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Sustainable LCA of biofuels
Comparison of different types of biofuels in their life cycle stages

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ABSTRACT:

As global warming becomes more real every day, a new, sustainable resource for energy must be found. It has also been stated that the fossil fuel resources are starting to decrease and the prices increase. These signs show that it is time to find a new source of energy. The purpose of this thesis is to produce a sustainability life cycle assessment (LCA) of different kinds of biofuels.

The theoretical part of this thesis views LCA through different models. Especially LCA stage- and LCA framework theories should be mentioned as they play a significant role when analysing the empirical data.

The source for bioenergy is divided into five main categories, these are; biogases, bioliquids, biomasses, peat and wood-based biomasses. These types of biofuels are chosen because they can easily be compared to each other,first within category in itself and then cross referenced to each category.

This thesis is explorative in nature, and should therefore be seen as a base for wider and deeper research. The data collection is done through deep interviews with experts in within the mentioned biofuel categories. The results of these interviews will be used to create a empirical analysis of each biofuel category and then the suistainability of biofuels and LCA is combined.

The empirical findings of this thesis show that all the different biofuel categories can and should be used as a source for energy. All of these categories do however, have their pros and cons. In the conclusion the need for further research is again pointed out, as the mentioned pros and cons point towards a need for deeper understanding of each biofuel category, so that the potential of each biofuel can be harnessed.

KEYWORDS: Sustainable Development, Bioenergy, Biofuels, Life Cycle Analysis

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TIIVISTELMÄ:

Maapallon lämpeneminen on jo tänä päivänä todellinen ongelma ja on aika löytää uusia energiamuotoja fossiilisten polttoaineiden tilalle. Fossiilisten polttoaineiden lähteet ovat jo ehtymässä, mikä ei ainoastaan aiheuta hinnan nousua vaan myös tulee luomaan energiakriisin lähitulevaisuudessa.

Tämän pro gradu- tutkielman tarkoitus on luoda sekä analysoida kestävä elinkarianalyysi biopolttoaineille. Tutkielman teoreettinen osuus tarkastelee elinkaarianalyysiä ja sen eri malleja, eritoten elinkaarianalyysin eri vaiheita, sekä elinkaari analyysin kehystä. Nämä kaksi mallia otetaan esille siksi koska ne esittävät isoa roolia luodessa empiiristä tutkimusta.

Bioenergia lähteet on jaettu viiteen pääkategoriaan; biokaasut, biopolttonesteet, biomassat, turve sekä puupohjaiset biopolttoaineet. Nämä kategoriat valittiin siitä syystä, että ne ovat vertailu kelpoisia sekä sisäisesti kategoriassa että ulkoisesti keskenään.

Tämä pro-gradu tutkielma on luonnoltaan eksploratiivinen ja on siksi tulkittava alustavaksi pohjatutkimukseksi joka toimii suunnan antajana jatkotutkimuksille. Materiaalin keräys empiria osioon suoritettiin syvähaastatteluiden kautta. Haastateltavana oli jokaisen biopolttaine kategorian erikoisasiantuntijoita. Haastattelun löydökset toimivat pohjana luodessa empiiristä analyysiä jokaisesta biopolttaine kategoriasta sekä sen kestävästä elinkaaresta.

Empiirisen osion lopputulokset ja niiden yhteenveto osoittaa että eri biopolttoaine muotoja pystyy ja kannattaa käyttää energialähteenä koska yksikään ei voi täysin korvata tällä hetkellä fossiilisia polttoaineita. Myös biopolttoaineiden hyvät sekä huonot puolet osoittavat tarpeen lisätutkimuksille jotta saadaan syvempi käsitys jokaisesta biopolttaine muodosta.

AVAINSANAT: Kestävä kehitys, bioenergia, biopolttoaineet, elinkaarianalyysi

1. INTRODUCTION

1.1 Background, motivation and starting point

Biofuels, recycling and sustainable development are current and valid topics of discussion. Biofuels are rectified from dozens of different plants and dozens of different kinds of wastes (Ketola & Myllylä 2009). The motivation for further research into biofuels and sustainability comes from many different studies which state that by using biofuels in a sustainable way, the global warming process may slow down.

This research is also motivated by the idea of endless recycling, also known as the cradle-to-cradle approach. This potentially means that there would be no harmless forms of fuels anymore. One major reason is to present cheaper biofuel options to compete with the traditional fuels.

The purpose for this research is to produce a sustainability life cycle assessment (LCA) of different kinds of biofuels. Sustainability can be subdivided into three categories: environmental, socio-cultural and economic sustainability (WCED 1987, United Nations 1992). When considering sustainability LCA these tree subdivisions should be evaluated fully when doing the analysis.

LCA involves most often environmental aspects of a product system throughout its life, also known as cradle-to-grave or cradle-to-cradle assessment. In this case, the assessments will help to present the research to find out what kind of biofuel is the most environmentally friendly as well as best on the economic, social and cultural sustainability point of view.

The starting point of this research is to draft a theoretical framework, which lead to conduct the empirical part of the study, where the sustainability LCA of different biofuels is produced.

In the theoretical part of this research sustainable development is explained thoroughly and the different biofuels are explained. Also, generally acceptable sustainability LCA criteria for biofuels will be conducted.

The empirical part of this study will include a questionnaire which will take in the form of a interview to eight (8) different experts in biofuels. Each biofuel category will be separately analyzed based on the interviews. From these interviews, the theoretical and empirical parts will be interwined to each other and the model for sustainability LCA of biofuels will be presented and finally the conclusions will be conducted.

1.2 Research problem, goal and limits of the research

The research goal is to create generally acceptable sustainability LCA criteria for biofuels. This goal can be reached by interviewing different corporate, political and scientific actors, whose views and experiences of sustainability LCA criteria for biofuels will be gathered. All this information will be complied with a model of generally acceptable sustainability LCA criteria for biofuels.

Usually LCA is defined exclusively as an environmental LCA (Guinee 2002, Hendrickson et al. 2006); however this research will take more of a holistic perspective on LCA, this means that the sustainability LCA as a whole determines and evaluates in and considers the environmental, social, cultural and economic consequences of a certain product, process, activity or service from cradle–to-grave as well as in some circumstances from cradle-to-cradle.

LCA covers the whole life cycle of biofuels, starting from raw materials, production, transportation and distribution to usage, maintenance, reuse, recycling and disposal as well as energy production and consumption during all these stages (Ketola & Myllylä 2009).

Limits to this research include the dozens potential biofuels. Due to the fact that there are so many biofuels, only a number of biofuels are considered in this research, and therefore only the LCA of these selected bifouels are included. However, this limitation will be discussed in the later part of the research, when many biofuels are discussed and the motivation for not creating a LCA analysis for some biofuels will be included.

The goal is to keep this research on a holistic level: aiming to find out what experts and researchers say about biofuels and what kind of effects biofuels have during their life cycle stages.

1.3. Research Methodology

This research is done by producing sustainability LCA of different of biofuels. The basis for this research methodology is qualitative research method with a holistic view (Heikkilä 1999: 15-17; Hirsijärvi, Remes & Sajavaara 2000: 151-155.).

The qualitative research is a reflection and explanation of a real life case, where the goal is to research the subject as a whole, as well as understand it completely from the view of the research subject as well as the decision and conclusion (Heikkilä 1999: 15-17; Hirsijärvi et al 2000: 151-155.) The qualitative research method is used when wanting to enhance some kind of operation or find alternatives (Heikkilä 1999: 15-17; Hirsijärvi et al 2000: 151-155.).

A typical qualitative research method is interviews, which will be used in this qualitative research as the method of getting the desired information. The answers will be mainly based on basic questions, why and how (Heikkilä 1999: 15-17; Hirsijärvi et al 2000: 151-155). When doing a qualitative research by interviewing, the following methods are a good aid to an interviewer; observation of the situation and interviewee, self-memos and maintaining a researchers diary of the interviews (Saunders et al 2007: 508).

A qualitative holistic research method basically means that the research will be based on a real life case, which has a theory but is mainly based on experience and people´s knowledge (Heikkilä 1999: 15-17; Hirsijärvi et al 2000: 151-155.). This research however, cannot be completed by certain parts alone, (e.g. doing sustainability LCA of different biofuels, but not considering all of the sustainable categories). Instead the system as a whole determines in an important way how the parts behave. In this case, the system determines how the LCA will be comprised, when all the sustainability categories have been considered while doing the life cycle assessment.

As this research is based on a real-life case, the data collection method will be carried by collecting both primary data and secondary data. Primary data is new, as in interviews, surveys, observations as well as experiments. Secondary data is collected by somebody else and is mostly theoretical, from written materials as in databases, books and reports (Christensen et al 2007: 88-102).

In this research, secondary data will be collected first, using books and other research papers and articles. The empirical part is entirely based on interviews. These interviews held in August to October 2009, each of the interviews lasted from forty five (45) minutes to two (2) hours. In Table 1, all the interviewees are listed as well as their occupation, motivating the reason why they were selected, each of the respondents are either researchers and/or working in positions which involve the use of different bioenergy resources and methods. Also the date of the interview is listed.

The reason why there were eight interviews and not more, is that the amount of information received from these interveiws was very vast and informing to the level of receiving needed infromation for this research.

Name and company	Profession	Area of expertise	Interview date
Simo Honkanen, Neste Oil	Research Manager	Bioliquids (palm oil) Biomasses	10.08.2009
Ahti Fahgerblom, Finnish Forrest Industry	Counsellor, Energy Policy	Wood based biofuels	11.08.2009
Maija Suomela, Greenpeace	Palm Oil Campaign Correspondent	Bioliquids (palm oil), wood based biofuels	12.08.2009
Pirkko Vesterinen, Technical Research Center of Finland	Technical Researcher,	Wood based biomasses, peat	13.08.2009
Mia Wallen, Finnish Energy Industry	Representative of the Pool for Environment	peat	19.08.2009
Leif Åkers, Stormossen	Managing Director	Biogases	2.09.2009
Petri Torri, Gasum Oy	Business unit Manager	Biogases, biomasses	12.10.2009
Erkki Hiltunen, University of Vaasa	Energy Institute Manager	Biogases, bioliquids, biomasses	12.10.2009

Table 1. Information of the intervewees

"When qualitative data is analyzed, it includes both deductive and inductive approaches; it ranges from the simple categorization of responses to processes for identifying relationships between categories" (Saunders et al 2007: 470-471). In this research both deductive and inductive approaches are used. However the deductive part approach is a very small portion of this research and it only explains the theory behind this research. Inductive approach is the main approach in this case, because with the inductive approach the results of the interviews can be analyzed.

1.4. Research Structure

The research began with assimilating to the subject itself, by reading material on sustainable development and biofuels as well as on how the LCA. This research is divided into four chapters (see Figure 1). The first three chapters include all the research information, research findings. The fourth chapter gathers all the information and concludes the results of the research, both theoretical and empirical.

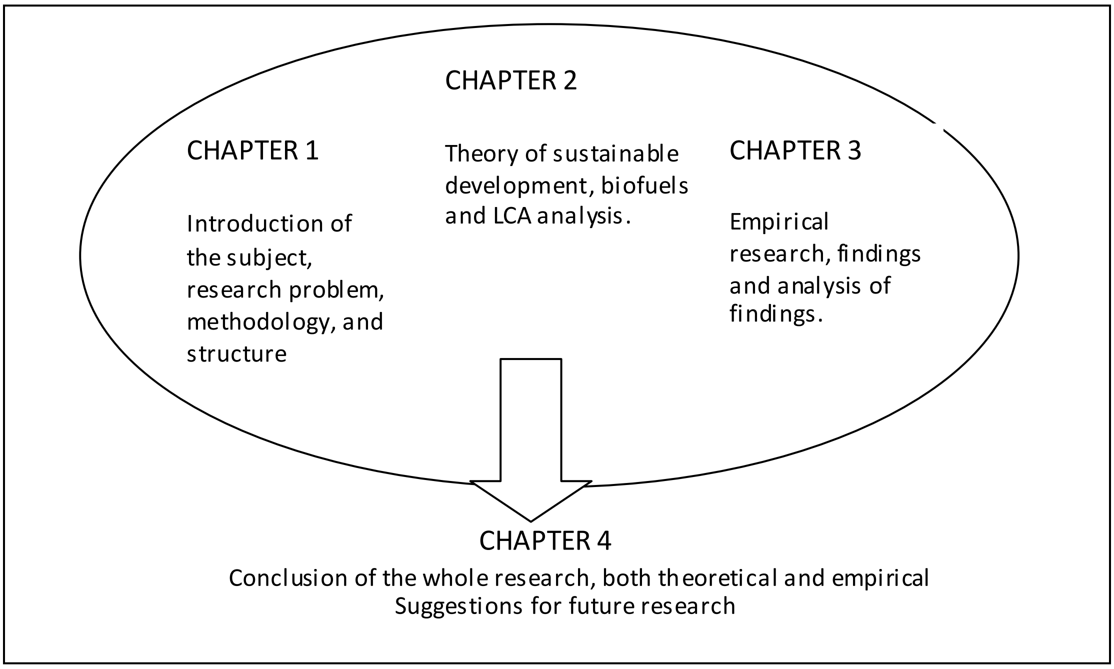

Figure 1. Research Structure.

In chapter one the background, problem, goal and limits of the research are introduced. The methodology and structure of the research are also explained. In chapter two, the research will explain the theoretical side of sustainability as well as biofuels. It will include the explanations of sustainable development, what are biofuels, how can they be divided and how sustainable they are. Also the theory of LCA of biofuels is included.

In this way the research subject is explained at a basic, theoretical level, covering all the needed theory to be able to create the empirical part, which is chapter three. In this chapter the material gathered from findings, which in this case, are interviews. These findings will be analysed and connected to the theoretical view of sustainability of biofuels.

Chapter four will be a conclusion of all the information gathered into the research, both the theoretical as well as the empirical research will be concluded and further research ideas will be suggested.

2. THEORETICAL FRAMEWORK

2.1 Sustainable Development

Sustainable development is a development that “meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED 1987: 47). Sustainable development is an ethical standard that has to be translated into a manageable standard (Baumagartner 2007:13). Sustainable development is a broad subject which has to be categorized when sustainability is evaluated. In that way sustainability and its development can be analyzed accurately.

The fundamental principles and the programme of action for achieving sustainable development were established at The United Nations Conference in 1992, in Rio De Janeiro. Since then it has been referred to Agenda 21, which refers to the fact that the program includes plans and suggestions to reach sustainable development in the 21st century (WCED 1992).

To analyze the sustainability of biofuels, it is easier when sustainable development is divided into four (4) different dimensions. These dimensions are:

- environmental sustainability
- social responsibility
- cultural sustainability
- economic sustainability

Environmental sustainability comprises of biodiversity and natural resource use. There is a prudence principle that measures environmental quality, ecosystem health and the carrying capacity of the earth.

Social responsibility covers diverse issues such as wellbeing, employment, alienation, aging, equality, justice and participation. It is about responsibility that will lead to the stage where all social, environmental, cultural and economic matters will be handed forward to the coming generations. Cultural sustainability encompasses values, attitudes and customs. Economic sustainability extends so far as global, national issues and regional to corporate and household economy issues that emphazise a balanced economy everywhere (Ketola & Myllylä 2009).

Sustainable development has four major dimensions. However, all the dimensions have their pillars and altogether there are eight pillars that sustainable development stands on; poverty, population, pollution, participation, policy, market failures, prevention and management disasters (Rogers et al 2008:47).

Sustainable development governs these pillars, and to be able to reach sustainable development, these major pillars must be translated into manageable standards. These pillars can be linked to the dimensions of sustainable development. Table 2 shows the pillars divided into the relevant dimensions on with practical examples.

Environmental sustainability	**Social responsibility**	**Cultural responsibility**	**Economic Responsibility**
Pollution ➔ biodiversity ➔ using natural resources *Prevention* ➔ Using public transportation ➔ Alternative fuel usage	*Poverty* ➔ wellbeing *Population* ➔ the effects on population *Participation* ➔ reduce alienation ➔ increase equality and wellbeing	*Policy* ***Prevention*** ➔ in the law	*Market failures* ➔ minimizing the risk *Management Disasters* ➔ management must be kept in balance

Table 2. Dimensions and pillars of sustainable development.

The dimension of environmental sustainability stands on two pillars, *pollution* and *prevention*. These two pillars represent biodiversity and its survival and the use of natural resources. One reason for loss of biodiversity and natural resources is pollution, which is why it needs to be reduced and managed.

As pollution is most commonly from manufacturing as well as from manufactured products, the prevention of the negative effects to nature must be incorporated when a product is planned, from what method and how much of raw material is collected, how it is manufactured, how it affects nature and its surroundings during usage and after. Prevention is about trying to stop the loss of biodiversity and nature resources, both in manufacturing as well as in everyday life, such as recycling, using bike or public transport instead of a car, or using a car that runs on biofuel. Prevention is the key to keep reduce pollution and keeping biodiversity diverse.

The dimension of social responsibility stands on three pillars, *poverty, population* and *participation*. As social responsibility is about human wellbeing, the pillars in this dimension correspond to the same matters. Poverty is a very big issue and it has been increasing since the global economic crisis 2008-2009. Population has been rising and the major concern is that the population is growing more in the developing countries, where the general wellbeing of people is not so good. This is where the pillar of participation comes in; by getting people to participate in reducing their ecological footprint, reducing alienation, and increasing equality and wellbeing. The participation of all is very important; otherwise social responsibility will not get over the problems it is now facing.

The dimension of cultural responsibility stands on one pillar, *policy*. A policy is something that the population of a country has done for a certain time. It is a policy that everybody knows and uses. For example recycling in Finland, it is a policy, a custom, and it is taken for granted that most finnish residents recycle.

The reason why *prevention* is in the dimension of cultural responsibility, is because it is something that should belong to the dimension of cultural responsibility, however it is not yet so common around the world that it could be categorized into this group. There are developing countries that do not see prevention as a value that should be concidered. However, there are countries which do have prevention as a value that everyone must and do, obey. A good example of this is Germany where recycling is in the law and everyone must obey to it. The policy pillar is a good start, but prevention should be included in to this dimension of cultural responsibility.

The dimension of Economic responsibility stands on two pillars, market failures and management disasters. As economic responsibility is about global economy issues that emphasizes on a balanced economy everywhere, these two pillars fit into this dimension perfectly. Market failures cannot always be totally prevented, but they can be minimized. The same goes for management disasters. These two go hand in hand. If a business is not run properly, it can end up as a market failure. When these two are kept in balance the economy is doing well.

These pillars help sustainable development become much more defined and in this way sustainable development is easier to be analysed in different cases. When analyzing the sustainability of biofuels all these pillars are very important supporters.

2.1.1. Reaching sustainable development

It has become much more difficult to reach sustainable development, as the gap between poor and rich is getting bigger, for example, 20% of world´s wealthiest population earns 87,2 % of the total global income (Rogers et al 2008:47). Also globalization has created new dimensions to reach the goal of sustainable development. Nowadays the integration of markets, mobility of capital and increases of investment flows has become extremely rapid, causing the benefits as well as cost to be distributed unevenly. Loss of biodiversity is also continuing, natural disasters are more frequent and air water and marine pollution continue to rob millions of a decent life (WCED 1992).

To reach sustainable development standards will take many years, but at least the problems have been manifested and the solving of the problems is starting to be executed. The earlier mentioned dimensions make the goal to reach sustainable development more clearly, and it is easier to see what the whole concept of sustainable development includes and what kind of improvements should be done so that the world would become more sustainable. From these dimensions and pillars a six-step guide to reach sustainable development can be drawn (Table 3).

1. **Conserve biodiversity**
2. **Use renewable natural resources sustainably by using them within their capacity of renewal**
3. **Minimize use of non-renewable natural resources**
4. **Keep ecosystem healthy**
5. **Keep environmental quality high**
6. **Carry the capacity of the Earth**

Table 3. Six steps to achieve sustainable development.

There are six steps to achieve sustainable development. The first step to achieve sustainable development is to conserve biodiversity. By considering nature's resources are to be used and how much they will be used, is it possible to live without harming the biodiversity to the level of extinction. Secondly renewable natural resources should be used sustainably, by using them within their capacity of renewal.

While renewable resources should be used in their capacity of renewal, it is also very important to minimize the use of non- renewable natural resources, e.g. creating limits of the usage of non-renewable resources. The fourth step is to reach sustainable development is to keep the ecosystem healthy and this can be done by assessing ideas and manners to cultures, e.g. by reducing pollution and increasing recycling.

The fifth step is to keep the environmental quality high, both socially as well as environmentally, for example reducing noise levels and clean water for all. The most important step is number six, the capacity of the Earth. This means controlling overpopulation. The more people there are on earth, the more difficult it is to reach sustainable development, and the steps towards sustainable development are more difficult to carry through.

Sustainable development is a broad subject, but the main idea behind it is to decrease harmful waste, both from products as well as pollution that is created by humans, and increase the wellbeing of nature and humans as well all other living creatures. The goal of sustainable development is to leave nature and all that it includes to good and unchanged condition for the next generations.

2.2. Biofuels

Bioenergy is energy that is produced from biofuels. Biofuel can be refined from many different natural resources; wheat, barley, oats, potatoes, soya beans, palm oil, rapeseed oil, sunflower oil, sugar beans, sugar roots, switch grass and alga. Also wood and forest residue can be used. The basic rule is that any kind of biodegradable waste and sludge can be used as raw material for biofuel (Ketola & Myllylä 2009).

The demand for biofuels is continuously growing, and many countries have made national goals to increase the use of biofuels as well as slow down the global warming for example, tax reductions and obligations. The directive for EU was accepted in December 2008. This directive includes the goal of increasing 10% of renewable energy until the year 2020. It also includes some sustainable development criteria for fuels, which has to be filled to be able to fit into the group of biofuels and sustainable development (Neste Oil 2009).

As global warming is of common concern, the energy industry is fronting its biggest challenge ever, because the demand for energy producing solutions which are compatible with sustainable development is growing all the time. There must be new energy solutions that do not accelerate the speed of global warming. There have been redescovered new raw materials for sustainable energy use, such as biomass, and oils received from plants (Honkamaa 2008).

When categorizing a biofuel, it needs to fill certain criteria, such as; is it economical it easy to maintain, is there easy access to raw materials for the production, and is the production itself ecologically sustainable as well as ethical? It also needs to reduce the usage of fossil energy and greenhouse emissions (Klemola, 2006).

In this chapter, biofuels are categorized based on these criteria and after that analyzed if they are sustainable enough to fill these criteria.

2.2.1. Categorising and analysing biofuels

When a biofuel has obtained the needed criterias, the next step is to put it into a suitable category. This is a way to analyse them both as a whole group as well as separately. Biofuels can be categorized according to the production method, mass of the biofuel, energy saving possibilities, how much energy does the biofuel has, or how expensive it is to produce.

Categorising can also be done by the production method of the biofuel, for example is it made by recycling, or is it a product of farming biofuels (Mäkinen, Soimakallio, Paappanen, Pakkala, Mikkola 2006: 24-25). However, there is no such thing as one right way to categorise biofuels (Mäkinen et al 2006: 24).

In this research, categorizing has been divided into five separate groups, by similarity and material:

- Biogases → waste
- Bioliquids → different plant oils
- Biomasses → farming waste/fields/swamps
- Peat → organic material
- Wood based biomasses → industrial wood residue/ industrial by products

The analyses of these biofuel categories are done by giving them negative and positive effects on the environment and how sustainably responsive they are in each category of sustainable development (environmental, social, cultural and economic).

This analyse is done in a manner that the categories are analysed in a very common way, which means that the most known biofuels are analysed. The analysis is based on their production methods, what effects they have during and after usage, and how they affect life of normal people, in a social, cultural and economical way. Also the explanation of their life cycle is explained, if they are cradle-to-cradle biofuels or if their life cycle is shorter, cradle-to-grave. These two life cycle methods show how sustainable a biofuel can be.

Cradle-to-cradle (Figure 2) is an intelligent approach that distributes energy, but in a way that it is healthy and restorative. After the biofuel is used as an energy source, it should support life after that too; by being a nutrient to the nature or otherwise being reusable. The cradle-to-cradle approach also means that when a biofuel is used in this way, the biofuel is in a closed loop cycle of production, recovery and remanufacture. Cradle-to-cradle approach is a way that a product is sustainable economically, environmentally, socially and culturally. Cradle-to-cradle approach is a must have- quality in a sustainable biofuel.

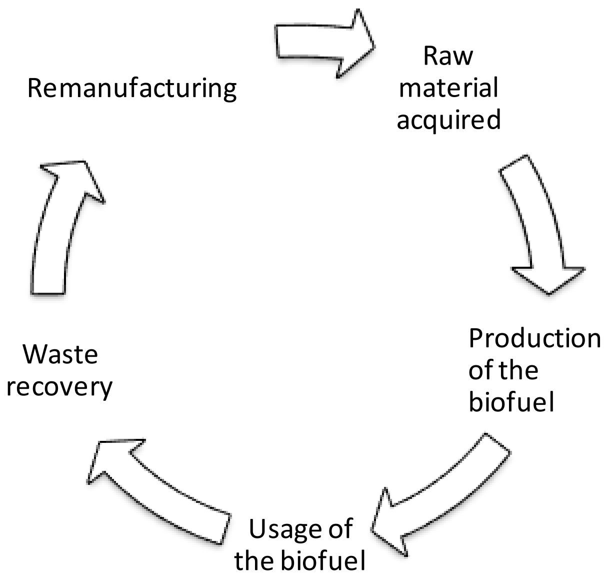

Figure 2. Cradle-to-Cradle.

Cradle-to-grave (Figure 3) approach can be partly sustainable, unlike in cradle the cradle-to-grave approach does not go in a closed loop cycle of production, recovery and remanufacture. Cradle-to-grave is used once; when a biofuel has this life cycle it is not very sustainable, because the raw material can be used as a energy source only once, which produces waste that is hard to dispose sustainably. A biofuel with this type of approach creates loss of biodiversity because to be able to create energy, unlike in cradle to cradle approach, after usage new raw material must be acquired. Again the biofuel is used and all there is left is the waste which has to be disposed because the reuse is not possible. This is the problem with the cradle-to-grave approach not being sustainable, even if waste disposal is done correctly there is the fact that the disposal is not done sustainably or in a way that the waste disposal would create energy.

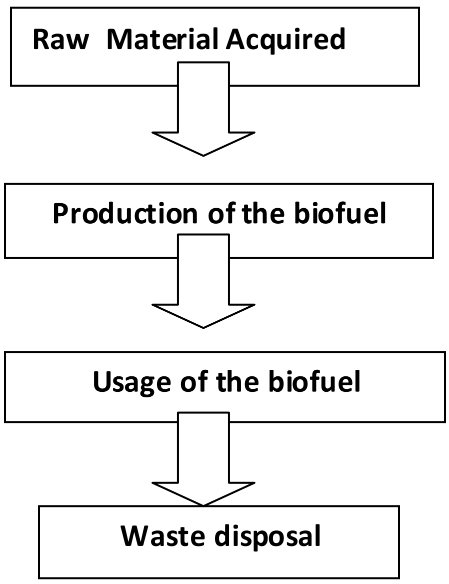

Figure 3. Cradle-to-grave.

When a biofuel is analysed, it must be remembered that in the real world of using biofuels the opitions are very limited. Even though different engines, exhaust gas cleaners as well as fuels have been established into an entity that functions well, it must be remembered that it is not acceptable that there are any compromizes when it comes to reliability, energy efficiency, and exhaust gases. Nor should the price be too high. If these points can be changed dramatically, consumers will not be comfortable and rather remain using well known fossil fuels. It is extremely important that when biofuels are produced, they should not affect the usage of a consumer too much (Sipilä, Mäkinen 2006:34).

There are few ethical matters that affect the analysis of biofuels and which have been taken into consideration: One major issue with biofuels is that some of them are produced from crops,ethically, crops should be used to feed the people of the world. The World Food Programme is campaigning against how food is not for play, nor is it for fuel (World Food Programme, 2009).

This issue with corps becoming fuel, has raised a lot of discussion, and lowered the chances of field biomasses become a good source of energy. Another major problem is that the knowledge of the affects of biofuels to the environment are small and are difficult to measure (Helsingin Sanomat, 2009). These following analyses are based on theoretical findings of what kind of biofuels there are and how sustainable they can be. Table 4 will demonstrate the dimensions of sustainable development, the biofuel categories and their sustainability in each dimension. After that the discussions on each biofuel selcted will begin.

It is important to note that Table 4, which will be presented on the next page, is in no form a final conclusion. Instead it is more like a mind map which is designed to help the researcher to ponder upon how the different forms of biofuels should be viewed, through their both advantages and disadvantages during their life cycle.

Biofuels	*Environmental*	*Social*	*Cultural*	*Economic*
Biogases	+ Ecological + Cradle to cradle -Infrastructure -Volatile	+ Creates jobs - Car industry suffers	+ Known - Education	+ Pollution Reduction - Expensive at start
Bioliquids	+ Good improvement -Cradle-to- grave -Pollutes -Biodiversity loss	+ Creates jobs	+ Known, good potential -Life cycle not so long -Cultural biodiversity loss	+ Uses a known research method -Life cycle is not long
Biomasses	+ Easy to produce -Cradle-to-grave -Landsacpe changes -Loss of biodiverstity	+ Creates jobs + An option to the consumer -Food is not fuel	+ Known type -Food is not fuel	+ Creates jobs to the whole chain
Peat	+ Producing is ecological -Cradle-to-cradle - Production is slow - Usage not ecological	+ Creates jobs	+ Easy to adapt -People know the negative sides of Peat	+ Brings more money and jobs -Short living solution, creates emissions
Wood based biomasses	+ Created from wood residue and by-products + Cradle-to-cradle -Loss of biodiversity -Doesn't create enough energy	+ Gives jobs -Not democratic usage	+ Wood as the source of heat and energy	+ Forest industry benefits + Easy to sell -Part time solution

Table 4. Theoretical advantages and disadvantages of biofuels.

2.2.1.1 Biogases

In Table 3 the first category is *biogases*, which refer to constituents like methane and carbon dioxide that are produced by the anaerobic fermentation of biological materials. Biogases are most commonly produced by agricultural and organic waste. Sewage gas is produced by sludge digestion in the tanks of sewage treatment plants. Landfill gas is produced by organic residues in garbage tips (General Electric Company 2009). An example of this is from Vaasa, Finland where the regional waste management company, Stormossen, has converted 100% of biogas into energy (Stormossen, 2007).

When considering the environmental, social, cultural and economic effects of biogases there are both positive and negative effects, as do the other five categories of biofuels.

Biogases are environmentally sustainable because as friendly to nature and clean when compared to traditional fuel. However, to use biogases as an energy source, it requires a lot of space and infrastructure to be able to produce the product, which is one reason for biogases not being so common yet. They improve waste management and have given biogas-fueled engines a chance to improve waste management while maximizing the use of an economical energy supply. However, biogases are still volatile, and this is mainly in the beginning of the life cycle, when the material for the biogas is acquired; heavy machinery is needed, and heavy the machinery still used fossil fuels to run.

When considering the social responsibility of biogases, they do create jobs in industrial working environments but the car industry can suffer, especially if a manufacturerer developsof biogas car and other brands can suffer. Cultural responsibility of biogases is good, since biogases are known and they can be adapted to a culture easily. However, methane is quite dangerous and people need to be educated in the usage of it, because biodiesel is still much more known and even easier to be adapted by people. Economically biogases are still expensive to use, especially to start to use biogases an industrial level. It is very expensive to build needed infrastructure, however once it has been started up, it does not pollute so much and is cheaper to use than traditional fuels.

Biogases are a cradle to cradle type of biofuel. Even if they are not designed to nourish nature after use, they can be put into a recycle loop; being recovered and remanufactured. The only major downside that biogases have is the heavy machinery which must be used to collect the waste, because heavy machinery used, cannot work on biogas as yet. Also the needed infrastructure can create some problems but not for a long period of time.

2.2.1.2. Bioliquids

The second category in the table three is *bioliquids*. This refers to biodiesel which are based on plant oil produced to diesel. This diesel is made out of biomasses that are refined. These types of biofuels can be used for example in diesel engines in public transport (Finbio 2005). Another example is palm oil, which has been produced by Neste Oil Oyj. This type of biofuel is produced in South East Asia and the yearly production is about 40 million tons a year. (Honkamaa, 2008).

When considering the environmental, social, cultural and economic effects of bioliquids they have both positive and negative effects. Bioliquids are a good improvement from traditional diesel and fuel, however, bioliquids are still not a major step away from polluting fossil fuels. But they are the first attempt to improve on traditional fuels with a better energy producing liquid than fuel. There are downsides when producing bioliquids, for example when producing bioliquid from palmoil; farming palm oil trees destroys rainforests in South-East Asia. A major invester in this is Neste Oil Oyj and this problem has been noted by Greenpeace. Locals want jobs, so they destroy the rainforest in order to plant and grow palm oil trees (Yleisradio, 2009).

Socially, bioliquids have created jobs (e.g. Neste Oil Oyj´s palm oil has produced jobs in south-East Asia) both in industrial and farming surroundings. Culturally these types of biofuels have potential because they are much known as well as close to the basic fuel and diesel. They are also easier to be taken into use and being adapted to by consumers. However, when there will be more sustainable biofuel, these bioliquids can be forgotten faster than thought, due to the fact that nowadays people are willing to choose the most ecological option. Bioliquids also create the cultural biodiversity loss, which means that when palm trees are to be grown, all the other forest is cut down, which of course creates loss of biodiversity, in plants, animals and insects. And there are plants that are very important culturally for the people, for example in South East Asia.

People will stop growing the culturally important plants because they need the money and are willing to lose the plants to grow trees. Economically bioliquids are also sustainable because the research is created from basic fuel and diesel research; these fuels have just been improved to be more environmentally sustainable. But as mentioned earlier, these fuels doesn´t necessarily have such a long life span, due to the fact that this is a case cradle to grave biofuel. And this is why it will not have economically such a good effect, because it is not as environmentally friendly as other options.

Bioliquids are a cradle to grave type of biofuel. They do not reach the level of cradle-to-cradle, because bioliquids cannot be used as a nutrient to the nature after usage, on the contrary, they produce pollution. Bioliquids cannot be used in a closed-loop cycle of production, nor recovered or remanufactured. Cradle to grave is not however all bad; it does mean that bioliquids are designed to be healthful and restorative, but when looking at the complete sustainable development system, this biofuel dimension does not reach the level of cradle to cradle.

2.2.1.3. Biomasses

The third category in Table 3 are *biomasses*. This refers to ethanol produced from different crops which are farmed either on fields or swamps. A good example of a field biomass farmed in field is barley ethanol. These biomasses can be produced to either solid or liquid fuel. It is not yet so common in Finland and it is being researched and tested, in southern Sweden and central Europe for example field biomasses are important sources of energy (Finbio 2005).

When considering the environmental, social, cultural and economic effects of bioliquids they have both positive and negative effects.

Environmentally field biomasses are globally easy to produce. For example, barley is a crop that is easy to farm. If and when biomasses are produced for wider usage, it also means that there will become bigger, wider farms, which also means that more and more forest must be cut down to make space for farming. Landscapes change when forest is cut down and more heavy machinery is needed, which run on fossil fuels, which in turn, create more emissions.

Socially this kind of a new biofuel does create jobs and does give options to a consumer to choose what kind of energy resource to use. One major problem socially is that biomasses are mainly produced from crops, which can be, and according to many people and organizations, should be used for food, not for fuel. This is the same problem when looking at biomasses from cultural perspective: Organizations have reacted to this, that food for fuel is wrong, it is unethical and killing the culture of farming for food. Biomasses are not a very new biofuel type so it is also easier for people to adapt to a normal life as an alternative option to fossil fuels. Economically it does create jobs to a whole chain when considering the production of biomass from raw material to grave.

Biomasses belong to both cradle-to-grave and cradle-to-cradle approach. The reason behind this is that these biomasses are produced as a liquid as well as a solid fuel. Biomasses that are liquid fuel belong to the approach of cradle-to-grave, due to the fact that they are healthy to the environment and restorative, but they cannot be used as a nutrient nor can they be recovered or remanufactured. However, the solid fuel types of biomasses are on the cradle-to-cradle level, because they can be used as a nutrient for nature after use,.

When the solid fuel has been used, the remains of the solid fuel (ashes for example) can be put into the ground again, giving the soil nutrients. Field biomasses do have more chance of reaching sustainable development, in all the four dimensions of sustainability, even though it has become very known that these types of biofuels do affect the farming for food supplies to people and animals.

2.2.1.4. Peat

The fourth category on Table 3 is *Peat*. This is produced from organic material. Best known is Peat diesel and Peat is mainly used for production of heat. Peat is also a product which is not so known in every corner of the globe, and it also cannot be produced everywhere because it is nature's own ingredient.

When considering the environmental, social, cultural and economic effects of Peat, it has both positive and negative effects.

Considering the environment, Peat is produced ecologically; however the usage of peat is not as environmentally friendly as first thought. For example, biogases are much more environmentally friendly than peat. When considering the production method of peat, it is very slow, slow compared to production of biogases, bioliquids and field biomasses. However, the Technical Research Center of Finland, VTT has analysed that if peat is produced to become a diesel, the emissions of the production and utilisation can be 10–80% lower compared with fossil diesel. Based on a life cycle analysis VTT has calculated the greenhouse impact of peat diesel supply chains in Finnish conditions and it has been analysed also that within a 100-year duration, the greenhouse impacts of peat diesel chains remain below those of fossil diesel if the peat is obtained from cropland and low-emission electricity is used in the process (VTT 2007).

Socially peat creates jobs, because peat is mostly a local solution to creating energy and this way it can create many jobs at the place where there are peat fields. Culturally peat has seemed to be easy enough for people to adapt but it has also been learned fast that is not so environmentally friendly as other biofuels. Peat has brought a new idea of a biofuel into the market which has brought jobs and of course money. However, as peat is quite slow to produce and it does pollute during usage, it might be a short- lived solution, mainly because of these two reasons.

Peat can be put to the approach of cradle-to -cradle. The reason being that it is ecologically intelligent, and it can be used over and over again; however, this option for biofuel might not be such a long living option, because it does create emissions during usage.

2.2.1.5. Wood based biomasses

The fourth and the last category on Table 3 are wood based biomasses. These biomasses include industrial wood residue and industrial by-products. These include sawdust, wood waste, construction wood and other kind of demolition wood. There are also wood based biomasses which are processed; refined wood fuels such as pellet and briquettes or charcoal, gas and pyrolysis oil (Finbio 2005).

When considering the environmental, social, cultural and economic effects of recycled biofuels there are both positive and negative effects.

Environmentally, wood based biomasses pollute during usage and these kind of biofuels are also low in energy, which means that wood based biomasses are good in household usage, but not in any bigger industry or housing. Wood based biomasses are a good solution to regular households as a source of energy and heat. Environmentally the collection of the raw material is not so clean nor sustainable, heavy machinery is required and if the production becomes very wide it can lead to loss of biodversity and also the soil can suffer a lot.

Socially wood based biomass does give jobs (forest harvesting) but it is not very democratic, the reason being is that these types of biofuels are used mainly in rural areas, for heating. Culturally wood based biofuels have been known for a long time.Iit started from plain wood, and now it has been created into refined wood fuels, pyrolisis oil and so forth. Culturally wood based biomasses are known as being the source of energy and heat. Economically wood based biomasses have created jobs in the forest industry and these types of biomasses are easy to sell too, especially in countries where wood is used as the source of heat.

Wood based biomasses have the approach of cradle to cradle. This means that after the usage the waste can be put into the soil as a nutrition, and so the waste is back again in the system.

This way wood based biomasses have the approach from cradle to cradle. Wood is not produced artificially nor does it need any toxic substances to be grown or harvested, when the circumstances are right and the process from planting to usage is not done as a mass production.

Biofuels may not be the answer to slow down the global warming, but these fuels can reduce emissions and that way slow down global warming. This is the reason why environmental politics have concentrated recently on reducing emissions, trying to find a new substitute to fuel and diesel.

Even though there has not been much research and results about how biofuels effect the environment, these are the results that were acquired during the information research and analysis. The idea behind finding a substitute to traditional fuel and diesel is good; however the good and bad effects of biofuels have not been fully explored so that the best biofuel can be found yet.

2.3. LCA Analysis

LCA analysis is a method of investigating how to minimize a effect, for example of biofuels on the environment. As it has been recognized environment and biodiversity is a vanishing resource. It has become more natural for people to try and reach sustainable development in order to save our environment as well as biodiversity. Today it is much more common to demand more environmental friendly products and services (Curran 2006: 1).

LCA analysis has many stages: it begins with inputs and ends to outputs. Inputs and outputs are the most important matters that are measured. LCA considers the whole life cycle, from cradle-to-cradle or from cradle-to-grave, as LCA is also known to be able to have the activity to follow a product or service from cradle-to-cradle, which is known as the endless recycling method (Ketola & Myllylä 2009).

It can also include impacts of the product on nature which other analyses do not necessarily execute (e.g. ultimate product disposal). Figure 5 on chapter 2.3.1. will go into the stages of a LCA analysis (Curran 2006: 1-2).

"LCA analysis is a decision support tool (European Environment Agency, 1998)." This means that when LCA is used in the right way, it can help a company to ensure and decide if their choices are environmentally friendly. This is a good way to a company to make their own environmental, social, cultural and economic sustainable decisions regarding their raw materials, completed product or service. It is better to find it out by themselves than through a competitor. However, it should be remembered that when doing LCA analyses, it does not mean that the analyses results are proving that a particular product or a service is environmentally, socially, culturally and economically friendly.

However, it can be said that a particular product or service can be more environmentally, socially, culturally and economically friendly than another one that is similiar to the tested product or service (European Environment Agency, 1998: 10-12). In other words, LCA is a decision support tool that shows the difference between a product or a service. It does not give one clear answer; it gives many answers that can be analysed.

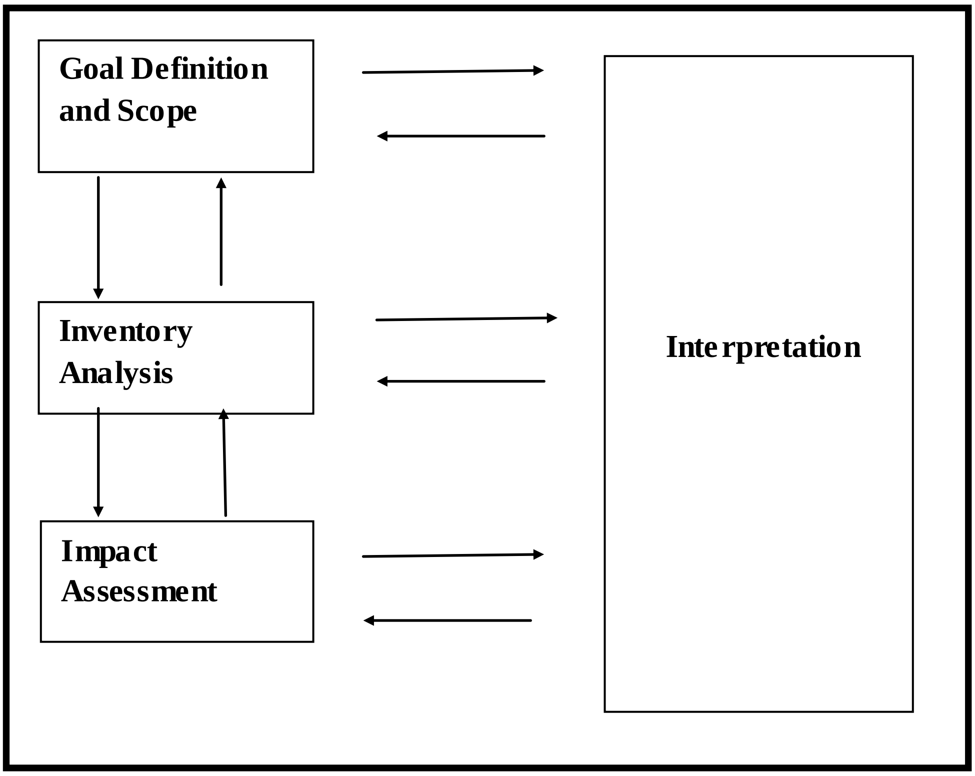

Figure 4. Life Cycle Assessment framework (Curran 2006: 2).

The framework of a Life Cycle Assessment (Figure 4) begins with assessing a goal definition and scope; the purpose and function of the research, boundaries of the research and the quality of data needed.The inventory analysis is then made, which includes data collection, refining system boundaries, calculation, validation of data, relating data to a specific system and allocation. After these two stages impact assessment must be done, which includes category definition, classification, characterization and valuation.

The arrows in Figure 4 describe that while doing this type of research, there can always be a justified reason to go back in the research: when doing impact assessment, for example it can be found that there is lack of information, and an inventory analysis must be checked, or even something must be added to the data. In this framework, interpretation is the last step to take, which includes the identification of environmental issues, as well as evaluation, conclusions and suggestions that are to be made in interpretation (European Environment Agency, 1998: 51-68).

2.3.1. Life Cycle Stages

LCA framework is the basis of how a LCA analysis is done. It explains what a good LCA analysis must include to be able to make findings. However, there are deeper stages for this type of analysis with its inputs and outputs. In Figure 5 his is explained and the inputs and outputs of a LCA analysis are shown as well as what happens between these stages.

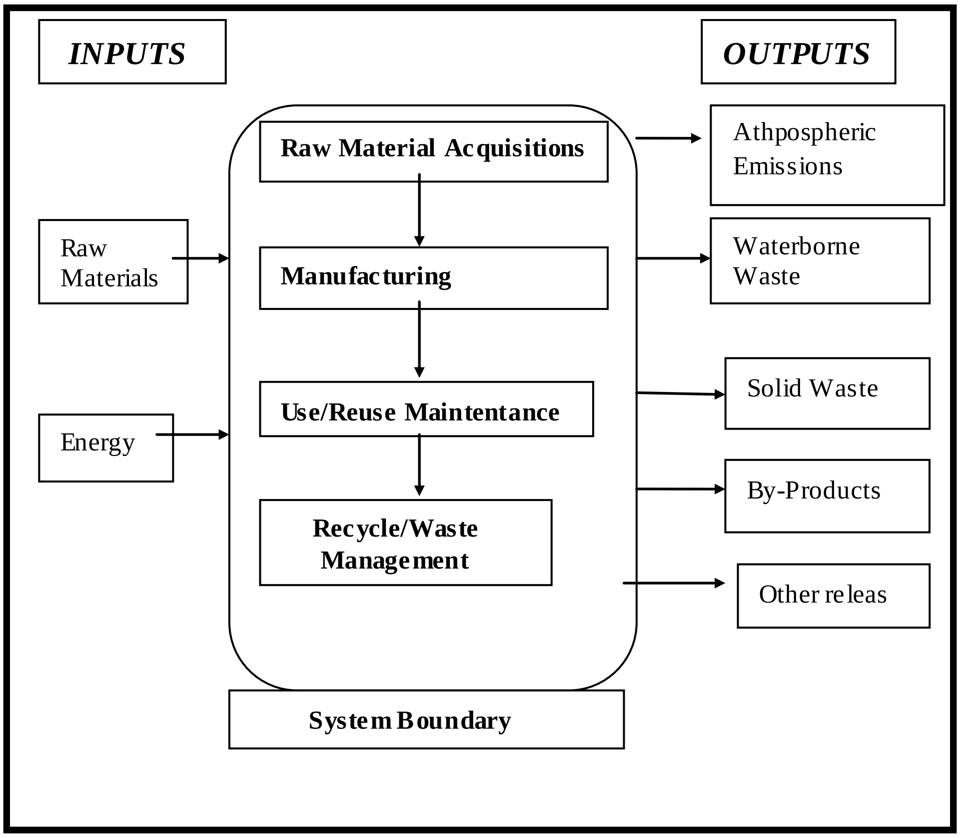

Figure 5. Life Cycle Stages (Curran 2006: 1).

Figure 5 explains what kind of stages a LCA analysis has. LCA analysis begins with inputs, such as raw materials or energy. Those are measured the most, with how harmful they are and what they consist of. After that they are processed through four different stages: raw material acquisitions, manufacturing, use or reuse and maintenance, and recycling and waste management.

These are system boundaries that manage the raw material or energy produced, and from these the outputs come to life; how much does this manufactured raw material produce emissions and wastes, by-products and other releases. The output stages of LCA are all the pollution and waste emissions which are produced by the product which is tested with this analysis. On outputs it will show what kind of atmospheric emissions, waterborne wastes, solid wastes by-products and other releases the system boundary creates.

LCA analysis and the stages of it create simple but effective results for a product or service to be analysed for its environmentally friendliness. As seen from the Figures 4 and 5, LCA describes the environmental aspects of a product system through all it stages of life. It is also known as life cycle analysis as well as cradle-to-grave- analysis, which means a product´s life cycle from the moment of creation to the death of the product. This includes and is not limited to the product´s manufacturing, transportation, usage and disposal of that product.

These stages have many sub-stages, including procurement of raw material, extraction of the raw materials, designing and formulation of the product, processing it, then manufacturing, packaging, distribution, use, re-use, recycling and waste disposal (European Environment Agency, 1998: 9).

LCA is also known to be able to have the activity of cradle to cradle, the endless recycling method (Ketola & Myllylä 2009). LCA is not very common or well used however still it has the potential to become a way to find out the true quality of a product.

2.4. Sustainable life cycle assessment of biofuels

Sustainable development is about conserving biodiversity so that the resources used are natural as well as renewable and the use of nonrenewable natural resources is minimized. In this way the ecosystem can be kept healthy and of environmentally high quality, which helps the capacity of earth to be kept in high standards. As sustainability has become more important to the earth, it has also created the idea of sustainable fuels, known as biofuels.
The idea behind biofuels is to be sustainable and not harm the environment, cultures and economy as much as fossil fuels.

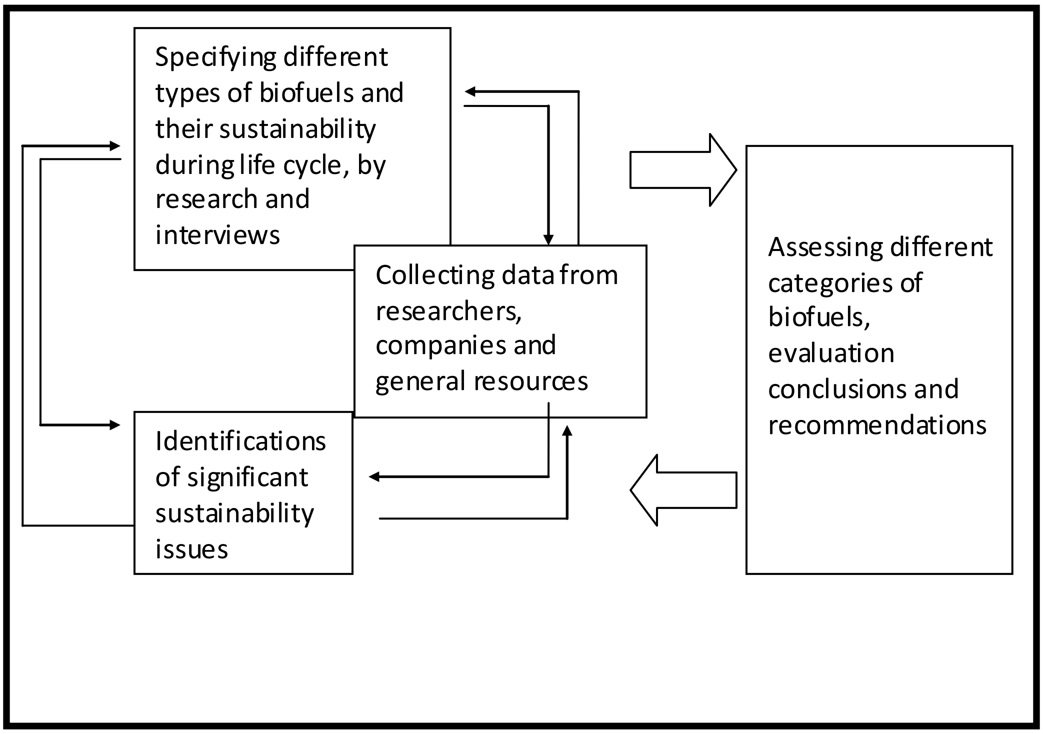

Figure 6. LCA framework of biofuels.

Figure six is a LCA framework of biofuels based on the Figure 4 (Curran 2006: 2). In this figure the framework of biofuels is explained; what must be done in order to create a LCA. Goal definition and scope is the start of the research, in which the different types of biofuels are specified and their sustainability during life cycle. The first stage is to create a theoretical framework of different types of biofuels (in this case divided by their raw material resources) and their pros and cons of sustainability. After the theoretical section, the empirical part will continue, presenting more Information in the form of interviews and research. When the goal and scope are clear, then the inventory analysis, collecting interviews with researchers, companies and general resources will follow.

When looking at the Figure 6, it can be seen from the arrows that already in this point of doing LCA framework, it can be noticed that something may be added to the theoretical part while doing the interviews, or some facts must be checked or changed. Going backwards is very common when doing an LCA. It is the way of keeping the research alive and also making it very comprehensive.

After goal and scope the impact assessment follows, where the sustainability of biofuels is measured and analyzed according to the findings from interviews and research. In this point the goal and scope are usually checked, because there might be slight changes in the research, however the main idea of the research must be kept in sight. When these three parts of LCA are completed, the interpretation of the LCA begins. Different categories of biofuels, evaluation conclusions and recommendations are assessed. This usually means going back to each stage of LCA framework, which will help to create a comprehensive LCA framework.

This framework has been the source for this sustainability LCA of biofuels. The next step in this research is to go into the interviews more deeply with inventory analysis and impact assessment.

3. EMPIRICAL STUDY

3.1. Data Collection

Data collection was executed as a qualitative research method is usually carried out, by interviewing people. The answers were based mainly on basic questions, why what and how. The questions were wide and open ended i.e. the respondent was asked a question where they could give their open opinion built on their own expertise. The researcher did not want to control the answers in any other way than to keep the respondent focused on LCA and sustainability of biofuels.

There were eight interviews, five of them were completed face-to-face and three of them were done as a telephone interview. Each interview lasted from 45 minutes to two hours. The respondents received the questionnaire a week before the interview, so that they could prepare themselves with needed information. In order to retain validity and reliability the respondents were given the opportunity freely express their opinions and give insight into all of the questions. The respondents did not know what other respondents had answered, also interviewer did not comment in a larger degree on any of the answers given during the interviews. This way the answers were of the most reliable sort.

The data collection itself was done by two methods; by recording the interviews or directly transcribing. The reason for not using a recording device on all of the interviews was due to technical limitations. The recorded interviews were also transcribed after the interviews. Even though the actual content of the conversations did undergo some changes when presented in the empirical part of this thesis, the meaning and purpose behind the answers was not changed in any significant way. All major changes are centered around in linguistic reasons, as the interviews were made in Finnish but in this research they are presented in English. The questionnaire can be found in Appendix 1.

3.2. Analysis of findings

In this chapter all the different categories of biofuels are introduced and their good and bad effects to environment, social life, cultures and economics are presented. The data in these sub-chapters were entirely collected from the interviews which were held in august-October 2009. The chapters will present each of the different bioenergy sources, and in the conclusion they will all be compared in their sustainability during different phases of the life cycle. Finally, based on these findings and results the conclusions will be drawn and further suggestions and improvements will be given.

3.2.1. Biogases

Biogases are a source of bioenergy which has reached the point of becoming one major replacement to fossil fuels. It is a biofuel with a cradle-to-cradle life cycle. Biogases do not create emissions and the raw material is easily found.

Biogases refer to constituents such as methane and carbon dioxide that are produced by the anaerobic fermentation of biological materials. Biogases are most commonly produced by agricultural and organic waste. Sewage gas is produced by sludge digestion in the tanks of sewage treatment plants. Landfill gas is produced by organic residues in garbage tips (General Electric Company 2009).

Biogases are a good solution because the raw material for producing the energy is not created for only one thing. The raw material has been a nutritient or food from which it has turned into waste, which is used as a source of energy. These research results were received from interviews with Leif Åkers (Stormossen), Petri Torri (Gasum Oy) and Erkki Hiltunen (University of Vaasa). The results of the interviews can be seen in Table 5.

3.2.1.1. Environmental responsibility of biogases

The environmental responsibility of biogases evolves around the fact that it does not create pollution. Pollution happens mainly in the beginning of life cycle (Interview with Leif

Åkers,2.9.2009). This means that the pollution is created when the raw material is collected from different places, because collecting all the waste requires heavy machinery, which still requires fossil fuel to function. However, creating biogases is a intelligent way of disposing waste (Interview with Leif Åkers. 2.9.2009, Pasi Torri 12.10.2009 and Erkki Hiltunen 12.10.2009). This also makes biogases to become cradle to cradle type biofuel, since biogases are created from a substituent which has been used once or twice, and after that can still be used again.

There has also been lof of discussion about fields that are not being used as farming land nor to any other usage, mainly because the nutritients in the ground are not good enough to grow food. These fields could become useful by growing plants that are not otherwise useful but as an energy source, this would mean there would be less fields “standing empty” (Interviews with Pasi Torri 12.10.2009 and Erkki Hiltunen 12.10.2009).

Another major reason for biogases being an excellent substitute to fossil fuels is that it would make the harmful substances disappear (Interview with Torri 12.10.2009).These substances include carbon dioxide which has been analysed to be dangerous for the earth, as well as nitrogen dioxide and different types of particles which are harmful more to people, these substances cause cancer and other types of diseases. However, with each type of biofuel there is the same problem; It don´t create enough energy in order to replace all other forms of biofuels (Interview with Leif Åkers 2.9.2009). There is not enough waste in this world for the biogas to replace fossil fuels totally, but locally it is a good source of energy and for certain areas or even a whole country.

3.2.1.2 Social responsibility of biogases

Socially biogases create jobs; there are new places to work because there is new machinery to be produced and new factories to work in. And biogases as an energy source are socially very easy to adapt to because implementation is fast and infrastructure already exists small level. Also it is very generally accepted as a method of creating energy. To make biogas as a common source of energy, it requires a change of people’s ideology, however it is not so difficult a change is not as initially thought. Mainly it can be difficult to make everyone understand the real meaning of recycling. Without recycling there is no energy (Interview with Leif Åkers. 2.9.2009, Pasi Torri 12.10.2009 and Erkki Hiltunen 12.10.2009).The downside of this biofuel's social responsitbility is that it can also create a loss of jobs as old energy sources, e.g. fossil fuel business dissapears

3.2.1.3 Cultural responsibility of biogases

When looking at the cultural responsibility of biogases, they are easy to find in industrialized countries these types of biogases is easy to adapt to, mainly because the infrastructure already exists and also because biofuels especially gas has been on the market for a while (Interview with Leif Åkers. 2.9.2009, Pasi Torri 12.10.2009 and Erkki Hiltunen 12.10.2009). However biogases, as any other type of biofuel will have difficult becoming common in developing countries (Interview with Leif Åkers. 2.9.2009 and Erkki Hiltunen 12.10.2009).

There has also become one new raw material for biogas; human waste. This is a major opinion divider among people; many people do not see it as a resource to energy, even if it would be a high-level source of energy as well as a nutritient to the ground (Interview with Pasi Torri 12.10.2009). All in all, for biogases to become more globally acceptable in different cultures, it will require time and education

3.2.1.4. Economic responsibility of biogases

Economically biogases are very responsible; it uses already existing technology and it is cheap and easy to use, which makes it very quickly adaptable: Gas created from sewage and land gas can be put into the same system from where it can be used as a energy source. Also existing landfills can become useful, by converting them into fields where the source of energy can be farmed.(Interview with Leif Åkers 2.9.2009) These sources are mainly raw materials which cannot be used in any other form.

To create biogases into a much more common source of energy it will require large investments from the bioenergy companies, car industry and government. However, farmers with big farms and lot of sewage waste on hand, can start using their own sewage and waste to create gas, which can be used to warm up their own homes and other buildings on their land. This way, economic responsibility of biogases are very vast and also very local(Interview with Leif Åkers. 2.9.2009, Pasi Torri 12.10.2009 and Erkki Hiltunen 12.10.2009).

Environmental	**Social**	**Cultural**	**Economical**
+ Pollutes mainly in the beginning of life cycle + Intelligent way of disposing waste + Cradle-to-cradle + All fields become useful + Toxic substances disappear -Requires heavy machinery -Does not create enough energy in order to replace all other forms of biofuels	+ Creates jobs + Implementation is fast (infrastructure) + Generally accepted as a way of create energy -Loss of jobs ("old" energy) - Requires a change of ideology	+Easy to implement in industrialized countries - Requires a big amount of education in developing countries - Addresses problem of using human waste -Requires time and education	+ Uses existing technology + Cheap to use + Converting existing landfills into energy centre - Requires big investments from the bioenergy companies, car industry and government

Table 5. Sustainability of biogases.

3.2.2. Bioliquids

The topic of bioliquids is a major opinion divider. It is a biofuel with a cradle-to-cradle life cycle. It does not produce as much emissions as a fossil fuel, however still it has its weak points.

Several different bioliquids were introduced in the theoretical part of this thesis (Chapter 2) Due to time, accessibility and geographical restrictions only palm-oil as a source for biodiesel will be discussed in the empirical part of this thesis. The importance of other source material for biodiesels, e.g. rapeseed-oil and ethanol made from biomass are acknowledged, and it is suggested that the other source materials should be studied at a later occasion. It is however important to note that the general basics in creating biodiesel from both palm-oil and rapeseed-oil are similar.

As Neste Oil Oyj and Simo Honkanen are at the moment putting in a large effort on refining palm oil into biodiesel, this thesis follows the general principles that surround the use of palm oil as a biodiesel. These research results were received from interviews with Simo Honkanen, (Neste Oil Oyj), Maija Suomela(Greenpeace) and Erkki Hiltunen (University of Vaasa). The results of the interviews can be seen in Table 6.

3.2.2.1. Environmental responsibility of bioliquids

Bioliquids is a good improvement on fossil fuels (Interview with Simo Honkanen. 10.8.2009). The Finnish oil company Neste Oil has created their own biofuel NExBTL, and it is a good biofuel of the future when it comes to the emissions: It has a low emission level during usage. However, the process of production creates higher levels of emission (Interview with Maija Suomela, 12.8.2009). When palm oil is produced, the ground work to get the crops growing is a big investment.

Palm oil is produced in South-East Asia where the big rainforests must be cut down in order to make space for palmoil plantations. The local farming grounds must be capitulated to plantations. This creates loss of rainforests and biodiversity. Also the damage made to the ground and soil is very high, as it can take up to seven hundred (700) years to get the soil back into its original state. Also, some of the natural swamps are lost because the soil needs to be changed so that the palm oil trees can grow. Also the biodiversity of animals has suffered. It has been forecasted that within five to ten years the endangered species of orangutan and tiger of will become extinct (Interview with Maija Suomela, 12.8.2009).

3.2.2.2. Social responsibility of bioliquids

Socially, bioliquids create jobs throughout the whole life cycle; from farmers of the palm oil to the distributors of the bioliquids. As palm oil is produced in parts of Asia, where poverty is an issue, it is a good way to create jobs to them, which also decreases hunger when , and locals can benefit from palm oil by using it as a energy and heat source (interview with Simo Honkanen 10.8.2009).

However, there is another side to this story: Farming of big palm oil plantations has created major disputes between native tribes in Indonesia, which has made the living situations very uncomfortable for these people (Interview with Maija Suomela 12.8.2009). This is a big social issue with different types of bioliquids; socially it can be very destroying when the farming becomes unilateral; bioliquidsa are good source of energy in a smaller, local scale, as it has been noticed also in other forms of biofuels (Interview with Erkki Hiltunen 12.10.2009).

3.2.2.3. Cultural responsibility of bioliquids

Culturally, bioliquids are easy for people to adapt to as bioliquids do not require anything extra or new from a consumer during usage. During summer 2009 Neste Oil Oyj´s NExBTL has been taken into usage in certain Neste Oil stations in the Southern part of Finland, and people have not noticed any difference (Interview with Simo Honkanen. 10.8.2009).

Culturally, the negative side of bioliquids is that it has made some native tribes vanish in Indonesia; when there are big plantations, people become spread around and tribes are scattered all over the island (Interview with Maija Suomela 12.8.2009).

3.2.2.4. Economical responsibility of bioliquids

When looking into the future, it has been predicted that in year 2020 the big fossil fuel fields will be drying up and there is much more demand for biofuels. Even if bioliquids are more expensive now than fossil fuels, it will change as the less there are sources for fossil fuel, the more expensive it will be. And, as mentioned in social and cultural parts, it does create jobs during the whole life cycle of bioliquids (interview with Simo Honkanen. 10.8.2009). However, the growing business of bioliquids can endager other industries and business, for example other biofuel businesses, such as producing biogases or biomasses (interview with Maija Suomela 12.8.2009). Economically bioliquids can become and are, a good help for farmers. For example, in the palm oil industry the large farms can run their machinery and cars with the same bioliquid which they sell(interview with Simo Honkanen. 10.8.2009). In the future this can also happen in smaller farming households where the bioliquid could be manufactured from sewage and used in the needed heavy machinery (Interview with Erkki Hiltunen 12.10.2009).

Environmental	**Social**	**Cultural**	**Economical**
+ Good improvement + Minimum pollution levels during usage -High level of pollution during production -Damages the ground -Loss of biodiversity -Loss of rainforests -Loss of natural swamps -Cradle-to-grave	+ Creates jobs -Creates dispute amongst people -Food for fuel	+ Easy to adapt to -Creates cultural loss in the beginning of a life cycle	+ Cheaper in the future than fossil fuels + Fuel usage becomes cheaper for farmers + Creates industry + Creates jobs - Might create the loss of other industry - Expensive to produce (rapeseed oil)

Table 6. Sustainanbility of bioliquids.

3.2.3. Biomasses

The third category is field *biomasses*. This refers to ethanol produced from different crops which are farmed either on fields or swamps. A good example of a farmed field biomass is barley ethanol. These field biomasses can be produced as either a solid or liquid fuel. It is not yet common in Finland and it is being researched and tested, however, in southern Sweden for example and central Europe field biomasses are important sources of energy (Finbio 2005). These research results were received from interviews with Pirkko Vesterinen (Technical Research Center of Finland, VTT), Pasi Torri (Gasum Oy) and Erkki Hiltunen (University of Vaasa) The results of the interviews can be seen in Table 7.

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3.2.3.1. Environmental responsibility of biomasses

Environmentally, biomasses are responsible only in a way that it is easy to produce.It does not require any difficult machinery which would cause extra emissions and it can be created as normal biomass, e.g. barley. It can also be made from waste too, for example from bakery waste. Biomasses are a good thing if there are barrens, fields that can be used as a cultivation of biomass raw material (Interview with Pirkko Vesterinen 13.8.2009).

However, biomasses have more bad than good influences to environment. As it is easy to produce, it can create loss of biodiversity because farming becomes more unilateral and when it becomes “mass production” it means that more and more nutritients as well as pesticides are used, which create loss of biodiversity in the ground and around the fields.

As mmentioned earlier, bakery waste is used as a biomass, but it does create emissions, It can only be used once, which means that mass becomes cradle-to-grave (Interview with Pasi Torri 12.10.2009). Any other kind of biomass is also one way- energy, when the energy is taken from the raw material, it cannot be used again.

3.2.3.2. Social responsibility of biomasses

Socially, biomass production creates jobs, as is the case with farming and using waste, e.g. from bakeries. It creates jobs along the whole chain; from farmers to biomass factories. It is a good option for a consumer to be using, however, there is one issue that is of concern, and that is the fact that food is not fuel. This is a issue that cannot be forgotten and will not be (Interview with Pirkko Vesterinen 13..8.2009). Socially biomasses are a good thing as long as manufacturing stays local and in that way benefit can be received from the biomasses (Interview with Erkki Hiltunen 12.10.2009).

3.2.3.3. Cultural responsibility of biomasses

Culturally this type of biofuel is much known, because it is one of the first biofuel forms which was utilised. However, there are the same problems in cultural and social responsibility; it is very difficult for people to adapt to because food is not fuel. It is not an issue if it is created from waste, for example the waste which is created in bakeries. However, if the biomass is created from barley, it will stop people from buying the product. Also, when there are better options such as biogas, biomasses will not be able to become a major resource of bio energy (Interview with Pirkko Vesterinen 13.8.2009).

3.2.3.4. Economical responsibility of biomasses

Economically biomasses do create jobs for the whole chain, as mentioned in the social responsibility of biomasses. It also brings more business to the farming industry and also can bring more business and income to bakeries if their bakery waste is used (Interview with Pasi Torri 12.10.2009) It also does not create big investments for companies because the biomass usage is about using an existing product (crop or waste) and machinery to collect the raw material for it(Interviews with Erkki Hiltunen 12.10.2009).

Environmental	Social	Cultural	Economical
+ Easy to produce + Loss of biodiverstity + Use for landfills - Farming becomes more unilateral - Cradle-to-grave	+ Creates jobs + An option for the consumer - Food is not fuel	+ Known type -Difficult for people to adapt to -Food is not fuel	+ Creates jobs along the whole chain + More business to the farming industry + Uses exsisting product and machinery + Locally economical

Table 7. Sustainability of biomasses.

3.2.4. Peat

The fourth category is *Peat*. This is produced from organic material. Best known is peat diesel of its end products. Peat is mainly used for production of heat. Peat is nature's own resource, which makes it a biofuel, however it is a major opinion divider amongst people. It is also a resource that has its limits when it comes to producing it. These research results were received from interviews with Mia Wallen (Finnish Energy Industry) and Pirkko Vesterinen(Technical Research Center of Finland) The results of the interviews can be seen in Table 8.

3.2.4.1. Environmental responsibility of peat

Peat is a raw material produced by the nature itself. When peat rises from the ground the greenhouse emissions get lower. However, this becomes un-useful when the need of heavy machinery and infrastructure is needed when collecting peat (Interview with Mia Wallen 19.8.2009). This means building roads that lead to the swamps where the peat is, building factories that turn the peat into energy and so forth. This entire infrastructure creates change in the landscape, it can also create flowing and definitely creates methane emissions, phosphore loading to the soil. Another major issue is that this type of biofuel is cradle to grave type of biofuel and another issue is that there are limited amount of swamps that can be used as a source for peat (Interview with Mia Wallen 19.8.2009).

3.2.4.2. Social responsibility of peat

As peat is a local solution creating energy, it has a good social responsibility, it creates employment into an area where the peat is being lifted from the swamp and then created to become energy. This type of business can create up to 100 working places in a town (Interview with Mia Wallen 19.8.2009).
However, the usage of peat began in the 1970's and back then the infrastructure was not good. It also created the loss of nature, swimming areas and recreational areas, and since then it has remained in peoples mind as a negative source of energy.

3.2.4.3. Cultural responsibility of peat

Culturally the responsibility of peat is moderate. It has been accepted as the natural method of creating energy, however it does have issues with the change of landscape and that is very difficult to minimize. Also culturally this type of biofuel is unknown in several countries (Interviews with Mia Wallen 19.8.2009 and Pirkko Vesterinen 13.8.2009). The cultural responsibility of Peat is difficult to increase because the reputation peat has had for decades.

3.2.4.4. Economical responsibility of peat

Locally this type of biofuel is very productive and effective, it boosts the local economy but it also requires high investment from the community and municipality. There is the big question for economical sustainability; as peat cannot become a big resource for energy it can't become a big business, it can't be economically sustainable because peat can't be harvested from the same swamps for many years in a row. Peat cannot rise as much as would be needed (Interviews with Mia Wallen 19.8.2009 and Pirkko Vesterinen 13.8.2009).

Environmental	**Social**	**Cultural**	**Economical**
+ Mostly produced by nature itself +Reduces greenhouse gases -Requires heavy machinery and infrastructure - Change in the landscape -Flowing - Cradle-to-grave -Methane emissions -Phsosphore loading - Limited amount of swamps	+ Employment opportunities -Negative beliefs - Loss of pure nature, swimming areas, recreational areas - Fear of changes in the landscape	+ Easy to accept as a ”natural” method of creating energy -As a concept relatively unknown in several countries	+ Locally very productive and effective + Boosts local economy -Requires high investment from the community and municipality - Economical sustainability?

Table 8. Sustainability of peat.

3.2.5. Wood based biomasses

This chapter will discuss wood based biomasses as a source for bioenergy. This chapter creates a list of effects that wood based biomasses have in their life cycle. Biomasses include industrial wood residue and industrial by-products, such as sawdust, wood waste, construction wood and other kind of demolition wood. There are also wood based biomasses which are processed; refined wood fuels such as pellet and briquettes or charcoal, gas and pyrolysis oil (Finbio 2005).

It is important to note that the effective use of wood based biomasses varies a lot depending on countries, even among EU members. As Finland is one of the pioneers in utilizing wood and other wood based masses as a source for energy, it will be used as a comparison point to other EU members that could utilize the source material in a better way, such as Spain and Belgium.

It is important to note that the life cycle analysis takes into consideration both Finnish and foreign methods in the creation, refinement, use and disposal of wood based biomasses. These methods and how they affect each other during life cycle will be discussed through the five sustainability factors. These research results were gained from interviews with Ahti Fagerblom (Finnish Forest Industry), Maija Suomela (Greenpeace) and Pirkko Vesterinen (Technical Research Center of Finland) . The results of the interviews can be seen in table nine.

3.2.5.1. Environmental responsibility of wood based biomasses

Environmentally, wood based biomasses have a low emission level. When this type of bioenergy is burned, the emissions are fairly low and also the waste after the burning process is ashe, which can be put into the ground as nutrition. What comes out of the chimney is natures own ingredients (Interview with Ahti Fagerblom 11.8.2009).

When looking at the life cycle of a wood based biomass, they do not create a massive amount of waste or emissions. This is when wood based biomass is used as a local source of energy, which is most efficient when considering the effects on the environment. Wood based biomasses are not a resource for massive amounts of energy, however as a local solution to create heat or electricity, this source of bioenergy would be excellent (Interview with Pirkko Vesterinen 13.8.2009).

When wood based biomasses are produced commercially and forests are being planted just to be cleared for mass production, the problems and emissions grow. Intensive production is a problem that is when heavy machinery is used, causing emissions. Toxic substances can be used to get rid of the undesired species of plants (loss of biodiversity), and irrigation is used to make the raw material grow faster. This is when erosion and land sags will appear.

Wood based biomasses are a good investment as a new source of energy, however when it is being intensively produced, the problems begin to be too great.
Wood based biomasses are one of the few biofuels that belong to the type of cradle-to-cradle description. As wood based biomasses are burned, their residue can be returned to the soil which gives nutrition to the new, growing forest.

3.2.5.2. Social responsibility of wood based biomasses

Socially, the responsibilities of wood based biomasses are good. This multiplies in countries where wood is a natural resource and when there is no intensive production. Wood based biomasses create a lot of jobs: All through the life cycle, from planting to producing the wood into different types of energy resources for example pellets and sawdust (Interview with Pirkko Vesterinen 13.8.2009).

As mentioned in environmental responsibility this type of bioenergy is locally good, and not only as an environmental fact, but also as an industry. It creates jobs for many different occupations, as wood is also used in many other products, for example furniture and as a packing material.

The wood industry can also socially make a difference towards the attitude of wood based biomasses, and also forests. People see the good in them, both as an energy source as well as a livelihood. The dangers behind production of wood based biomasses are that when it becomes a more intensive production, it can reduce production of food. This problem is usually faced in Asian countries, and less so in Europe (Interview with Ahti Fagerblom 11.8.2009).

3.2.5.3. Cultural responsibility of wood based biomasses

Culturally wood based biomasses are good. They create new lines of business and a good example of this is the pellet industry. However they can also destroy some line of business due to intensive production. This occurs when normal forest farming is forgotten, and even this type of industry can reduce the production of food. This is when it can affect cultures negatively; the biodiversity of culture can be lost (Interview with Ahti Fagerblom 11.8.2009).
One major problem with wood based biomasses, especially in Europe, is that the industry is not understood, especially in countries where the forests are becoming extinct (Interview with Pirkko Vesterinen 13.8.2009).

3.2.5.4. Economical responsibility of wood based biomasses

Economically, wood based biomasses create many kinds of industry, as mentioned before, and that way it can give jobs to different occupations, which is good for a country´s economy. Creating wood based biomasses is a very good business for a country when it is properly operated, meaning that it is not an intensive production, and many kind of industries and professions benefit from the business. However, in some countries it can be very bad due to difficult working conditions, making the job dangerous and very slow (e.g.when the forests lie on steep hills) (Interview with Pirkko Vesterinen 13.8.2009).

Environmental	Social	Cultural	Economical
+ created from wood by products + Pollution level low + Cradle-to-cradle -Intensive production -Erosion -Land sags -Loss of nutrients from the soil -Problems in irrigations -Using toxic substances -Forest clearance	+ Creates Jobs + Locally good + Appreciation towards forests arises -Reduces production of food	+ Can create new line of business -Can destroy some lines of businesses -Not understood in many countries -Affects culture negatively	+ Creates jobs + Very good business for a country (when properly operated) -Bad cost-effectiveness; if working conditions are difficult

Table 9. Sustainability of wood based biofuels.

3.4. Model of sustainable LCA of biofuels

The model of sustainable LCA of biofuels can be seen in Figure7. When gathering information about biofuels, their life cycle stages and effects on sustainability and its dimensions, the LCA framework is a good base to have. Both life cycle stages (see Figure 5 on page 31) and LCA framework of biofuels (see Figure 6 on page 33) has to be considered. These two combined with the dimensions of sustainable development, the model of sustainable LCA of biofuels can be drawn. This model has been concluded from all the material gathered from both theoretical and empirical parts of this research, it summarizes the intention of the research; What is needed to create a sustainable LCA of biofuels?

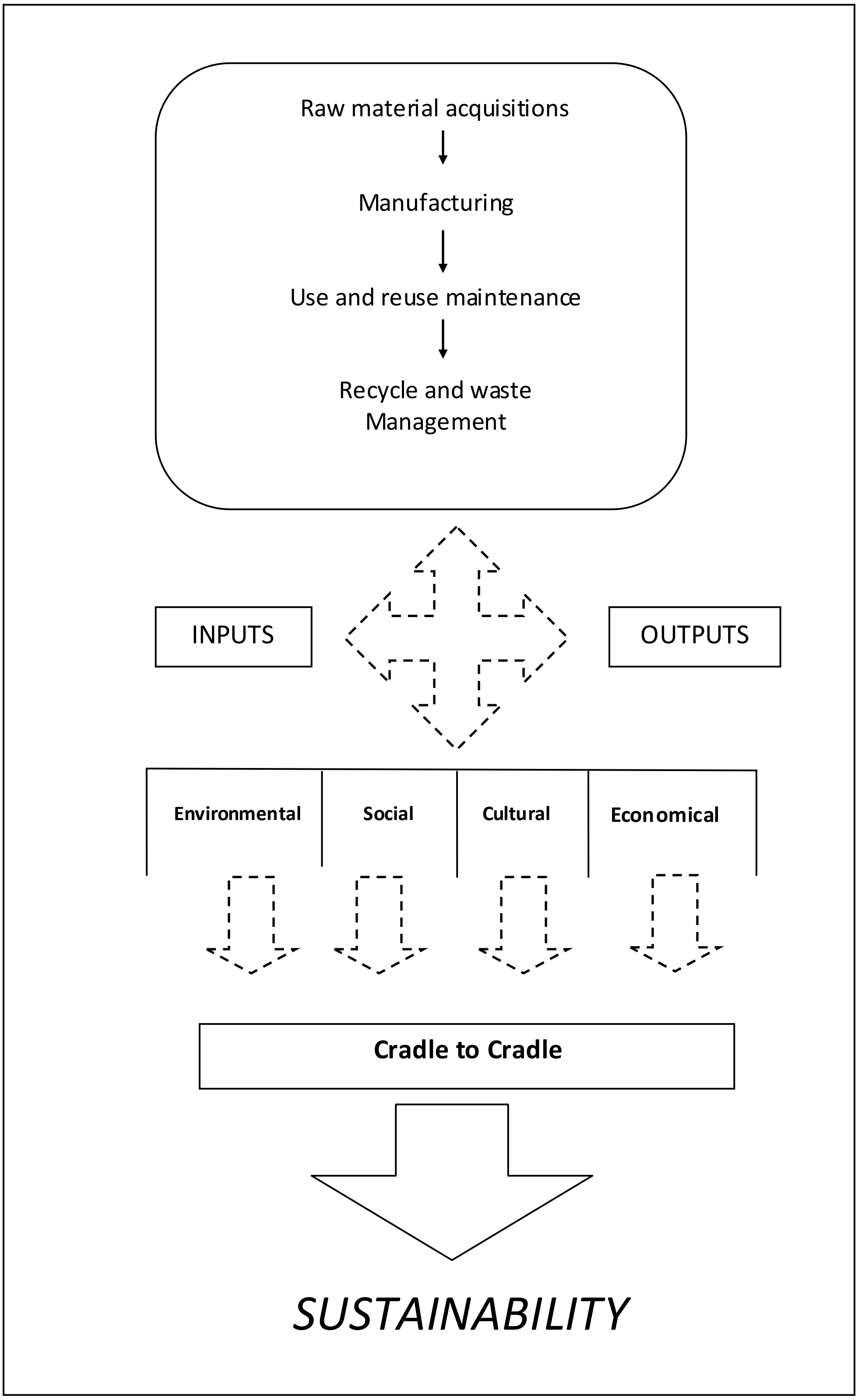

Figure 7. Model of sustainable LCA of biofuels.

The model of sustainable LCA of biofuels is created from seven steps. As the LCA is about the whole life cycle of a product, it must have all the components from each life cycle stage. The raw material and its acquisitions, determines the type of the biofuels, from what are they made from and how. How they manufactured to become sustainable biofuels and how sustainable are they. A example can be wood based biomasses as the raw material is acquired from nature, mostly in a way that the nature itself is not harmed, or waste and by-products of wood that are used to create energy. In this regard the manufacturing is usually a side product of wood production.

Use and reuse is also very important to the model of LCA of biofuels; it is the phase where it can be seen for the first time. Most sustainable is cradle-to-cradle, where the waste can be reused to product energy or as a nutritient and after all the usage it still creates the minimum amount of emissions. A good example would be biogases, which are already used when the process of turning waste into energy begins. In some cases the waste after that can be used again, and the emissions in biogas are insignificant. Less sustainable is cradle-to-grave.

As Figure 7 shows, the last step is the recycle and waste management, which goes hand in hand with use and reuse maintenance, because the keyword in biofuels is use and especially reuse. The biofuel is best serving its purpose when the raw material is a by-product from nature or waste.

As mentioned, the inputs and outputs define the type of the biofuels. Inputs are the raw materials and what type of energy can be received from the raw material. Outputs are the emissions, wastes, by-products and other releases which are inevitable when biofuels are produced. As it can be seen from Figure 7 that raw material acquisitions, manufacturing, use and reuse maintenance, recycle and waste management are inputs and outputs.

Inputs and outputs must be evaluated from the whole life cycle of biofuels, from the beginning to the end, or as it would be most preferable, to never ending loops of recycling. These inputs must be evaluated from all the aspects of the sustainable development: environmental responsibility, social responsibility, cultural responsibility and economical responsibility. In this manner the determination of the sustainability of biofuels can be made. Either cradle-to-cradle approach (endless recycling) or cradle –to-grave (biofuels that only have “one life”) approach. To reach sustainability biofuels must have the approach of cradle-to- cradle. This is the reason why the cradle-to-grave approach is not mentioned in this model of sustainable LCA of biofuels.

Examples of biofuels that fit this model of sustainable LCA would be biogases (waste, sewage waste) and wood based biomasses (wood by-products and wood itself). The reason being that these biofuels are not taken from anyone or anything, they create the lowest level of emissions and can be reused or recycled and waste management is excellent, handled so that the emissions during the management is small.

This is the manner in which the model of biofuels and their sustainable life cycle can be created. All the aspects of biofuels must be taken into consideration, from raw materials to the recycling or waste management and all the effects on environment, social and cultural life of people, economical aspects and effects of the biofuels must also be considered. The most important analysis of biofuels is made of two choices; cradle-to-cradle or cradle-to-grave, and from there sustainability can be best noted.

4. CONCLUSIONS

4.1. Matching theoretical framework and empirical framework

The research findings that were made in the theoretical part of this thesis support each other. In theoretical framework, in Chapter 2.1. the sustainable development is divided into four different dimensions; environmental, social, cultural and economical responsibilities dividing these pillar were a further seven pillars: pollution, prevention, poverty, population, participation, policy, market failures and management disasters.

In the empirical framework, the dimensions of sustainability of each biofuel category were analysed and these can be seen in Chapter 3.2. When the interviews were made, each of the intervewees always had something to say about pollution, prevention, poverty, population, participation, policy, market failures or about management disasters. All these dimensions of sustainability and their pillars support the theory of sustainable LCA of biofuels.

Biofuels were introduced in the theoretical part, chapter 2.2. Also their effects to the dimensions of sustainability were introduced. These biofuels were categorised the same way as in the empirical part, however, the analyses were made more accurately and each biofuel category were analysed separately, in Chapter 3.2. The findings of the empirical part support the theoretical framework of biofuels, however the analyses of biofuels in the theoretical part are not as extensive as the analyses in the empirical part as empirical is much more in depth and into detail.

LCA analysis has been thoroughly explained in the theoretical part, Chapter 2.3. This analysis can be seen in the empirical part; in the interviews all the life cycle stages have been taken into consideration and LCA framework of biofuels has been conducted. The identification of significant sustainability issues has been made, the specification of different types of biofuels has been conducted and their whole life cycle has been taken into consideration, with the help of interviews and research. These interviews and other research data was collected from companies and general resources, also evaluation conclusion and recommendations will be done. In Chapter 3.4. the model of sustainable LCA of biofuels has been conducted using the data from theoretical part and empirical part, including the LCA framework in the model and creating it according to the findings and analysis of findings.

Figure 7 which is presented in Chapter 3.4. is built upon the theoretical reference points already mentioned in and around Table 4 in Chapter 2.2. A conclusion can be drawn by comparing Table 4 to Figure 7. This conclusion shows that the theoretical reference is in no way excluding the empirical data, instead the results show that the empirical data supports existing theory.

When comparing the empirical data to the theoretical references, the conclusion is that no forms of biofuels can for now substitutes the use of fossil fuels as a dominant source of energy, although the mentioned bioenergy sources are excellent supplements as sources for energy to reduce the amount of fossil energy in use today.

As a final conclusion, when it comes to comparing the theoretical framework and information to the empirical study, a final observation is that this research can be motivated as both valid and reliable as the theoretical and empirical parts of this thesis support each other strongly.

4.2. Suggestions to further research

All research results have some limitations when it comes to data and findings that are presented. Therefore it is very important to know in which areas deeper research can and should be made. The limitations that apply to this thesis will be listed in this chapter.

The biggest shortcoming of this thesis is the fact that the biofuels and their categories are introduced as well as analysed in a much generalized way. This thesis is only scratching the surface and serves mainly as a base for choosing a direction for further studies. Another issue which could have improved this research is the limited number of interviews. In authors' defense, time and other diverse resources were not available when completing the empirical part of this research.

The conclusion made by the researcher, when using the LCA of biofuels, points towards biogases as the most effective way of creating energy,(in regards to biofuels) because the raw materials already exists (waste) as well as the Infrastructure, which makes the biogas business a smaller strain on the environment.

Globally sewage and waste can and should be used as a source for bioenergy. However this will require lot of time and local action (think global, act local). The use of bioenergy will decrease waterways; however it is important to note that biogases alone are not the solution. Other forms of bioenergy should be used to supplement the creation of energy and fuel by not destroying their natural capacities.

However, biogases are not a global solution, which could replace the use of fossil fuels. Instead local actions are important, as they lead to national progress in using bioenergy (in this case gas). This can be achieved by nations working individually to create a global solution.

The suggestion for further research is multifaceted. Each biofuel category must be researched more in depth, including all the different methods of acquiring raw material and producing that form of bioenergy, for example such as bioliquids ; rapeseed oil , sunflower oil, palm oil, fish oil, sugarcane and so forth.

These categories should be viewed not only through sustainable development dimensions but also national economical, technological and political dimensions.
It must be kept in mind, that this type of research does not have only one solution. Instead it has several and at the moment no single biofuel form can replace fossil fuels however, it should instead be viewed as a partial solution in the bioenergy puzzle.

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APPENDIX 1

QUESTIONNAIRE

The sustainable LCA of biofuels

The idea of this interview is to receive information about biofuels so that the information can be used to create a comprehensive sustainable LCA of biofuels. The motives of this interview are the different types of biofuels and their effects during life cycle in environmental, social, cultural and economical dimensions of sustainable development.

1. **Personal information**

- Name?
- Profession?
- Specification? (research/development/biogases/bioliquids/biomasses/peat/wood based biomasses)
- How long have you researched or been involved with biofuels?

2. **Biofuels : Biogases, bioliquids, biomasses, peat and wood based biomasses**

(a) ***Environmental effects of biofuels in different stages of their lifecycle***

- How does the acquirement of biofuel raw materials effect the environment?
- How does the manufacturing process of biofuels effect the environment?
- What kind of impact do biofuel emissions have on the environment

- ➔ *How harmful are biofuel emissions and wastes to the environment*
- ➔ *Are biofuels a sensible solution productionwise when considering*
- ➔ *Are the biofuel emissions significally lower when comparing to regular petrol or diesel?*

(b) The economical effects in the different phases of the biofuels lifecyckle

- What economical effects does a country experience, when raw materials are used for biofuel production?
- What kind of economical efects are there in general for a country that produces biofuel?
- How does the export of biofuels effect the exporting country
- How does importing biofuels affect the country in question?
-

- ➔ *Is it geo-politically productive to produce biofuels? (E.g. In Finland, the competition towards other countries, like Russia for instance)*
- ➔ *Does using biofuels make economic sense to the consumer?*
- ➔ *Are biofuels a economcally sensible option in the long run?*

(c) The social effects during the different phases of the lifecycle

- How does the production of biofuels affect the society as a whole and humans in person?
- How does the import of biofuels effect the society as a whole and humans in person?
- How does biofuel consumption the society as a whole and humans in person?

- How much time will pass before biofuels are taken into the use of the general public; there is a lot of research in this field and also a high level of know-how. However the question stands; how much development is needed until a general level of use is reached?
- How long will it take before people are willing to accept biofuels properly; in such a level that the biofuels can be marketed as and sold on the same level as fossile fuels are today.

(d) The cultural effects during the different phases of the life cycle.

- How does biofuel production effect cultures?
- How do exporting biofuel raw-materials effect the countrys culture?
- How does the import of biofuels affect the contrys culture?
- How does biofuel consumption affect a certain countrys culture?