2	0.000287
Denmark	5476000	1130	78.3	135.9	87.8	0.000152
Iceland (2006)	316000	136	54.8	74.9	100.0	0.000576
Norway	4737000	9183	63.3	735.2	99.2	0.000264
EU27	497649000	35283	64.9	46.8	98.1	0.000151

Table 4 (as seen above) shows some very interesting calculations based on the previous three tables. One can see that Denmark has an energy efficiency of 78%. This is a reflection of how efficient their energy production is; or rather that only 21.7% of their gross energy consumption is used to create energy for the three sectors. This is a very good standard, and illustrates that the technologies and processes used by the Danish are very efficient and competitive. One may also notice that they have an energy self-sufficiency of 136%. This indicates that there is an overproduction of energy that is exported (Exports consisting of Cude oil/feedstocks, petroleum products, natural gas and electricity) (Eurostat 2010, 66). What is most interesting though is the fact that Denmark is only 88% self sufficient in regards to renewable energy. The remainder is imported. This is interesting because it shows that there is a determination to reach a certain percentage of Gross Energy Consumption from renewable energy. Denmark can in reality completely satisfy its energy consumption with non-renewable energy, yet does not do so. Finally there is the energy consumption per capita, which is remarkably low when compared to the other four similar countries. This could be the result of either an energy conscious population or high domestic energy costs. Be it one or the other this is a favorable circumstance since it can be a potential driver to introduce a cheaper sustainable energy solution.

4 Mapping and Understanding, the Danish Biofuel Process and Industry

This section is intended to give the reader an idea of how the Danish biofuel industry is landscaped. In this context it would also be beneficial to present related information regarding biofuel. Information such as, the framework that drives the industry, in depth descriptions of biofuels and their creation processes.[5]

4.1 Biotechnology and its Circumstances

1gen biotechnology (biotech) has been in existence and usage since the Second World War. It is no secret that during wartime, technological innovations happen often, and they tend to develop quickly as well. This is due to the nature of war. Circumstances demanding innovation arise faster then during peacetime and the demand for solutions are driven stronger, since lives or victory is on the line. The development of alternative fuels was necessary since oil supplies tightened and enemy forces targeted oil transports.

Today biofuel production exists on a commercial scale in several parts of the world, predominantly in Brazil and the USA. 2gen biotech has consequently been under development for some time as well. It has been constantly undergoing developments to its process and yielding better results (Novozymes 2010).[6] (The Danish Board of Technology 2009, 17).

The Basic process from which 2gen is made has already been developed and tested in at a laboratory scale. In countries such as Denmark, Canada and Sweden, there exist small pilot and trial facilities that are operating at an experimental operations level. The Danish Board of Technology (DBT) in their 2009 report claim that there is not yet full scale 2gen plants in existence at a commercial level anywhere in the world. However they do state that these plants

[5] The structure of this chapter is inspired by the report from (The Danish Board of Technology 2009, 12-89)

[6] The source cited from DBT is approximately one year old; therefore I am taking into account developments, not into the fundamental process, but the efficiency since then. Stated in source preceding it from Novozymes.

are up and coming in Denmark and larger countries such as China and the USA. (The Danish Board of Technology 2009, 17)

This is contradictory to claims made by REN 21 in their renewable global status report: 2009 updated version. They state “The cellulosic ethanol industry accelerated development of new commercial-scale plants in 2008. In the United States, plants totaling 12 million liters per year were operational, and additional capacity of 80 million liters per year was under construction (also reported as 26 new plants under development and construction).” (REN21 2009, 16). This contradiction has been presented to underscore the fact that even something as clear-cut as energy landscaping can be relative. Perhaps the DBT consider commercial production at a scale where it can rival fossil fuel production, and REN21 regards it by a small yet significant amount being commercially consumed. In either case there does not currently exist at a level or scale that can out compete fossil fuels.

This is due to the nature of the 2gen biomass used. Since it is fibrous it is harder to break it down into a form that can be processed for energy usage. Physics teaches us that actions that are arduous generally consume/cost energy to the host performing it. In laymen’s terms since 2gen processes are harder to pull off then 1gen, they use more energy to produce. Meaning that the final energy yield is lower since more energy went into production.

The other side to the medallion is that the biomass used in 2gen processes are cheaper than biomass used in 1gen. This is because the biomass used in 2gen is comprised of waste products and is in greater abundance for that reason. 1gen biomass is derived from footstock such as corn and sugar, making it controversial to use (the proverbial expression of “taking food out of someone’s mouth” explains the scenario best). 2gen actually provides a waste management service and does not create moral implication in doing so. In an interview with Stefan Mård, Senior Sustainability Advisor, Novozymes he stated that Novozymes were interested in switch grass for cellulosic biomass material. “A great thing would be African elephant grass (switch grass), a huge fat grass that grows everywhere in a big area between Kenya and South Africa. But second generation is eventually going to get bigger than first… will eventually be strictly second generation plants.” (Mård 2009). Here Mr. Mård shows that there is also potentially a benefit in harvesting 2gen cellulosic energy crops. This means that 2gen would no longer have to rely on waste from 1gen production and other biomass waste, but can have its own direct biomass resource. Then again this can raise the question that land use for agriculture will be cannibalized by land use for energy crops (same as in the known coffee and tobacco industry where farmers grow cash crops instead of food crops). Then again using Brazil as an example, it has 23% of the world's arable land around half of that is unused (keep in mind these figures are without clearing rainforest). (Dyson 2008). Perhaps more exemplary than Brazil in this case, would be that Africa current holds half of the worlds unused arable land (also without endangering forests or other ecosystems). (Thurow 2010).[7]

As previously stated, 2gen biomass is harder to break down into ethanol due to its fibrous nature. This demands that the biomass is pretreated with an array of energy consuming processes, such as costly enzymes (such as are produced by the Danish; Novozymes, Danisco and Haldør Topsøe). This drives up the cost for energy, the plant facilities and operations. The challenges that lie ahead for 2gen is how to develop technology to optimize production processes and increase energy efficiency. (The Danish Board of Technology 2009, 17)

4.2 General Bioethanol Production Process

This section, relative to the nature of this thesis, is quite technical. However it does serve the purpose of giving a deep insight into the functions and processes involved in making bioethanol and therefore gives important considerations to biofuel industry strategies later on.

4.2.1 Components of the process

Bioethanol can be produced from vegetative raw materials consisting of various natures. In both 1gen and 2gen technologies, through different process, carbohydrates in the plant matter are transformed into ethanol. 1gen utilized biomass of a starchy and sugary nature, which contains easily accessible carbohydrates. By implementing microbial fermentation processes these carbohydrates can be extracted with relative ease from the substrate.[8] 2gen biomass is however

[7] The notion to investigate the extent of unused arable land to counteract the "cash crop land use" argument was inspired by the Stefan Mård interview.

[8] This is the substance that is being acted upon by enzymes and fermentation. In this case enzymes are the catalysts for the fermentation process.

much more fibrous. In this plant matter the carbohydrates polymers are weaved into a compact chemical matrix, lignin (lignincellulose), making the carbohydrates less accessible. (The Danish Board of Technology 2009, 17)

Carbohydrates (saccharides) can be segmented in accordance to their molecular complexity, from mono to polysaccharides. The less saccharides a compound has, the sweeter it is and easier to break down like in sugar. The more it has, the opposite become true as in grass.

Lignocellulose is the term for the three critical compounds within plant fibers called cellulose, hemicellulose and lignin. If one leaves out lignin then the term is called **holocellulose**. All green plant life is comprised of approximately 75-85% Lignocellulose.

Cellulose is a relatively complex polysaccharide carbohydrate consisting of large number of small glucose units. **Glucose** is a monosaccharide that essentially functions as fuel for nearly every living organism. Cellulose is one of the most common organic compounds.

Hemicellulose is a heterogeneous polysaccharide that is comprised of varied polysaccharides, which have shorter strands than in cellulose.

Lignin, contrary to holocellulose, is not comprised of carbohydrates, but by polymers of various aromatic connections. Lignin is very complex and built up irregularly as a macromolecule. These molecules are so tough that they are unable to be dissolved easily by water. It is therefore difficult to hydrolyze and break down. Lignin can be found in the wall of the plant cell. Its features make it an ideal outer coating that protects from fungus, oxidation and viruses. Lignin is second to cellulose as the most common organic compound.

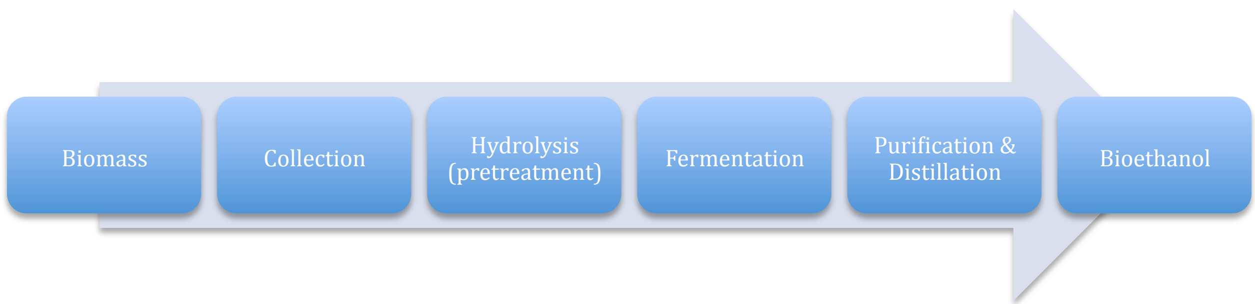
In the plant cell wall macromolecules form a tight chemical structure of resilient lignin wrapped around the holocellulose. This structural composition makes the wall very stiff and resilient from microbial and chemical attack. It provides a stumbling block for decomposition and is the scientific explanation to why carbohydrates tied into plat fire matrixes' are difficult to extract. This makes it hard to access the monosaccharides that are uses in the actual fermentation process. Unfortunately there does not exist a single microorganism that can effectively convert all monosaccharides for the fermentation process.

(The Danish Board of Technology 2009, 17-19)

4.2.2 Pretreatment and decomposing lignincellulose

Not unlike most things in life the first step is always the hardest, the process from which creating 2gen is no different either. In order to gain access to the desired monosaccharides within the holocellulose the tough lignin exterior must be bypassed. This is therefore the most crucial stage in 2gen bioethanol creation.

A combined series of mechanical, thermal, chemical and biological pretreatment methods are applied at this first phase in processing. Currently further research is being conducted in methods using acids, bases, microorganisms, pressure and temperature. What all these pretreatment methods have in common is the high consumption of energy, because it is arduous to decompose lignin. This is the most important place to look in the energy creation process when attempting to reduce energy input, to secure higher yields. The most common pretreatment methods utilize hydrolysis, it fits into the process as seen in **figure 2** below: (The Danish Board of Technology 2009, 19)



For enzymatic hydrolysis enzymes called cellulases are used. They convert celluloses into glucose by breaking down the glycosidic linkages. Over the past few years there has gone a lot of R&D into enhancing cellulases. However there is a fundamental problem with it today, and that is that is productivity and efficiency is relatively low. Even worse is that its cost is quite high as well. There is debate on which of these two problems is holding back the real world application of 2gen process to a higher degree. Some would argue that it not being totally effective can be overlooked if it just cost less. Then you could just use more to get the desired effect. However that is not optimal either. Over gearing an ineffective process to meet demands is a system that is doomed to fail at one point. If the productivity of the enzymes is not improved the process is not optimally sustainable since a lot of energy is "wasted" in the creation process. However the advances so far still make this all look very promising. Since 2006 the enzyme cost has essentially halved, and is expected to drop even further. By 2015 it is expected to fall another 40% hereby only costing 2 Danish kroner (dkk) per liter. An alternative to enzymatic hydrolysis is the application of acid hydrolysis. The deterrent from using it is that, like cellulases its cost are high, and additionally it has a detrimental effect to the sugar output. A less conventional approach to pretreatment is gasification. This process eliminates the need for hydrolysis to break down holocellulose. It converts the biomass into synthetic gas (syngas). There are different methods for gasification in existence, and some are used in collaboration with one another. The syngas is then exposed to microbial fermentation or chemical catalyzation and turned into bioethanol. This process is however still experimental and under development. (The Danish Board of Technology 2009, 19)

4.2.3 Fermentation

The next step in the production process, fermentation, is not without its woes either. Fermentation faces challenges in converting all the sugars that the potential available. It has been difficult of find an organism that can convert the hemicellulosic D-pentose sugars. Those pentoses can amount to between 10 – 60% of the sugars, depending on the type of biomass. Conventional fermentation with yeast is only able to convert the glucose. So making this phase more efficient and productive can also have very positive outcomes in regards to yield.

Not surprisingly, there have over the past decade been made attempts to genetically modify yeast to convert pentosugars. The great advantage to yeast is that it is very tolerant to high concentrations of sugar and ethanol. The great problem with them is that they do not convert the sugars in unity, and that can make the fermentation process unreasonably long. The conversion time of these pento sugars is generally very long so using yeast to ferment biomass with a high concentrate of this sugar is not ideal in any circumstance. Another solution to extracting these pentosugars must be found to get the full energy potential from the biomass.

There are however three major corporations that have attempted another approach to extracting sought after sugars; BioGasol (Danish), Masoma (USA) and TMO (UK). They use a process involving thermophilus bacteria for the fermentation of C5 sugars. They face challenges however with this type of organism being sensitive to process inhibitors. This can sink the fermentation process and result in low ethanol productivity. BioGasol has however produced an organism that can successfully convert all pentosugars and glucose. They have accomplished this by modifying the organism's genetic code.

(The Danish Board of Technology 2009, 19-20)

5 Danish Bioethanol Production Technologies

IBUS and Maxifuel are two Danish examples of 2gen bioethanol technologies. They have two different approaches to producing their primary product, bioethanol.

5.1 IBUS

IBUS is a daughter company of DONG-energy and is short for integrated biomass utility system. It gets its name because the method in witch it produces bioethanol runs parallel to CHP-plants (The CHP-plants are run by a company called Inbicon). A synergy is formed where the coproduction of ethanol, heating, electricity and feed yields more total efficiency.

The IBUS process is in fact flexible in regards to which type of biomass it can process. This makes it easily adapt to external determinants and variation such as growth seasons of agriculture prices.

The production process results in an outcome of three different products bioethanol, molasses and fiber residue. The bioethanol is obviously the prime product that was the purpose of the production, however the byproducts are not without their use. The molasses can be used in animal feed and the fiber remains can be incinerated by the CHP-plants. This incineration is one of the linkages to the CHP plant that make this process synergetic. Since the production process results in several usable products, the IBUS plant can be classified as a biorefinery.

(The Danish Board of Technology 2009, 21)

5.1.1 Pretreatment

If the biomass input were straw the production process would appear as following. First the straw is mechanically treated, by getting shredded into 1-5cm pieces. Next is a hydrothermal circulation process. This is where the straw is mixed with water under high pressure, at temperatures of 200 degrees Celsius, for approximately 10-15 minuets. The energy input needed to heat the water under pressure is directly infused from the CHP-plant. The CHP-plant provides the energy needed to boil the water, and later on receives a portion of it back in the form of fiber remains. This is how the synergetic cycle if formed between the two. It is however worth noting that the power given to the IBUS plant is more that the CHP-plant gets in return.

This pretreatment phase has the effect of wearing away at the biomass just enough to break up the tough lignincelluloses chemical bonding. What one is left with is a so-called fiber soup. The straw in this soup has its lignin more or less intact, however the holocellulose has been significantly decomposed. The liquid that is filtered out of the soup can thereafter be steamed resulting in a molasses residue, which can then be used as animal feed.

(The Danish Board of Technology 2009, 21-22)

5.1.2 Pretreatment with enzymatic hydrolysis

The pretreatment has had the effect that it has separated the fiber matrix of the biomass creating greater voids in between the actual fibers. This allows enzymes physical access to the oligo and polysaccharides. This next stage is where the filtered biomass is transferred from the boiler into a liquefaction tank where water and enzymes are added, in what is known as a hydroenzymatic process. During the hydrolysis the fibers dissipate from a lumpy irregular mix and become more homogenous in regards to the viscosity. The hydroenzymatic process can in reality be called a secondary pretreatment that operates at a more detailed and intricate level.

The enzymes used in the liquefaction tank have varied properties and effects on the substrate. They function in unified coordinated synergy, where they pool together to decompose the material. There is an ongoing intensive research into the improvement of these enzymes. This research is taking place within the two world leaders on the topic (both of whom are Danish Companies) Novozymes and Danisco (Genencor).

(The Danish Board of Technology 2009, 22)

5.1.3 Fermentation

Once the sugars within the straw have been released via hydrolysis the next step is fermentation. The fermentation process is a microbial decomposition that is initiated through adding yeast to the mixture. This breaks the mixture down into a material that is organic or nonorganic or a combination of the two. The microbial conversion of the sugars results in organic bioethanol and nonorganic CO2. This is called and alcohol fermentation process (it is similar to the fermentation processes of breweries).

In traditional breweries common baking yeast is applied for the fermentation process. However in the creation of bioethanol traditional yeast is not efficient enough. This is because its genome is not equipped with the proteins that allow it to break down pentose sugars. Luckily, the department of system biology from the Technical University of Denmark have isolated some thermophilus bacteria, found in the hot springs of Iceland, which can do the job. What is unique with these bacterias is that they have the protein to produce an enzyme that efficiently decomposes hemicellulose, and they can withstand high temperatures.

The term used to describe the process where genes are added or removed to alter the properties of a cell is called metabolic engineering. The biotech industry use molecular biology to metabolically engineer a cell for the development of what is referred to as a green cell factory.

Green cell factories are microorganisms that are modified to carry the qualities of both yeast and the thermophilus bacteria found in Iceland. So with the addition of the substrate, the green cell factories can now using environmentally safe methods, ferment the mixture into bioethanol.

(The Danish Board of Technology 2009, 22-23)

5.1.4 Distillation and final processing

After fermentation, the soup is taken for further distillation in the final creation process for pure bioethanol fuel. What is left behind is a mixture with a very thick viscosity. It contains approximately 60% lignin and remains of hemicellulose. This mixture is the separated into solid and liquid segments. The solid segment is the riches in lignin, and after drying and compacting it can be used for incineration at the CHP-plant. The liquid segment is steamed into molasses. However some of this molasses is reintroduced into the production process since it is rich with active enzymes, the remainder is put to use as animal feed.

(The Danish Board of Technology 2009, 23)

5.2 Maxifuel (BioGasol)

Maxifuel is a project that was developed at the Technological University of Denmark. I was later on, developed into a spin of company, and called BioGasol. The process lives up to its namesake in the sense that it is based on maximizing the fuel yield as much as possible. Contrary to the IBUS project Maxifuel is not based on integration with a CHP-plant. This mean that is has to be self sufficient in producing or acquiring the energy needed for high energy consumption pretreatment processes. However the design of the process does allow for CHP-plant integration should the circumstances demand it. There are advantages and disadvantages to such a design. The obvious disadvantage is that energy for the production process must be bought by the plant and delivered in some manner. The advantage is that location is not determined by the necessity to be near, or built into, a CHP-plant.

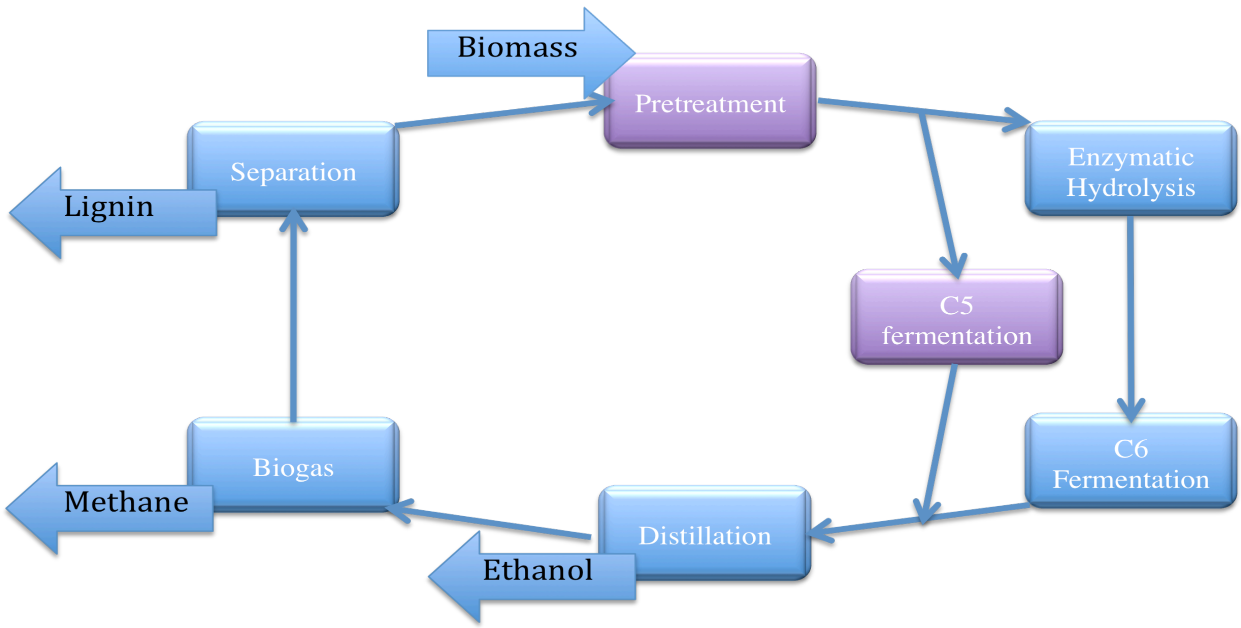
Like IBUS, Maxifuel is flexible in regards to the input biomass type. The ability to take on various biomasses and or combinations of them, gives it the same liberties as IBUS. In that seasonal growth and price fluctuations allow for various biomass to substitute one another in times of abundance or shortage. This flexibility also allows the plant to be set up at different geographical locations with different biomasses available at different locations.

The Maxifuel project supply three main products at the end of production, bioethanol, biogas and plant fibers. There is no molasses production because there is a higher yield of ethanol production. This process is able to break down the C5 sugars of hemicellulose and therefore able to ferment more ethanol from the same amount of biomass. This amounts to a potential ethanol production of 300 liters to every ton of biomass. Which is equivalent to a 30 – 40 % higher yield from straw than IBUS can generate. The biogas that is created comes from the cleansing of the remains from fermentation.

Besides the three main products there is also an array of byproducts. First there is hydrogen, which is produced to an amount that is equivalent to 1 % of the total energy production. Then there is a selection of salts, which can be used in agricultural fertilizer. By tweaking production processes one can derive select amounts of each byproduct. Alternatively one can make other biochemicals instead of ethanol from the C6 and C5 sugars. One can produce different plastics and chemicals that can substitute the products from oil based chemical plants.

(The Danish Board of Technology 2009, 23-24)

Figure 3 as seen below is an illustration of Maxifuel's production process (The cells in purple indicate a process unique for Maxifuel and, arrows indicate in and output from the cell):



5.2.1 Pretreatment

For pretreatment to begin it starts of in the same way as with IBUS. First the biomass is shredded into small pieces and then fed into a boiler chamber. Here water is added and boiled under pressure in a thermal process to ensure the release of the sugars. The next stage is unique and patented by BioGasol; it introduces oxygen into the process to create controlled combustion for a period of 10- 15 minuets. The parameters of this process are varied depending on the nature of the biomass input. The result is a mixture of thick viscosity, however due to its treatment process, has a high hydrolytic ability. This inherently gives benefits to the rest of the production process. Additionally the pretreatment process has been optimized to use less energy and release more sugars, making the phase itself even more efficient. So when enzymes are introduced through hydrolysis they have even better access and efficiency in extracting the long chains of C6 sugars in the cellulose. Another optimization is that there is a reduction in unwanted waste products that can act as inhibitors to the fermentation process.

(The Danish Board of Technology 2009, 24)

5.2.2 Cellulosic and liquid stream treatment

After the pretreatment phase the mixture is segmented into two streams, a cellulosic and a liquid stream. The fibrous cellulosic stream primarily contains C6 sugars as glucose and the liquid stream contains the C6 sugars. The cellulosic stream is exposed to conventional enzymatic hydrolysis process where the longer sugar strands are broken down into smaller strands suitable for fermentation. Thereafter the mixture is cleansed and distilled into pure bioethanol consisting of 98.8% alcohol.

The liquid stream is sent to a C5 fermentation process that works on the basis of thermal biochemical treatment. This happens at relatively high temperature of 70 degrees Celsius under anaerobic conditions. A thermophilus microorganism is then introduced to convert the available carbohydrates into ethanol, CO2 and hydrogen. The microorganism is the same as the Icelandic one mentioned earlier and has the same properties. The difference is that this process is under gone at high temperatures in anaerobic conditions. Meaning that the waste produced by the microorganisms does not act as an inhibiter, as when there is yeast fermentation. The waste (inhibitor) is simply immobilized since there is not opportunity for outside contamination. Another advantage this organism has is that it can convert both types of C5 sugars unlike conventional organisms that only can do one or the other.

(The Danish Board of Technology 2009, 24-25)

5.2.3 Distillation

After the two separate fermentation processes the streams are reunited for the distillation process. The mixture is condensed at first separating the fibrous matter of high lignin properties. This matter is sent forward to the next phase. In the meantime the mixture is further distilled resulting in a bioethanol that has a 95% alcohol content. After placing some additives the bioethanol reaches an alcohol percentage of 99.8%, suitable for engine combustion. The distillation process is the same as with conventional bioethanol production. (The Danish Board of Technology 2009, 25)

5.2.4 Fiber matter

The fiber matter that continued in the production process is headed to create biogas. At this stage bacterium is added to the matter, and left to work it over at a comfortable temperature of 32 degrees Celsius, for approximately 15 days. A gas is created from this process consisting of 56% methane and 44% CO2. The gas is cleansed and sent to a gas turbine that uses the gas to create sustainable eclectic power. The biogas has the advantage that it can be stored and combusted at times of peak-load to assist the power grid. The biogas process is a known practice in the agricultural sector and in water purification plants. (The Danish Board of Technology 2009, 26)

5.2.5 Separation

This is the final stage in the Maxifuel production process. The fiber matter left over from the gas production is sent over to a separation phase. The lignin fibers are pulled apart and dried into compressed combustible matter. It can be used for incineration at the Maxifuel plant to create energy for its processes, or it can be shipped to a CHP-Plant. This is why there is an easy opportunity to integrate this process with a CHP-plant. The residual water can either be steamed to create salts for fertilization or sent back in the process to the initial pretreatment phase. (The Danish Board of Technology 2009, 26)

5.3 Danish Biofuel Projects

In may of 2009 the parliament of Denmark ruled that by July of 2010 all gasoline sold in Denmark must contain a minimum of 5% bioethanol in its mixture. By the year 2012 this percentage must climb to 5.75%. This legislation has sparked a boom in bioethanol production in Denmark. Both 1gen and 2gen production has sprung into action dispersed into the following plant facilities. There are two large 1gen plants each located in Grenå and Tønder. Both plants are to process wheat and corn biomass.

Denmark is also reasonably far in regards to 2gen technology and fast catching up in regards to its 2gen plant facilities. In Kalundborg there has been established a full-scale demonstration plant and another one is being built on Bornholm.

(The Danish Board of Technology 2009, 26)

5.4 Danish 1gen projects

The two bioethanol plants in Tønder and Grenå are expected to be completed by 2012 and operational by mid 2012.

5.4.1 Grenå plant using 1gen production

The Grenå plant is expected to produce 555.000 liters of bioethanol a day amounting to an estimated 200.000.000 liters of ethanol a year. This can substitute 144.000.000 liters of petrol. This is equivalent to 5.75 % of the Danish petrol consumption levels, by today's standard. (Danish Biofuel 2010). Not surprisingly this is the amount that needs to be met by Danish legislation for that period. With some quick calculation one can determine that the annual Danish consumption of petrol is roughly 2.880.000.000 liters. It would take 20 plants with Grenå's annual output summing to 4.000.000.000 liters ethanol to completely substitute petrol consumption in Denmark. The reason it takes more ethanol to replace petrol is because ethanol burns cleaner and therefore faster, using more fuel to do the same work. However since it burns purer it outputs more power. In laymen's terms, ethanol gives more performance in combustion engines but also gets consumed faster. There will have been invested a total of 2 billion dkk into the Grenå project. To meet legal demand the plant must be able to reduce a $CO2$ amount of 35%, Tønder is estimated to reduce 70% whilst Grenå is expected to achieve 80%. (The Danish Board of Technology 2009, 26-27)

5.5 Danish 2gen projects

There are currently two full-scale 2gen projects underway in Denmark, with the purpose to convert cellulosic biomass into bioethanol fuel.

5.5.1 Kalundborg Plant using IBUS 2gen production

DONG-energy has received a grant from the EU in the amount of 50 million dkk to establish a small-scale plant using the IBUS concept. It functioned in a synergy with a CHP-plant and it has been operational for over 5 years with good results.

DONG-energy has been active on this frontier for many years and their next project is to launch a full-scale plant using the IBUS concept in Kalundborg. The plant is currently operational and producing bioethanol. It was in 2009 the largest 2gen plant of its kind. The figures in 2009 suggested the plant would have an input of 30.000 tons straw biomass and produce 4300 tons ethanol, 13.000 tons fiber plant matter and 11.100 tons molasses. It operates on a budget of 300 million dkk with a CO2 reduction of an estimated 85%. It operates in synergy with DONG-energy's daughter company called Inbicon through its CHP-plant.

(The Danish Board of Technology 2009, 29)

5.5.2 Bornholm plant using Maxifuel 2gen production

In 2006 a small-scale pilot project plant was established using Maxifuel production methods using a 14 million dkk grant under a 20 million dkk budget. BioGasol was then established to carry on the R&D of this pilot project with the ultimate goal to bring into full-scale production. In conglomeration with investors, venture capitalist, DONG and other partners they were able to pursue full-scale construction in Bornholm.

Phase one has been in operation since 2008 and been geared towards developing and up scaling the initial pilot projects structure. In 2010 it was due to start up its second phase with the addition of the technologies that would complete the Maxifuel process, namely phase 2. However in 2009 BioGasol ran into some financial problems and was close to dropping the plans for expansion. Luckily new investors have sorted the problems, to a satisfactory enough degree that they are planning to launch phase 2 shortly. (Qvitzau 2010). Phase two (or rather, the full Maxifuel production concept) is estimated to intake 23.800 tons of cellulosic biomass and produce 5.200.000 liters of ethanol. Its budget for this phase is set to 205 million dkk, however that figure was stated back in 2009 before there was wind of the problems at hand. Its CO2 reduction figures were unknown at the time, yet logic suggests it is well within the legal parameters for this type of plant operation. Fortunately an investment company has funded research into reducing enzyme costs, with Novozymes and Genencor working on it as well. This has resulted in a significant cost reduction where the enzymes now cost less than the biomass being purchased (this had always been a stumbling block for serious production to be realized). There is still however room for improvement on a vast array of fronts such as production energy efficiency and yield maximizing.

(The Danish Board of Technology 2009, 29-30)

Table 5 as seen below is an overview of 1gen and 2gen production in Demark, with ethanol yield per ton of biomass presented: (The Danish Board of Technology 2009, 31)

2009	Grenå	Kalundborg	Bornholm
Biomass input in tons	600.000	30.000	23.800
Bioethanol output in liters	200.000.000	3.392.700[9]	5.200.000
CO2 reduction %	80%	85%	N/A
Liters of ethanol produced/ ton of biomass	333	113	218 (300)[10]

6 Legal Framework

6.1 Legislation and goals for biofuels

It was determined in 2007 that the Danish government was to have a green energy policy and a sustainable society. In the long run Denmark must become completely independent from fossil fuels. In 2008 a Climate commission was established to evaluate this strategy and suggest how one might go about realizing it.

February 21st 2008, the Danish parliament voted and passed, in near unison, a new **energy policy:**

- Denmark is to be using 20% of its gross energy consumption from suitable energy sources by 2011
- In 2020 the gross energy consumption has to be 4% lower than it was in 2006.
- There is to be constructed 400MW new windmills that would be operational in 2012.
- The pricing of electricity from windmills, biogas and biofuel would rise.
- Hydrogen and electric cars would be free from VAT until 2012 and 35 million dkk would go to electric car trials.
- 100 million dkk would be invested into tidal and solar energy.

[9] Actual figure was presented in tons of ethanol so the figure was multiplied by 789 (1 mL of pure ethanol = 798 mg ethanol) to get the result in liters (Toxbase 2003)
[10] 300 is the potential yield it can reach with current technologies

- Several arrangements would be set up, among others a financial settlement for residents living near windmill sites.

As a part of this energy policy the government made agreements to increase biomass utilization and give consumers a free choice in regards to what energy company they wish to choose. This means that certain CHP-plants now can adhere to caps on coal consumption, by substituting it with biomass.

In 2009 the Government started a plan called **Green Growth**. The intention was to have the Danish agricultural sector to start playing a larger role with contributing to the sustainable community. The agreement was that 50% of all slurry would pas through a biogas plant. Previously that amount had only been at 5%. There would be allocated 100 million kroner annually in 2010 and 2012 to fund biofuel plants. 32 million kroners would be invested into planting long-term energy crops (this is half the amount the project would cost). In 2009 the government passed a law called the **VE-law (**VE is a Danish abbreviation for Sustainable Energy), to enforce the plans stated in the February policy.

In 2009 the Government passed a **law on sustainable biofuels** aimed at reducing CO2 emissions from the transport sector. These were the previously mentioned 5% and 5.75% bioethanol to petrol ratios. This law meets the demands set by the EU and the Kyoto-protocol.

(The Danish Board of Technology 2009, 64-65)

PART III THEORETICAL APPROACHES

This part has been segmented into two main theoretical themes. The placement of a theoretical approach does not mean that it is not valid under another theme heading or can be cross-related to one another. It is simply segmented in this manner to present an organized structure and a red line the reader can easily relate to.

7 Governance and Managerial

This section approaches the thesis's theme from a managerial aspect. This gives insight as to the managerial considerations that are either taking place, or must be accounted for in a meso environment. In figuring out how to involve the corporate and regulatory actors into this industry one must be aware of their lines of approach, decision making strategies and general mindset.

7.1 The ecological environment

This subchapter should grant an understanding of externalities in a market-based economy and how governments can take different approaches to regulate the market. It will look at the various approaches organizations are subjected to in regards to climate issues and what effects this can have on their consumers. It will also look at the bargain power of the stakeholders in regards to ecological issues and how that can affect managerial decision-making. It will reflect on governance issues from a managerial perspective.

The growing concerns regarding the environment that have been widespread through agencies, governments and the public will be looked at. The impact this growing tendency is having on organizations will also be highlighted. The theory presented here by Brooks and Weatherston is heavily driven by a strong sense that there is undoubtedly a serious environmental problem caused by economic activity. "Whatever one's view of the seriousness of the problems of global warming and destruction of the ozone layer, it is clear that environmental problems result from economic activity. The growth of business activity is often at the expense of the environment." (Brooks og Weatherston 2000, 220) There is no concrete statement as to the degree of these environmental problems, however the tone of their book makes it clear that the authors believe it is to a very high degree. Despite the facts that this thesis has a different ideology to significance of the CO2 affect, and the degree of its environmental destruction, there is still a great deal of value to be gained here. It is very relevant to consider these author's theories and ideas, because most organizations believe the same thing they do. Even if they don't sincerely believe it, they are most likely still be operating on the basis of it.

7.1.1 Market forces and the environment

When one looks at market forces and the environment, some observations that can made may look like this. In an ideal world markets can regulate themselves given that they should always be maximizing utility an optimizing productions. However this is unfortunately not the case in reality. The chlorofluorocarbon (CFC) gasses example presented by Brooks and Weatherston are a great example of why this is not so. CFC gasses are proven chemical gas contaminates that are detrimental to the environment. However their function as propellants in spray cans and other products was very efficient. Their existence gave a great product for the consumer and profits for the producers. When this becomes the case there is little drive to take the initiative to evaluate the detrimental impacts under ones own initiative. The same can be said regarding the use of asbestos in construction. Therefore neither the contractor nor the producer where interested in putting a stop to its usage, or increase awareness of its damaging affects. This is when regulatory agencies typically the government should step in and evaluate the circumstances. Should they find it befitting, they should have the power and ability to implement and enforce regulatory rules and codex. An example of this is the Montréal Protocol enforced by regulatory bodies, due to pressure from the public and NGO's.

The same should be valid for the bioethanol industry. Despite the fact that it is initially well intent and serves the purpose of improving the environment, it has the potential to destroy a lot as well, outside the environmental spectrum. Organizations may feel an incentive to move production to countries where employment conditions are sub par, or embark on "un-fair" trade with agricultural and energy crop farmers. Markets are also not always able to select the ideal or optimal allocation of resources. Which is a critical point in regards to this thesis's theme.

7.1.2 Externalities

Externalities are when there is a spillover affect from producing or consuming goods and services, that affect a third party indirectly. For example, when an oil refinery pollutes or a tanker spills its content into the ocean, it has created damage in the process of its production (like the recent BP oil pipe ruptures). This is considered a negative externality, and incurs additional unbeneficial costs. The opposite is true as well though. In the case of bioethanol, the industry can actually help keep pollution levels down, and in the case of a spill it is far less damaging to the environment. This is called a positive externality, and can carry financial benefits with it.

Unfortunately there are some negative externality that are not "damaging enough" for companies to be motivated to fix them. Sometimes paying for the occasional damages is cheaper than fixing the actual source of the problem. In situations with negative externalities, governments/agencies can intervene and regulate the organizations behavior. Agencies have a series of methods that they apply, in order to achieve compliance to certain degrees. The following subchapters look at five techniques that regulatory agencies typically implement.

(Brooks og Weatherston 2000, 219-232)

7.1.3 Power of bargaining

The power of bargaining is when an agency does not directly intervene, but allows the actors involved to bargain an agreement amongst one another. A bioethanol plant being set up in a local community may displease local inhabitants, due to their desire not to have nearby industrial activity. As a settlement the plant may agree to sponsor certain local events, and contribute positively to the community it is displeasing. This compensation is derived from the two parties bargaining and negotiating a compromise. (Brooks og Weatherston 2000, 233-234)

7.1.4 Taxes and charges

Taxes and charges is one of the most abusive forms of regulation and are essentially flawed in their application. Brooks & Weatherston do not agree with this reasoning, and actually find it an efficient tool for governments to use. (Brooks og Weatherston 2000, 234) Here is another perspective on taxation.

It is flawed because its implementations are nearly always in scenarios where the problems are considered severe, but the production is necessary. The best example is CO2 taxation (the same example Brooks & Weatherston use). Here you have a problem that is considered severe and very damaging. The ideal scenario is that the problem should be eliminated completely and its damages rectified. This is what many countries have done with asbestos discoveries in buildings. When it is discovered it must be taken care of, with no exceptions, because health is at stake and that is serious. But with CO2 it is as if the argument is "what you are doing is very destructive, but as long as you compensate in a monetary fashion, you can keep doing it." So essentially if you can afford it you can keep being destructive.

The idea is that taxation becomes and incentive to reduce CO2 emissions or install processes that reduce it. It cannot be denied that it does have an effect in reducing emissions. Yet, one cannot help but ask if the reduction is enough. The only thing that happens here is that organizations fix up production processes that were grossly and unnecessarily inefficient to reduce avoidable emission. These improvements are however restricted by the technologies available to alleviate them. These costs will eventually trickle down to the consumer though.

So taxation is implemented and one can see a quick drop in emission, hereby proving to all that the theory works. But the reality is it does not do so in the long run, because after the initial drop it is unlikely that it will fall much more since there is still a necessary dependency for its production and consumption. People will install filters in their cars and drive a little more efficiently, but changes stops there. They still need to go to commute to work, pick up their kids and buy groceries. So the problem was not solved, one just forced costs to rise, and stay risen perpetually until the problem is truly resolved. If one is a logistics company, then one is forced to consume fuel, regardless of its price. The solution is that the consumer, that is having something shipped, must pay more for the service to cover the additional costs incurred. The logistics company is also likely to cut cost in operations, personnel, technologies and the acquisition of additional assets. This results may be a generally less stimulated economy, which given the principle of inflation economies with growth necessity, it is not an ideal scenario. After the market crashes of 2008-2009 (sparked by the financial sector) people spent less money in general and did not invest as much. Hereby creating a stagnant market that did not see growth until behavior started to normalize. In short, the constraint in spending and investing is detrimental to the structure of our market economies, and would only worsen a bad situation.

In other words, one creates a tax to solve a serious problem, and it results in a short-lived success with a long-term burden. The downside is that the problem is still fundamentally there. Taking the CO2 tax money and throwing it into the atmosphere does not make CO2 disappear, so where is the logic in collecting it for that purpose. Investigating better alternatives and implementing them does however make CO2 disappear. So one may ask why there is only a handful of institutions and organization doing that? Why is it then not logical to force the CO2 culprits to spend funds on alternative fuel R&D, instead of being forced to pay for the CO2? Even if every kroner collected from CO2 taxation went to resolving the CO2 problem (which it does not and never will), it would still not be optimal. With the ability to trade CO2 quota, a country that pollutes the most, simply buys CO2 quota from country that does not use their entire quota. So the CO2 tax money is actually being moved around, it is being sent to countries that don't have a CO2 problem.

7.1.5 Marketable permit system

A marketable permit system resembles taxation in some ways. The government issues a fixed quantity of waste that may be discharged annually by the organization (Brooks og Weatherston 2000, 235). It is the same as taxation in many ways because it does not solve the actual problem, it is tradable and an organization can buy more quotas if it needs it. One can attempt to make a qualified estimate on how much pollution the environment can afford to have discharged into it, and set permits that cap it at those critical limits. It still fails however because organizations cannot only trade quotas, but also buy additional permits. Since organization have this option, they will simply keep buying permits as long as it is cheaper than establishing pollution control methods (same as CO2). Brooks & Weatherston believe "Having such a market means that resources are used more efficiently to control the overall level of pollution." (Brooks og Weatherston 2000, 235) This would true if there was a cap on the permit and they were not tradable. Then one would establish a system in which there is a tolerable level of pollution, based on qualified estimates on what the environment can tackle. Should the need to increase production arise, the organization will be forced to find more efficient resource management strategies, and innovate to attain it.

7.1.6 Grants and subsidies

Grants and subsidies is where a sum of money is given to a polluter as an incentive to reduce pollution levels. Farmers can for example apply for such a grants from organizations such as the Common Agricultural Policy (CAP), and secure funds to improve operations. However there are reservations regarding this policy since it flies in the face of the "polluter pays" principle. (Brooks og Weatherston 2000, 235-236). The authors opinions expressed here are completely accurate and do offer up an ethical dilemma in regards to rewarding wrongdoers. However one must also understand that businesses that do not have massive turnovers cannot always afford to make the necessary improvements.

One aspect of subsidies that was overlooked by the authors is subsidies being used to promote certain processes and solutions. The eclectic car for example is heavily subsidized around the world. In the Danish economy the windmill industry is very heavily subsidized by the state. One can say that this is a good thing, in that it promotes good solutions. Yet, as always, there is a risk by doing so. One can end up subsidizing a solution that is not the optimal choice, hereby inadvertently locking out the truly optimal solution. If the eclectic car is being subsidies heavily, producers and consumers will have an incentive to invest in it. But if it turns out that biofuels or hydrogen cell cars were the truly better option, then what was intended as a good initiative turns out to become a detrimental one. Because by promoting one solution more than the rest, it indirectly holds back the others. This example will be discussed further in part four.

7.1.7 Regulation and legislation

Finally there is regulation and legislation. This is a very common practice for governments and agencies. This is usually done by establishing a set of guidelines and legal obligations, which consumers or producers must adhere to. It is popular as a measure to limit externalities because, it is easier to administer than other measures. Below one can see how regulations can be formulated: (Brooks og Weatherston 2000, 236)

- Prohibiting the use of contaminates and pollutants: CFC gasses.

- Setting maximum limits on the harvesting of a resource: fishing and forestry.
- Setting maximum limits on contaminate and pollution creation: vehicle CO2 emissions.
- Prescribing technology: catalytic converters in vehicle exhaust systems.
- Establishing ambient quality standards: hygiene ratings at restaurants.

It is said that "the simplest solution is often the best" and the same is true with regulations. This of course demands, that officials know a lot about what they are to regulate and construct them fairly. They should also be unbiased and able to update/evaluate their regulations promptly if the occasion should arise.

7.1.8 Summary

A pattern is forming with the five measures discussed above. They all have their flaws and cannot function ideally if the governments/agencies don't execute them logically and competently. Since no one solution is ideal, the best scenario would be a balanced mix of the measures. Bargaining works fine the way it is. Taxes and charges should only be used as an immediate measure for a short-term period. Marketable permits should be capped and not traded. Subsidies should be administered with care, as to not act as a stumbling block for other potential solutions. Regulation should be administered to set realistic goals and firm legislation where it is most necessary. Finally, a government/agency that is competent and very well informed regarding what they are enacting upon should be administering them.

7.1.9 Influence of stakeholder power

The influence of stakeholder power is not a force that should be underestimated by any organization. Stakeholders can be segmented into thee main categories as seen here: (Brooks og Weatherston 2000, 247)

- Internal: Employees/managers and shareholders
- Immediately external: suppliers and consumer
- Other external: community, government and NGO's

The expectations and objectives of each stakeholder varies depending on what category they fall in under. This is a generalization because one can experience that stakeholders in different categories influence one another or act together on the same interests. Shareholders may for example, primarily be interested in maximizing dividends at the expense of responsible CSR policy. Managers may be prone to short-term strategies with high pay-offs to keep shareholders content, yet neglect to secure long-term strategies for the organizations wellbeing (the principle agent problem). Consumers may be conflicted between trying to maximize their utility, and still be socially conscious. NGO's have a stake in strong ideologies they want the organization to conform to, trying to pressure the organization to behave a certain way.

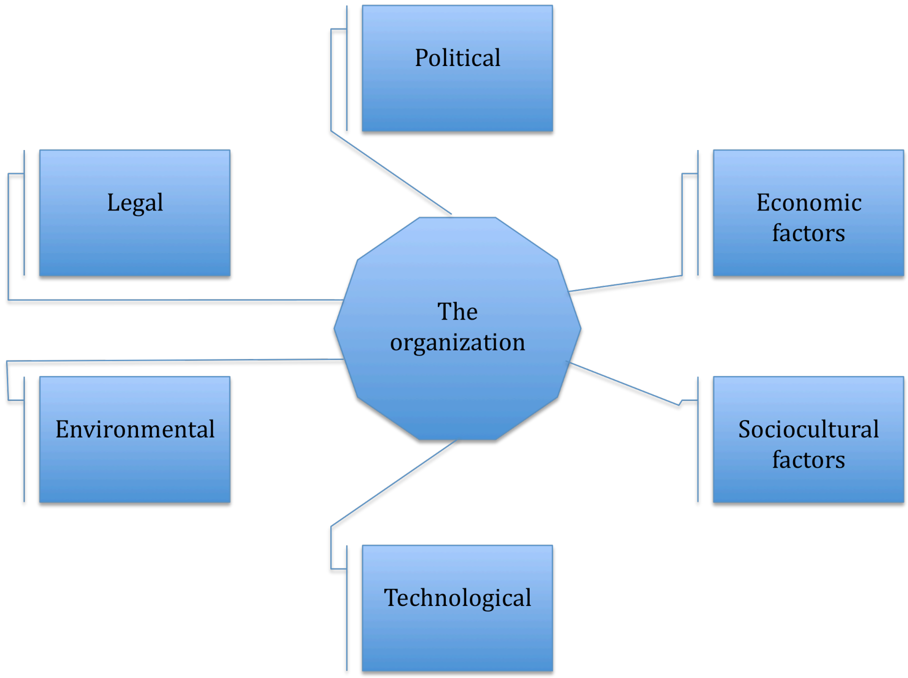
Pressure in regards to environmental issues can typically be initiated by NGO's. They can turn to other stakeholder groups and accumulate enough support to become influential. They can turn to government, which can manage the organization in respect to the five measures mentioned earlier. They can also turn to the consumer who can impact the organization through their purchasing power. The most powerful group is the consumer since day-to-day fluctuations in their behavior can make or break an organization. They are not surprisingly also the hardest group to get onboard. This is because they are only powerful as a united front. Fluctuations in the individual's behavior rarely have enough impact when one is referring to commercial B2C markets. Should the majority of consumers turn on the organization, the effects can be devastating and hard to repair if it is not tackled properly. A very good example of this is the Brent Spar incident. This is when Shell was going to sink an obsolete oilrig in the ocean, since it was cheaper than bringing it in for dismantlement. Greenpeace reacted strongly and got the public i.e. the consumers on their side. Even other organizations such as Body Shop and Co-Op Bank joined the "fight". The mistake here was that Shell underestimated the stakeholder power and never addressed the issue properly. It turned out that they were forced to bring the rig in for dismantlement. The irony lies in that it would have been more environmentally friendly to sink it and allow the wreckage to turn into a reef. Shell's mistake was that they never convincingly conveyed that message.

Stakeholder power is not necessarily a negative thing though. It can be used to make improvements in organizations, industry and society that would never have been initiated without the support. Denmark as a whole is going more and more green and the government is spending funds on this. The spending of these funds is possible because the consumers i.e. the society has called for it and is backing it up. Organizations can also use stakeholders such as governments to optimize their market conditions. The external stakeholder hopes are that they do with a good intent that ensures a prosperous market, and not more devious strategies such as creating artificial entry barriers.

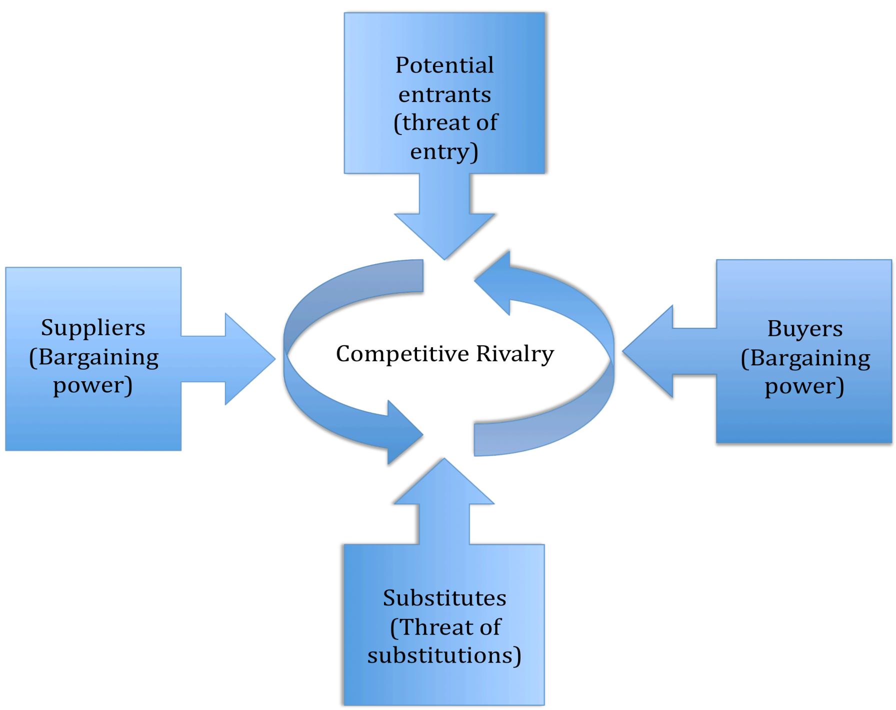
8 Strategic Analysis

There exists an extensive arsenal of strategic tools that can be implemented when ones attempts to attain certain goals and objectives. A strategy is fundamentally a series of ideas, plans and actions that synergies to formulate a method and process one can execute to achieve a certain intention. They can operate at different levels and scopes. Being extremely specific and also very broad depending on what it is to be applied to. Most importantly it acts as a medium that conveys ones ideas of how to do something to others. For those reasons, strategies know no boundaries in regards to what areas they can be utilized. They function in marketing, sales, management, accounting, human resources, production, service and the list goes on. It is therefore not uncommon for strategies designed for one function to overlap other functions as well. Therefore a strategist must have a good general insight into all these themes, since strategies will almost certainly demand their inclusion to some degree. What strategic theories do is they set up a framework one can operate with. It organizes thought and information into a model or concept that can be grasped and then enacted upon. Therefore it becomes critical to select the correct theory or framework, on the basis of the given circumstances and purpose of the strategy.

If one was to look at a macro strategy, one may consider the **PESTEL** framework illustrated in figure 4 on the next page. It function well since it looks at political, economical, sociocultural, technological, environmental and legal issues. It maps out how each of these topics influences the organization (or industry depending on scope). This is a broad perspective that is used to illustrate how external environments are influencing and enacting upon the organization. (Johnson, Scholes og Whittington 2005, 67).



If one was to look a little narrower at industries or sectors, there is **Porters fives forces framework** as seen in figure 5 below. It shows how consumer bargain power, threat of substitution products, bargain power of supplier and threat of potential entrants mesh together to give a total image of the industries competitive rivalry.



Porter's framework shows how competition may arise. Should one be interested in how competition operates over time, there is the **dynamics of competition**. This shows how interaction between the market incumbent and entrant can play out over time. (Johnson, Scholes og Whittington 2005, 78-87)

To bring the scope in completely narrow one may reflect on performance measurement systems such as the **balanced scorecard**. This lays out specific key success factors that despite being very static and generic are easy to relate to and understand. It sets up a ridged framework for managers to operate with at be measured upon. (Anthony og Govindarajan 2004). In this context the scorecard would not be applied to an organization sub business units or managers, but rather the actors in the industry. They would not be forced either, they would exists by the industry actors mutually agreeing on objectives they each must aspire for, to best promote the industries success.

These are just three examples of different of very types of strategies that operate with different scopes. Despite the fact that all of them can be modified to some degree and applied to the intention of this thesis, they all lack taking one important circumstance for the biofuel industry into account. That decisive factor is uncertainty. Using the concept of scenario planning in conjunction with considerations of the models presented above, means a useful multi perceptual empirical perspective can be taken.

8.1 Scenario Planning

This industry is riddled with uncertainty at nearly every front. The agricultural sector needed to sustain a full-scale industry is nonexistent. Government is not subsidizing the industry beyond its minimum requirements and show little ambition to do more. The technology is fundamentally in place but only serious innovation will bring it up to a competitive level. Also, the potential stakeholders (consumers) have little grasp of the technology or its potential to meet their demands (unlike the electric car).

The ideal strategic tool here is therefore scenario planning. It addresses the circumstance of uncertainty well " A scenario is an internally consistent view of what the future might turn out to be."(Porter 1985, 446) Equipped with this tool one is able to draw up various scenarios, and methodically explore each outcome, to see the consequences of these uncertainties. Instead of taking the organizations perspective as the focal point, this scenario plan places the industry centrally and takes on its perspective. With this enhanced scope, all other factors enhance with it. Internal operations then become the workings of the industry's actors with one another. Competitors would then be considered as the rival industries.

Before one can start to address the critical uncertainties, some distinctions need to be made. Scenario planning is a popular strategic tool among strategist and can therefore have many different interpretations of it. The structuring of scenario planning can therefore vary significantly depending on the topic, industry and the strategist.

There will be made a distinction between what is called a **strategic narrative and external scenarios**. A strategic narrative is a perspective of an individual or organization that is passed on their perceptions of the external world. The narrative takes the form of a casual story. It describes how an action take can lead to effects that might result in goal achievement. It is a personal idea of how internal perceptions of external environments are thought to play out in the future.

External scenarios are based on a shared common perception of the external world and its state. This external environment is of a nature that exists outside of the internal operations influence. Meaning whomever this external environment is enacting upon, has little to no say regarding it, and yet is impacted greatly by it. It can be especially frustrating for strategist to manage these external factors. The problems with them are that they lie outside the industry, meaning that the industry is not guaranteed a deep insight into it, neither can they directly control and influence them. Since this is the case, external environments become more something to deal with and anticipate rather than something to be controlled and directed.

From this point on external scenarios will be abbreviated and referred to as scenarios. The difference between scenarios and narratives is, that narratives describe the environment one wishes for and scenarios describe the environments that can be.

It becomes important to conceive scenarios as value-neutral, to best be able to work with them. It is about trying to see the world from different perspectives and aspects than one is accustom to. By doing so a greater understanding is developed, and factors once before unknown become evident. It is of course impossible to be completely unbiased since ones own conviction drive the understanding and reasoning applied. Much the same as the CO2 ideologies of this thesis give a predisposition to certain reasoning. Nevertheless, being aware of this factor is the first step to being value-neutral. The more one can reduce their own values and behave unbiased, the higher the quality of the scenario perceptions. It is important to realize that the scenario formulated is not unequivocally ones future, but rather a single possible future amongst many.

(Heijden 2005, 113-115)

The concept of the environment can also be distinguished into two separate segments. There is the **contextual environment and transactional environment**. The contextual environment is the playing field where the strategist has little to no influence. This is the scenario where one must make anticipations regarding the impacts onto the industry. The transactional environment is the playing field where the industry is in direct interaction, with others that are in it as well. With this interaction, influence can be given and received, however there is still no absolute control over its outcomes. They can be best described as seen below: (Heijden 2005, 115):

- Contextual environment: This is where circumstances that have a large impact on the industry can arise, yet not be controlled or influenced. The actors herein act as judges. They set the agenda, make the rules and pass down verdict. They are outside of ones direct contact and are not subject to massive influence. The primary tasks of the industry is anticipating circumstances and adhering to the conditions. The better one becomes at this the stronger a contestant to rivals one becomes.
- Transactional environment: This is the cozy environment with little turbulence and unwanted changes. The industry is a significant player and has therefore a direct and massive impact on the outcomes. Strategizing in this environment is targeted at manipulating the circumstances to unfold in the industries favor.

Scenario planning unfolds in the contextual environment given that it is the one with the uncertainties. “An (implicit or explicit) aim of the scenario based-planning exercise is to help managers in identifying possible strategies and to consider these against the possible ‘test conditions’ of the external scenarios in order to asses their strength and robustness.” (Heijden 2005, 115)

8.1.1 Addressing and establishing uncertainties

Below is an unfiltered overview of all the uncertainties that are linked to the current biofuel industry. They exist in both the contextual and transactional environments.

The Danish Economy has recently experienced a very turbulent phase. There is concern as to the probability of another market crash. The economy affects everyone and every thing. It is possible to anticipate a crash with a deep economical insight, however to guess what the outcomes will be is excruciatingly difficult. Imagine trying to anticipate when a derelict building will collapse upon itself. If one is a contractor, one may have a better insight into what may cause it to collapse. It could be due to rusted and eroded bolts holding up the roof structure or a faulty water heater that is flooding the sub structure. A flood in the foundation can cause the building to sink to one side and crack supporting walls. All of these can be anticipated but not confirmed as the definite cause or when exactly things will give way. This is much the same as economies with inflation of market bubbles. However if one asks the contractor how the fallen rubble will be displaced where fires in the rubble will start, etc., he will not be able to give a clear answer. Once everything starts to come down the amount of variables to consider explode in numbers and is incomprehensible.

A market crash can make the government re-evaluate the priority of its energy policy, to favor the diverting of funds for the reconstruction of the economy. It could have the opposite effect and make the government more determined to get "off the global grid" and become more self sufficient, as to not rely on the state of other economies as much.

The outcomes are numerous and the concerns are valid. The IT bubble popped causing the Federal Reserve to lower interest rates and inflate the money supply. The historically low interest rates gave way for cheap loans and in return a mounting debt. The loans were used to mortgage homes and eventually the debts defaulted. After the real-estate bubble, the banking sector and selected industrial sector were bailed out using government funds. These funds are printed by central banks in the exchange for government bond issues. In short, governments have indebted themselves (inflated the money supply further) to be able to provide these bailout. The next bubble could be a bond bubble where entire countries risk bankruptcy. Greece and Iceland are already suffering under these circumstances, and could be examples of what be in store.

Fossil fuel depletion dates are as previously described hard to anticipate. For the sake of keeping this variable constant, one delimitation was that the dates stated are to be considered constant. However they can still be a concern because in actuality, the Danish energy policy on fossil fuel independence is formulated under a long-term time horizon and not a solid date. The problem is that if depletion dates keep getting pushed back, one risks that the enthusiasm to find alternative fuels can drop. This will leave the industry unsupported by external stakeholders.

The forecasted biotech revolution is one of the biggest concerns. The predictions by Tvede (2010), indicates that they are in the near horizon. This is actually backed up by the findings in part two of the thesis.

When one considers the technological advancements that have occurred so far and the rate at which they have developed, the future should seem bright. Novozymes and GenCorp who normally are rivals are coming together and finding solutions for the Maxifuel process. The discovery of the Icelandic microorganism that has increased yield efficiency was also a massive breakthrough. Enzyme costs have dropped significantly and are predicted to continue doing so. The lists of accomplishments are long and impressive. However there is always the other side of the medallion.

When BioGasol was about to go bust it was a rude awakening for the industry. The Bornholm plant was close to not being able to develop into its second phase. If it had gone bust, the full-scale version of the Maxifuel concept would not have been able to get implemented. Should that happen the technological advancements for the production concept would also come to a stand still. There is no incentive to develop technologies for a production process that does not exist. Maxifuel could have been put on the shelf for several years. It could have even run the risk of being out developed by IBUS and never stand a chance of catch up. Worse yet, it is even conceivable that without Maxifuel the biofuel industry in Denmark would never reach competitive levels.

Technology is so critical to this industry because it has so much potential to secure it, but it just lack the last tweaks to make it a serious contender. The risk that these developments would not come to fruition is likely to happen due to lacking funds. However one must also still acknowledge that the industry might just never be able to crack the last breakthrough that will maximize yields to competitive levels, simply because the technology is not available in the foreseeable future.

For these reasons one may start to understand why the industry is cooperating so much despite their internal rivalry. If one notices the two biofuel processes share a lot of their technology and capabilities with one another. This is despite that fact that one may have invented something the other had not. When BioGasol was about to go bust, one of the "rescuers" was DONG energy, which operates with the rivaling production method by IBUS. Even if DONG did this to get a foot in the door with the other process so it has a stake in both of them, in case IBUS does not come out on top. The mentality of the industry is one of a pack. If one wants to invade an enemy's territory i.e. the petrol market, one has a greater chance of success if it is done as a group effort rather than an individual effort. It should be becoming evident why this thesis chooses to look at biofuel from an industry perspective while it still is in its emerging phases.

At this stage the industry has realized that if one of the actors drops out of the picture, all the reaming actors risk never being able to develop crucial industrial technologies.

The **establishment of an energy crop sector in Africa** is one that seems more unlikely than likely to go smoothly. There must be developed a large energy crop sector somewhere in order for this industry to rival fossil fuels. Its current processes are built on managing waste into fuel however regardless of how much waste one can accuse mankind of creating it will not be enough to sustain production demands of a full-scale commercial industry. Africa is therefore an option, but it is an option with risks and uncertainties. Due to the governmental structure in the majority of the countries of the region is full of corruption. This can prove to be a serious stumbling block since corruption is unpredictable.

Corruption is not a popular issue to mention and it is most certainly not popular to suggest conforming to it. Nonetheless the aim of this thesis is to be unbiased, value-neutral and address the uncertainties regardless of their nature. For the sake of clarity this thesis and its author is in no way condoning corruption, but merely examining it for the sake of argument.

Should the industry play the so-called game and bribe their access to the market a mess of uncertainties will arise. First though, one must ask oneself if the outcome (which is inherently good) justify the means (which is undoubtedly bad and unethical). If one does decide to go through with it there is no guarantee that the next official to take over for the bribed one does not have a different set of unreasonable demands. The fact is that once one has bribed another, there power is shifted over to the one who is being bribed, and one is left open to blackmail. So in an attempt to eradicate the uncertainty of market access, one may be opening Pandora's box and become vulnerable to even more uncertainties. Also, Africa has a history of unstable governments that in states of rebellion can overturn corporate interest in the country. The risk of loosing ones entire investment would also be lingering and unpredictable.

It is unknown if **CO2** will continue to play the same role in the future. It might get heightened as the global community is being taught more about it, or be crushed by the nonbelievers if they can gain headway. If the argument is crushed it wont impact this industry since bioethanol is not being build on design of the CO2 argument, but on resource management. However should it get amplified, it could devastate the bioethanol industry. Out of all the sustainable alternatives, bioethanol is defiantly the closest to being on the tipping point. The eclectic car would become a far stronger alternative since the electricity used to power it can come from alternative energy that creates nearly no CO2 such as tidal, wind, geothermal or solar.

The future **role of the government** in regards to biofuel industry is a big question mark. Within the next few years it seems quite transparent given their legislation and policy, but policy plans only a few years into the future, by industry standards is considered short run.

It is clear that the government is not very enthusiastic regarding the biofuel industry. The only major developments they have made were to meet minimum requirements set up by the EU and the Kyoto-protocol. The amounts that they have invested are only a fraction of what the industry costs, and they have not made any significant subsidies or initiatives that would promote bioethanol as a transportation fuel source.

What is even more unnerving is that the government can actually directly go in and grind the industry to a halt. Should the CO2 argument become exaggerated and get enough external stakeholder pressure the government could set up constrictive legislation.

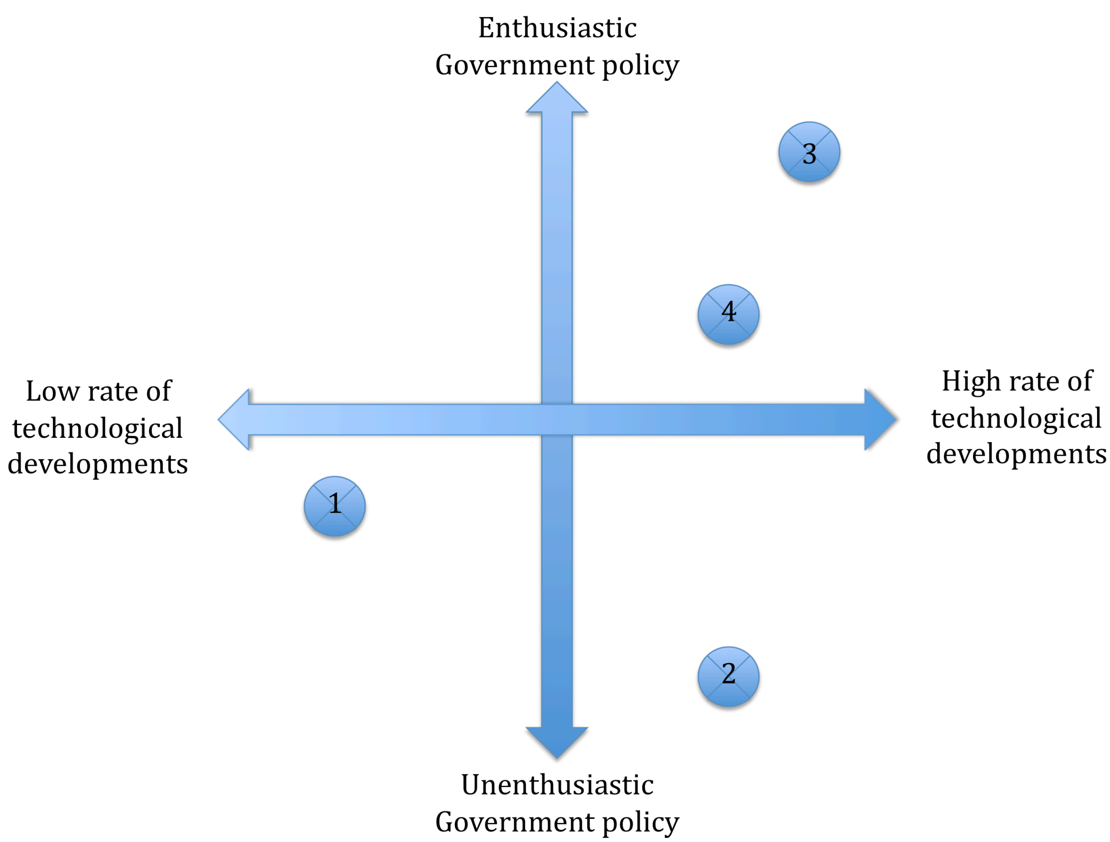
It is as if they see the potential of biofuels as a sustainable method to waste manage and at most as an addition to CHP-plants. CHP-plants that in the future might be based on wind, geothermal or tidal.

Their power is so absolute that they can make or break the industry by policy implementation, and at this stage they seem slightly indifferent to biofuels.

8.1.2 Industry scenarios and competitive strategy

Below is Figure 6 a Scenario Planning model which is an illustration of four various scenario outcomes. On the two axes are the biggest uncertainties that have a great amount of influence on the industry's future. They are scenarios that exist in the contextual environment and are therefore beyond the absolute influence from the industry.

The Y-axis shows the **enthusiasm of government policy** and the X-axis shows the **rate of technological development**.



The horizon year has been set to 2015 since this is when most government energy policy has been completed and is therefore in the unknown as to what their next step will be. It is also the year that the enzyme costs are set to have dropped the most hereby lessening the operation costs for production facilities. It is also enough years in the future for the initial energy crop plantation process to start being planted. Cellulosic energy crops are multi year crops taking two years to grow to maximum yield efficiency. Therefore the are two years available to negotiate entry into an agriculture market and set up basic agricultural infrastructure. It is also a reasonable amount of years for research and development breakthroughs to have occurred making production more efficient and yielding at competitive levels. 2015 is still very short term, but the year selection is very relevant because this is when most of the things that are certain about the industry start to become uncertain.

If the enthusiasm of government policy is high it means that government is supporting the promotion of the biofuel industry. It will be doing so by subsidizing the bioethanol car and relieving it from VAT taxation. It will also be supporting the expansion of plant facilities by heavily funding them. The government will actively support the industry's efforts for expansion and support campaigns to build large consumer bases. It would even go as far as to set up artificial entry barriers to help assist the industry in its initial stages.

If the enthusiasm of government policy drops below the x-axis it is low. This means that the government has stopped making further policies in favor of biofuels and is letting the industry manage itself.

If there is a high rate of technological development then the industry is in very good shape. The necessary production efficiency breakthroughs have panned out, and the ethanol yields are maximized. The industry now has a technological advancement that can start rivaling the petrol industry. Much more is now being created with less resource and therefore operations costs have gone down, giving more funds for expansion or further research.

If the rate of technological developments is low, the industry has stagnated. The necessary production efficiencies have never been accomplished and yields remain the same as today. The industry will be left to operate at the same level as now with little room for growth.

It is no coincidence that these two scenario drivers have been selected. They are not only critical to the industry and very uncertain, but they are also related. A variation or movement in one direction of the axis would spark similar movement in the other axis. If technology goes up government may become more interested. If government policy becomes un-ambitious, the desire to pursue the industry drops, along with funding for research. Out of the two axes selected, industry has more influence on technology, however this does not amount to control. They cannot force into existence something that is not feasible with modern utilities. Also, the technological innovations are mainly coming from companies such as Novozymes and GenCorp. Although these companies are considered actors in this industry, this industry is not their core-competency. New visions and goals for their other main operations may divert funds and interest away from biofuel. Partnerships with researchers in universities is also not a given. As researchers they are driven by what they think are future market trends, and if there does not seem to be a bright future for biofuels, the researchers would be more interested in putting their efforts elsewhere.

Scenario 1 is not a favorable situation for the industry to be in. The main driver here was technology. What happened was the biofuel industry never got the technological breakthrough necessary to enhance production as was predicted they would.

Government interest had fallen due to the lack of development and was only interested in maintaining the industry at its current state. The reason why the scenario was not located lower down on the Y-axis. Was that government still had to maintain some interest since they were bound by the EU and the Kyoto-protocol to have specific amounts of ethanol in their petrol. For those reasons 1gen were the only plants that went into full-scale operation.

The industry would only see growth if the need for waste management increased or if general fuel consumption increased. No new markets would have opened up and none would be investigated on the government's own initiative. Any growth desires other than that, would have to be completely initiated and created by the industry itself.

Investors would only look at this industry as a moderate investment that had some guaranteed production and therefore profit margins, but there was no excitement to be had or major profits to be made by getting involved. The likelihood then of other technological developments would also drop since there would not be sufficient funds for extensive research.

There would be no consumers buying or converting their cars to run on pure ethanol since the price of ethanol would still be high given that the yields are low.

The need to establish an agricultural sector to support production would be unnecessary since the likelihood of growth is restricted. The main biomass input would remain as waste products from other industries.

Rivaling industries would have started to secure market shares, since the only option for consumers wanting alternatively powered vehicles would be electric, hybrid and possibly hydrogen.

There is a chance that some actor will bail on the industry such as the research companies like Novozymes and GenCorp. If they bail on the industry their only function will be to produce the enzymes already in existence, for the industry.

The biofuel industry would have not been completely shut out though. This scenario just meant that accomplishing anything more, than there already had been. Would have taken great amounts of efforts and were very unlikely to ever have been able to compete with petrol.

Scenario 2 is another unfavorable outcome, but this time the driving force was government interest. What has happened here was the CO2 discussion had escalated due to some serious events taking place around the world. A slight rise in sea levels, approximately 20 cm, that had been forecasted until 2030 had occurred earlier than expected. (FOA 2010) This had caused minor flooding in some costal homes and plantations located near very low sea level landscapes. The damage was minute but had sparked a great deal of media attention and concern in the general public. CO2 regulations had heightened and biofuels had gotten a bad reputation given that they were already at the tipping point in regards to CO2. The technological advancements that were expected to occur by then had come to fruition and the industry was actually able to produce ethanol at competitive amounts and yields.

In light of the CO2 concerns and the bad light biofuels had come under, governments were acting in a manner that was detrimental to the industry. The industry was still producing ethanol to be mixed with petrol but there was a very small chance that number would be increased by legislation. Government had actually gone in and increased regulation heavily. Biofuels were only being created for waste management and petrol mixing, and the industry was so bound that growth beyond that was extremely difficult.

Given the negative focus that had befallen the industry, they would have also been getting heat on other issues. Biofuels were being criticized much more for 1gen production being based of food crops. 2gen production was also taking heat when trying to establish an agricultural sector that could support their fuel production, since it was happening in countries where work conditions were generally bad. It was also being criticized for encouraging a starving population to grow crops they could not eat.

The only positive outcome of the technological breakthrough was that production has gotten cheaper due to efficiency, however its potential to increase production was not being utilized.

The actors that are were the industry but not bound to were are defecting and taking investors with them.

The industry would survive and exist but that would be under very strict conditions and would only see growth when it became necessary.

Scenario 3 was a very optimal scenario for the biofuel industry. The main driver here was technology because not only did the production efficiency breakthrough come into the picture, but a few more positive innovations were also developed. Due to this exceptional boom government had been forced to take the industry seriously and was now considering it as a solution for transportation. The increased positive attention had gotten the ball rolling and headway was being made without extensive efforts from the industry itself.

The government had the policy enthusiasm level, regarding bioethanol, equivalent to the Brazilian governments. They were actively participation in aiding the industry achieves its objectives.

Supporting industries were also getting involved at their own accord and mechanic franchises were interested in the prospects of becoming engine conversion suppliers. The manufacturing industry was developing the existing conversion options under a heightened internal competitive rivalry within their industry.

Potential agricultural countries in Africa had realized the financial benefits of becoming biomass suppliers for this industry and were competing to give the most attractive offer as an agricultural sector. The industry did not need to fund the construction of the agricultural sector but was splitting the cost with the local government. Corruption was still ramped but no longer a moral issue for the industry since bribery was not necessary and did therefore not need to addressed.

The consumers were now becoming stakeholders of the industry by their own initiative, and were learning more about the benefits switching to bioethanol could have on the environment and their personal economy.

The industry would experience a flood of investors rush in and stock prices of the involved actors would have risen dramatically. There were enough funds to actively and aggressively pursue growth strategies and further research.

Scenario 4 was the most likely out of the four scenarios since it did not build on any extremities of the uncertain scenario drivers. What had happened here was that the expected production enhancements had been achieved. In light of this the enthusiasm of government policy has gone up slightly.

The government's interest had not been based on opening or investigating new markets for the application of biofuel. It made policy to support the existing industry where bioenergy is derived from waste and petrol ratios. It was looking at the possibility of bringing the fuel petrol ratio up further however no higher than 10%. It was also establishing policy that demanded industries that produced very large amounts of organic biomass waste to dispose of it at a bioenergy plant. The government was in this scenario just supporting the existing industry's market penetration but not doing anything to promote the industry's market development into the transport sector.

These factors demanded that at least four more plants would be established. Given the advancement in the technology and types of biomass input the future plants were to be 2gen. The plants would open in synergy with CHP-plants located on Fyn, North Jutland, Mid Jutland and the Southern region of Jutland. This was to give major industries, such as agriculture and waste management/garbage, that produced biomass waste, access to a plant facility that could process it.

The Industry was capable of producing higher yields and was becoming competitive with petrol. The necessary technology was in place, however the industry was far from being a threat to petrol. All market development growth was done on the initiative and cost of the industry actors.

The government did still not acknowledge biofuels as anything more that a fuel additive that helped them reach their CO2 targets easier.

The full-scale plants had been operational and running successfully for 3 years and they had started to breakeven with their operation costs. Investors were aware of the industry and were interested in it, however there was no real buzz. This had given extra cash infusion to pursue growth strategies. However the need to find additional funding from the EU and alternative fuel grants was still crucial to keep the existing industry strong.

The initial stages of entering the African agricultural market had started but taken longer than expected. There had been difficulty in organizing efforts there and the situation was still very fragmented. There were delays, meaning that energy crop farms had only just started to be planted and the agriculture infrastructure was still being established.

An interesting development had been that Statoil, a major oil company had started to get even more interested in bioethanol production. Terms were being negotiated to incorporate pure bioethanol as a product the gas station would sell along side conventional petrol and diesel. There were a few test stations with this concept being set up in the four major cities Copenhagen, Århus, Ålborg and Odense.

Existing combustion engine conversion kits were starting to be marketed to large mechanic franchises and would be able to be installed into cars should the consumer want it. However the interest amounts consumers had to convert their cars to run on ethanol was not very high. The price difference between ethanol and petrol was not very big given that the ethanol industry was not yet producing at full-scale commercial levels. The costs of the engine conversions were also quite high since the lack of interest meant that there were not a lot of sales. The consumers that were pursuing bioethanol at this stage did so because they were worried gas prices would get higher and because they have tendencies to live greener than the general public.

Electric cars were still more popular and the government was still not interested in biofuel cars. This meant that the industry had started looking for other modes of transportation that electric power could not substitute. Therefore markets were being explored in regards to aviation and heavy machinery. Bulldozers, trucks, buses and similar vehicles demanded high power outputs that existing electric batteries could not match. Therefore bioethanol was the only existing alternative fuel solution that was ready for the task and could be implemented without much technical difficulty. The same was valid for the aviation industry.

Biofuel production plants had started gain momentum and market penetration was growing. The government was supporting this industry to a satisfactory degree. Pure bioethanol as a substitute for petrol had now become a niche market and was driven entirely by the actors within the industry. The electric car had gained a lot more market share then they had in 2010, yet the vast majority of vehicles were still running on conventional fuels.

PART IV RECOMMENDATIONS AND STRATEGY FORMULATION

9 Recommendations: The Danish Commission on Climate Change Policy and the Danish Board of technology

9.1 The Danish Commission on Climate Change Policy

The Danish commission on climate change policy had the following considerations and recommendations regarding transportation based on alternative fuels.

The transport sector is one of the big energy-consuming sectors within Denmark. 65% of total oil consumption can be accredited to this sector. It will therefore be a major challenge for the government to achieve fossil fuel independence in the long run, and drastically reduce CO2 emissions by the year 2050.

There is wind of an alternative fuel revolution headed for the transport sector and it is starting to gain serious momentum, as technological innovations are securing the emerging industries foothold.

There are two main possible directions that can be perused in relation to the above. One can focus on electric powered or biofuel powered cars:

- Electric cars can run on renewable electric power, generated by the windmill industry. The fuel energy can be stored in the form of a battery or in the form of a hydrogen cell. The hydrogen cell would through clean chemical reactions produce electricity that could power the car. Besides pure eclectic cars there is also the option to run hybrid cars for a transitional period. (Hybrid cars are cars with both fossil fuel and electric engines built in, they synergies together to produce power for the car. It is popular because it gives off much less CO2 and gets good mileage).

The biggest barrier for the electric car is that the existing battery technology is inadequate when comparing it to conventional cars. This makes electric cars uncompetitive in comparison to existing transportation solutions. The batteries are simply too costly and do not have a large enough capacity. The cars are unable to travel very far between charges/battery changes. The supporting energy infrastructure for electric car is also problematic to establish. For without eclectic cars there is no incentive to produce charging stations, with the opposite also being the case.

- Biofuels can substitute petrol and diesel without any technical difficulties or challenges. This is however entirely based on the industries ability to be able to produce ethanol at the necessary volumes. There are other modes of transportation where biofuels could be more applicable. This would be in regards to airplanes and lorries. This is because of the practical and technical difficulties, related to running such machinery on pure electric engines.

There are several problems related to pursuing biofuels. The biggest is that there is scarcity with the supply, and that the industry strains the environment. This makes it problematic to based future energy strategies for the transport sector on biofuel. 2gen biofuel production will however be enhanced, for the purpose to use it in the transportation sector, by 10% before 2020. This is stipulated by the VE-legislation already being implemented. According to the EU directives 2gen biofuels account for twice the value as a sustainable energy source.

The suggested strategy for the transport sector is that radical alternative energy policy is not called for.

- In the short run, it is deemed that the increased fuel efficiency rates of newly produced vehicles, is the most economic strategy to follow. This is the cheapest way to cut down the transportation sectors consumption of fossil fuels.
- In the long run the strategy is to implement the electric car. It has a dual ability to cut CO2 levels and cut fossil fuel consumptions. Electric power plants can switch to wind energy reducing the CO2 emissions and use the electricity to power cars. This cut the fossil fuel consumption at both ends. Hybrid cars are to be used in the transition phase i.e. the medium run. However once the pure electric car industry starts to get a foothold, the hybrids will become more expensive to fuel from a consumer perspective.

- The government should still differentiate in VAT taxation of conventional and alternative energy cars. The registration and ownership fees of having an energy efficient car, should at a minimum continue at the same rate.
- The establishment of test facilities for the electric car would give a great deal of insight as to how a commercial industry would look like. Test and pilot projects can also be used for high fuel demanding transportation modes, where they can experiment with biogas and natural gas.

The official recommendations to the government is that tax and fee reliefs related to eclectic car ownership should continue until 2015, to ensure that car manufactures have a clear security of what future market circumstances are.

- Tax and fee relief strategy is implemented to encourage the purchase of electric cars. The hope is that the number of electric cars will grow to such a number that a full-scale test of the concept would be feasible. However, to maintain fiscal and economic stability the number of cars should be restricted to 100.000 (4% of the total car population) up to 2020.
- The tax and fee relief can be formulated to correspond to the level of energy efficiency of the car in question. The more electricity it runs off, the lower the registration costs. This method would then be phased out as the electric car becomes more competitive.
- The current tax and fee relief system should immediately be modified to also include hybrid cars (the policy only covers pure eclectic cars). This can, in the future, be altered to include other alternative fuels should the need arise.

(Danish Commission on Climate Change Policy 2010, 70-73)

9.2 The Danish Board of Technology

The DBT's recommendations are derived from a workshop debate that looked at development for 2030, 2040 and 2050 timelines. There where two workshops that took place and they consisted of various representatives from the industries actors. Among the attending were DONG, Novozymes, Siemens, Agro Tech, BioGasol, Statoil, DBT, The Partnership for biofuels, AU, KU, RUC, DTU, etc. These representatives come from universities, interest groups, the oil sector and private corporations.

The recommendations are targeted at a political level in regards to Denmark's future energy policy and the application of biofuels for transportation. The workshop highlighted that the political agenda and behavior had to be adjusted to meet; industry needs, solutions and productions in the near future. However it was important not to set up a short-term framework that inhibits long-term prospects.

The recommendations of the workshop efforts are presented in the following bullet points:

- A concrete analysis of the challenges, solutions, barriers and preconditions for the implementation of biofuels in transportation. The analysis should have a timeframe starting today and stretching to 2050.
- Financial analysis and forecasts should not be reviewed without being put into a proper context. The analysis should be coupled with the developmental trends of the industry and technological innovations to give the analysis contextual properties.
- To attain the industries goals much clearer political intentions must be established. The political sector must have more focus on designing and implementing incentives. Using a framework similar to the USA, that consists of annual goals and milestones, could be beneficial. The political targets could be formulated and communicated to the public. The current market is not a strong enough driving force to secure the so-called intelligent solutions needed, in regards to the future energy market.
- The taxation and fees system is not reflective of the true costs of what they are imposed on. This can lead to societal uneconomical behavior, and should be changed
- The industry should be self sufficient in regards to biomass input. However with a target of 10% bioethanol to petrol ratio by 2020, biomass input and bioethanol will have to be imported.
- A stronger focus on biomass production under sound environmental criterias is necessary. This level of ambition should preferable be higher that that of the EU's.
- The industry must be cautious not to only actively pursue one biofuel resource, namely bioethanol, and instead have a diversified product portfolio. Focusing on products such as methane and biogas.

- A desire to have an energy supply based on a wide array of sources, demands that the entire energy system is evaluated and synergized to accommodate all the current sustainable options.
- It is imperative to be aware of the existing infrastructure of the energy sector, and reuse it where it is available. For large CHP-plants closing in on the end of their life expectancy, a consideration to whether they should be dismantled into smaller decentralized plants should be under advisement.
- CHP-plants should be linked and synergized to other energy producing facilities.
- The synergy potentials for bioethanol production should be used to a higher degree. This way CHP-plants would be producing more than just electricity and water. For this to happen, there must be invested more into 2gen projects if they are to be operational at full-scale production. Full-scale pilot projects are necessary to gain valuable insight regarding the aspects of processes and production.
- More research and development must be preformed at biorefineries. There should be developments in synergy technologies and byproduct usage.
- With the demise of the "fossil fuel era" there will be a greater demand for cooperation and partnerships across sectors such as agriculture, energy production, nature and environmental initiatives. This will call for a cross-disciplinary decentralized partnership.
- One must be cautious with a complete taxation and fee removal policy, since this can cause an increase the amount of biomass and bioethanol imports.
- One must also be cautious with handing out too many favorable policies for electric and hybrid car promotion. This is because their success as a sustainable solution is heavily based on the source of the electricity that powers them. One should first have secured an intelligent and sustainable power grid system.

(The Danish Board of Technology 2009, 98-99)

10 Strategic formulation

Within the following subchapters one can find the strategy for the Danish biofuel industry founded on the findings of this thesis. The strategy is formulated on the basis that Scenario 4 was the most likely outcome. The strategies have been segmented into main central themes that are of great relevance to the industry.

The consideration, recommendations and strategies presented by the climate commission and the DBT where clearly biased to they beliefs and not value-neutral. The climate commission was very geared by the government and the existing policy. It does not demand any significant or new developments from the government's policy regarding biofuels. The DBT would like to see the industry grow in general and in all directions. They do so rather then come to the realization that the industry has its core competencies and other energy solutions are better than biofuels for specific functions.

10.1 Production Facilities

The first there that must be looked at is the production facilities. The industry needs to know what types of plants it should be building at for what reason it should be doing so. Laying out the correct production infrastructure will maximize success potentials regarding other strategic matters.
1gen production plants should not be developed after 2020. Currently with one production site it is possible to meet the 5.75% mixing ratios demanded in regards to VE-legislation. The ratio is estimated to rise to 10% by 2020, meaning that another site has to come online by then. This demand should not be filled by 1gen facilities. This is because 1gen is still heavily criticized and cannot be permitted to grow to large in production. Ideally there should be no further construction of 1 gen plants since the aim is to transition to only cellulosic biomass.
2gen plants are going to be the future of this industry. The intent is to have all biomass input derive from waste and cellulosic energy crop. The advantage to 2gen sustainability is that for the same amount of production as 1gen it is regarded at twice as sustainable. So it has a high ranking as an alternative energy production source.

The real question is which process methods to select for these new facilities. There should really be no doubt at this point that the better of the two options is Maxifuel. Both IBUS and Maxifuel are flexible in regards to what type of biomass input they can tackle, and both can be attached to CHP-plants for synergetic energy production. The difference is the Maxifuel does not produce molasses for animal feed like IBUS does. But that is due to the fact that their process is more efficient and the sugars that would have gone to making animal feed is converted into methane gas and used to power turbines for electricity. Not to mention that the ethanol yield potential by today's standard, is equivalent to 1gen, and almost twice that of IBUS. The Maxifuel pretreatment process is also more efficient in regards to energy consumption and would therefore be demanding less initial power from the CHP-plant it is linked to.

In the event that large CHP-plants become broken down into smaller decentralized plants, Maxifuel production plants should be built simultaneous with the new smaller plants and in synergy with one another. Therefore practical and technical considerations should be formulated now by the industry, so it can act immediately with solutions should CHP-plants suddenly become decentralized.

The 2gen plant facilities should be constructed in different regions of the country. They would obviously be built at a rate correlated to market demand and market expansion. One can be built on Zealand, despite the fact this was not mentioned in any of the scenarios. This is because that IBUS already exist on Zealand and a Maxifuel construction could risk cannibalizing IBUS's functions. However this is not a bad thing. If the industry is to get serious with its production it will have to optimize their processes. Another plant can be placed on Fyn whilst the three others could be distributed along the top middle and southern region of Fyn.

10.2 Energy Crop Agriculture

This is the hardest theme to devise a strategy on because it is so controversial. Should the industry continue with even the most modest growth, the need to import biomass would rise. Even if the Danish agricultural sector could sustain the heightened demand for 2gen biomass it would still not be a lost cause to invest in agriculture in Africa. The production down there could be exported to other countries that need the biomass for their own production. The export could be targeted for countries that cant or don't have an interest in producing the biomass themselves.

One could even be ready to go as far at constructing some Maxifuel plants on location and export ready to use bioethanol.

The likelihood for need for 2gen biomass production is going to be high. Even if there is never achieved a high market share of cars on alternative fuels, there will come a need for heavy machinery, lorries, busses and aviation crafts to run off ethanol. The production made in Africa should supply the Danish market with the resources that it needs, but can also supply other nations as their demand increases.

It becomes apparent that the aim is to go into Africa to support Danish production, but besides that, there is going to be a lot of profits to be had regardless. Getting the industries foot in the door now will make it more competitive in the future. Being a first mover into a market is a great opportunity to start creating entry barriers and securing potential suppliers.

The big question here is how should this be done optimally. The answer is unfortunately that it cant. Regardless of what one wants to think of this world the reality is that there exist some unpleasantries. The unpleasantry being referred to here is the nature of the governments in these regions, being corrupt. One must weigh out the options and consider what type of business one wants to run, and if this is something to be getting involved in. Africa is not the only region one can pursue this strategy in, but is does appear to be the best one. Should one then make some decisions that are unethical and do what must be done to achieve the best conditions for the industry? Or risk having competitors do it and gain the advantage instead of oneself? This thesis will not go so far as to recommend one option or the other, but rather explain the facts of the scenario and leave the decision open as an ethical dilemma.

If access is gained to the African market (either by unethical behavior or by some stoke of luck, that does not demand the bribery of officials), some essential frameworks must be established. The farmers that are to be producing these energy crops must be treated by fair trade standards. This means that they should be given work conditions and wages that secure them a good standard of living relative to the region they live in. This could prove to be problematic because corrupt governments try to keep standards low and their populations restrained. If one sector starts getting better conditions it could cause dissatisfaction amongst other sectors in the country. It could also cause a workforce migration to the agricultural sector since inhabitants can see it is lucrative. Should this type of migration happen, it could throw the employment balance elsewhere. One thing must be made very clear here, and that is that fair trade circumstances is completely non-negotiable as a factor. If this is something that causes problems for the region and they cannot be resolved, than the industry has to pull the plug on this strategy. Under no circumstances should an industry, essentially doing good, be involved in creating negative situations to such a large degree. It makes no sense for sustainable energy to be generated on the back of unfair treatment of the farmers.

To take a practical perspective, there has to be programs set up in the regions. These programs are to teach the local work force how to operate the harvesting machinery, re-sow the crops and in the event of production to be able to run the facilities.

This strategy has all the makings to become a win-win scenario, for the industry and the region they enter. However it also has the potential to be harmful if it is not executed with the industy's moral compass facing north.

10.3 Government

The strategy in regards to the government is one that has to achieve more enthusiasm and support. This is challenging since current circumstances don't show enthusiasm, and the climate commission established by the government to evaluate the energy sector, is not suggesting support for biofuels. Since this is the case one can lay out a strategy on how to operate with these conditions and make evaluations on what policy should look like from the government. There is a reason to why government is unpredictable after the short-term phase is over. This is because that government in a democratic society is exchangeable, and who is to say the replacement is not more prone to support the industry. Therefore knowing what is necessary and what is desired is an important distinction to be made before hand.

The biofuel industry should be marketing itself to the government and municipalities based on how efficient a waste management program they is. The industry can tackle waste from municipalities, industries and agriculture. It can take on any organic waste product meaning even sewage and slurry, yet it only has a policy that at the most would divert 50% of agricultural slurry to the production plants. Simply based on waste management the industry can gain some growth on the Danish market. It would also be alleviating current waste processing and incineration systems. The fact that current governmental policy is not more ambitious on this matter is truly odd since this is where the industry can contribute the most with helping the government reach its policy goals. Just being able to build one full-scale 2gen Maxifuel plant on this basis would produce valuable knowledge and experience as to how a 2gen industry can be run and looks like.

The industry should also be promoting itself as a fuel solution for heavy machinery, lorries and buses. Biogas can be used as fuel, yet does not appear to be as strong a product as ethanol. Aviation was left out since there is an idea that to replace jet fuels it would demand some other characteristics for ethanol that it is has today. This assumption is logical because bioethanol can directly replace conventional petrol, but conventional petrol cannot directly replace jet fuel. The important thing to note here is that jet fuel substitution is feasible and should be considered an option, however since this was not covered in part two of the thesis it is hard to make serious suggestions regarding it. Returning to the idea of promotion for heavy machinery, lorries and busses. This could be the second best option to getting in on the car industry. The climate commission even suggests this as a possibility and state that the electric powered options are unrealistic for these types of transportation. Biofuels might be held back from an easy entry into the 2.5 million cars in Denmark, but the industrial transport and public transport could also be lucrative. Given that the governments only suggested strategy in regards to these two transport sectors, was to wait for fuel efficiency to become better. The biofuel industry can offer themselves up as the only realistic solution that actively makes these transport sectors sustainable. They should make their first move on getting busses to run on bioethanol. If they can land contracts with the bus companies to make trials on some central buss routes, they can gain some valuable experience. They can make determinations regarding how one practically sets up such a transition, and how efficiently its works as a solution in the real world.

The government policies they should be striving for should are similar to some of DBT's points. They need policies that help encourage their facilities to be integrated into existing CHP-plants. They need some taxation and fees relief for bioethanol cars; currently they do not qualify for this. However like DBT stated, these reliefs cannot be too strong since one can risk the demise of entry barriers, and one could loose their own local market to that effect. There should also be a desire to have wide and varied sustainable energy sources. Biofuels need to get integrated onto that grid and play an active role in the upcoming energy supply network.

10.4 Infrastructure for Bioethanol Delivery Systems and Car conversions

This strategy is formulated to address the issue of how to, from a practical perspective, deliver the produced bioethanol product and create the opportunity for it to be consumed. The special attribute that bioethanol has, that electric car systems does not, is that the electric car has to start from square one. In regards to governmental strategy there is no emphasis on the car sector, but that is not to say the biofuel industry cannot pursue it on their own accord. And all the signs suggest that they should.

What was meant before in regards to the electric car staring from grounds zero, is the same as what the climate commission pointed out. If few people have electric cars, then no one will build the charging stations. Ironically though, if there exist no charging stations, no one will want to own an electric car.

Bioethanol does not share this problem since it generally has the same properties and viscosity as petrol. Meaning that existing methods and logistics networks that deliver petrol can be used for ethanol. Even the same pumps at the filling stations can be used for this. It was noted that Statoil attended the biofuel workshop held by DBT indicating that they have an interest in this industry and to some degree a stake in it (due to petrol ethanol mixing legislation). Also Statoil were the first to use and advertise the ethanol mixture, promoting it as a greener solution with no hassle for the consumer. Should the biofuel industry be able to generate a large enough consumer base, running test scenarios would be a breeze. With cooperation from for example Statoil, they can offer ethanol at their filling pumps. They can be taken from the existing 92 octane pumps that are rarely used anymore. They would start the test stations in major cities spreading them out a little thin to start with. To make the transition as little a bother to consumers as possible, they can make smart phone applications that show where the nearest Statoil, offering ethanol is located. This structure would resemble the one being used in Brazil where ethanol cars are relatively popular.

The product however would be useless without a means to consume it. As stated by the climate commission there is no great technical hassle in converting cars to run on ethanol. The conversion process is in actuality relatively cheap, especially when incorporating future savings into the calculations. At first these conversions will be expensive, but as more people start to use them the price will eventually fall. The conversion kit would resemble a customized carburetor that modifies the fuel/air mixture to account for ethanol's higher combustion properties.

10.5 Securing The Consumer

There is no direct way for the biofuel production industry to be in direct contact with potential consumer because at the end of the day they are just suppliers. There has to be created an additional link to complete the down stream supply chain. There has to be a retail industry that makes the sales to the consumers.

By following the concepts from the existing auto industry, the missing link here would be considered the car dealer. The fact is that car dealers get their products from car manufactures, and for biofuel industry to start a car manufacturing industry to sell ethanol is a ludicrous notion. These dealers would instead have specialized in taking the most popular (or estimated to be most popular) car models and have pre-converted them. It would be optimal if these cars where subsidized by the government to be a little cheaper than their fossil fuel siblings, but that does not seem likely. In effect if the conversion cost can be taken from the profit margin of the dealership (given that it would not be that much) it would solve the problem and the consumer would only be purchasing on the basis of what fuel consumption they prefer. Should the dealer not want to give up commission cuts, it would still not be play a large role since a sustainably motivated buyer would not have a problem paying 1.5-2% more for the car.

10.6 Technology

There is no inherent strategy in regards to technology. It is an absolutely critical element to the success of this industry and it is also filled with uncertainty. As many funds as possible should be directed with priority to technological developments. Without the necessary innovations and enhancements the industry's growth potential will grind to a halt. The strategy for technology is to keep doing what they are doing now. The aim is to keep seeing universities and research departments of corporations working together, to find better solutions and new innovations. Having actors throughout the industry in an understanding that they are working for the same common goal.

10.7 The strategy life cycles, termination and modifications

These strategies are not going to persist perpetually and at some point new uncertainties will affect them making them obsolete or ready for reevaluation.

In regards to the bioethanol car industry and rivaling with the eclectic/hydrogen car, the fight will be lost in the long run. The only thing really holding back the electric car is that the industry cannot get their hands on the high output lifespan batteries that they need. Regardless if the technology exists and is out of their grasp, or if it has not been invented yet, it is all the same. That once they secure this battery technology then in a matter of years they can start taking serious market share. The strategies suggested so far suggest that an entry into this market is a good idea, yet that is not logical if it may only last for a decade or so. This would be true, if the intent to enter the car markets were not replace the hybrid car. The suggestion is that bioethanol cars act as the transition to electric cars. It is also important to remember that converting an existing car to run on electricity is far more expensive than converting them to ethanol. So as the new car market grows with eclectic cars, more and more people with existing cars that are not buying new, will want to convert to ethanol. Once the converted cars are obsolete the industry might end up in a situation where they have more capacity then demanded for.

Superficial biofuel production will however always be able to be reintroduced into the energy sector. The over produced biofuel can be stored and used at periods of peak demands. Alternatively, over capacity production can be exported to countries where the electric car is not market dominant. This would most likely be to developing countries where the vast majority of the public cannot afford electric cars.

A modification to production processes could also be undertaken to cope with over supply. Given that the production plants are based on the Maxifuel process, they can be modified to produce less ethanol and more oils that are used in plastics production.

CONCLUSION

At the start of this thesis the question asked was, "What role, if any, can bioenergy assume in the quest for Denmark to achieve fossil fuel independence?"

The answer to such a question is never as easy or straightforward as one would desire. Often there are circumstances that must be accounted for and uncertainties to be assessed. The short answer to the question is "They can potentially assume as large a role as they are ready to take on, however it will not last forever."

The catalyst that sparked this thesis to make its analysis was the desire for *Denmark to become free from fossil fuel dependency*. It becomes very evident that these are well-founded desires given that the fossil fuel market may soon be reaching the end of its life cycle, and until it is depleted, there are no guarantees for supply.

The current state of the Danish energy sector is not the least bit optimal. In order for it to meet its own standards of sustainability it must import renewable energy from elsewhere. What is surprisingly positive though is that is one of the most efficient energy sectors presented. The wind energy sector however was shockingly inefficient and low, when considering how heavily subsidized it is, and is projected to be.

There are various ways to produce bioethanol, however there is one process in particular that stands out remarkably. The Maxifuel process in it current state, and in its estimated future position stands extremely strong, and is very competitive. *The state of the current bioethanol industry* is very limited though; it is still in the initial stages and in its most vulnerable period.

Biofuels have an array of applications and are suited to several commercial markets. However where it is best suited is for waste management systems and for the transportation sector. In regards to transportation, the market share can start off wide and eventually get narrower as competing solutions will inevitable gain headway. However it does not seem likely that it will get drastically narrower.

Based on *the various biofuel industry scenarios* it became possible to structure and formulate a *meso strategy that catered to the private market in a sustainable context*. It becomes evident that the government is not going to be supportive of this industry outside of its potentials as a waste management solution. Therefore anything beyond that, which the industry desires, must be accomplished by the industry itself.

The bioenergy sector generally appears to be underestimated from every direction. This is a shame since the potentially large positive impact this industry can have is quite significant. This author's conclusion is that the industry should be pursued, and be done so with great enthusiasm.

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12 Appendix

12.1 Energy Table Calculations and Methods

All the figures derive from the Eurostat statistical database, which was issued in their energy report for 2008.

The figures in the report where stated in 1000 toe (tonnes oil equivalent), these figures where converted into PJ (petajoule). This has been done to ensure a reader friendly statistical layout. It creates similarity between all the figures presented, hereby enhancing the reader's ability to quickly compare the figures to one another without having to convert units first:

1 unit of X = 1000toe

*PJ = X * 0.041868*

Standard percentage equations have been applied to retrieve percent calculations:

*(x/y)*100 = Percent of y*

Energy efficiency was calculated by:

*(Final Energy Consumption/Gross Energy Consumption)*100= Efficiency*

Energy self sufficiency was calculated by:

*(Primary Energy Production /Gross Energy Consumption)*100= Self Sufficiency*

Renewable energy self sufficiency was calculated by:

*(Primary Renewable Energy Production /Gross Renewable Energy Consumption)*100= Renewable Self Sufficiency*

Consumption of energy per capita was calculated by:

Gross energy Consumption/ Population

Table Notes:

N/A = Not Available (or stated)
All of Iceland's figures date from 2006
EU 27 "Final Energy Consumption" data is provisional data for 2008
Iceland "Final Energy Consumption" & "Gross Energy Consumption" data is provisional data for 2006