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Moving Towards Sustainability with Biodiesel in Singapore

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Abstract

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Biodiesel is an alternative fuel for diesel engines that is produced by chemically reacting vegetable oil or animal fat with an alcohol. Since the carbon in the oil or fat mostly originates from carbon dioxide in the air, biodiesel is considered to contribute much less to global warming than fossil fuels and is thus often referred to as a renewable energy source.

In 2004 the company Alpha Biofuels was created and has since then worked with a sustainable fuel option by using waste vegetable oils (WVOs) to produce biodiesel. In contrast to Europe, biodiesel is not commonly used in Singapore. There exists for example no biodiesel from crude palm oil, making Alpha Biofuels biodiesel quite unique in Singapore.

When making biodiesel from waste vegetable oil the process includes not only the environmental benefits of replacing a petroleum-based fuel with a biofuel, but also the effects from the recycling process itself: Recycling can encourage greater awareness on sustainability as well as reducing the harmful effects waste vegetable oil can have if left un-recycled.

By many means, Alpha Biofuels biodiesel can contribute to a more sustainable living on more than one level and can therefore be a good inspiration for future development in Singapore. What impacts biodiesel and a company like Alpha Biofuels can have is further regulated by the context it operates in; in this case Singapore. The context shapes implementation possibilities and thus also impacts from technology.

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Populärvetenskaplig beskrivning

Biodiesel är ett alternativt bränsle för fordon med dieselmotorer och produceras genom en kemisk process där vegetabilisk olja (eller animaliskt fett) reagerar med en alkohol. Eftersom kolet i den vegetabiliska oljan tas upp från koldioxid i luften anses biodiesel vara koldioxidneutralt och därmed inte bidra lika mycket till växthuseffekten som ett fossilt bränsle gör vid förbränning.

Alpha Biofuels är ett företag i Singapore som tillverkar biodiesel från använd matlagningsolja som de samlar in från lokala restauranger och mattillverkare. I Singapore används inte biodiesel från rå palm- eller rapsolja, den typ av biodiesel vi ofta stöter på i Europa, vilket gör Alpha Biofuels biodiesel väldigt unik i sitt område.

Förutom att ersätta ett fossilt bränsle med biobränsle, ger just återvinningen av använd matlagningsolja den största positiva effekten på miljön och människors hälsa. Genom att göra biodiesel av matlagningsoljan förhindras den att antingen hamna i avloppet eller att säljas vidare för fortsatt konsumtion. Olja och fett i avlopp är orsaken till ca 90 % av stopp- och översvämningsproblem i avloppssystemen eftersom fetterna stelnar i rören och pluggar igen dem. Vidare kan den redan använda oljan säljas i fattigare länder som ”fräsch” matlagningsolja av den orsaken att den är billigare än oanvänd. Detta är farligt därför att oljan kan innehålla gifter från tidigare användning.

En annan positiv effekt från att återvinna matlagningsolja är att det inspirerar till vidare återvinning av andra material eftersom Singapore trots sin höga standard har ett underutvecklat återvinningssystem.

Alpha Biofuels kan alltså på många sätt bidra till ett mer hållbart Singapore och fungera som inspiration för fortsatt miljöarbete i landet. Dock påverkas implementeringen av biodiesel, och vilka effekter och möjligheter den ger, av det kontext detta sker i. Denna studie handlar därför även om hur lagar, landets miljöagenda och attityder i Singapore påverkar Alpha Biofuels möjligheter att inverka på landets hållbarhetsutveckling.

Acknowledgments

I would like to thank Mattias Lindahl for all his help from start to finish with this project. Without him I would never have had the opportunity to do this. I would also like to thank the many people that welcomed me at SIMTech, especially my supervisors Hui Mien Lee and Bin Song.

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1 Introduction

This Master Thesis is written for the Master of Science in Sociotechnical Systems Engineering program at Uppsala University, in collaboration with Singapore Institute of Manufacturing Technology (SIMTech).

When a word becomes so popular it can be heard everywhere, in all sorts of marginally related or even unrelated contexts, it means one of two things: Either the word has devolved into a meaningless cliché, or it has real conceptual significance. *Sustainable* or *Sustainability* is being applied to everything from agriculture to economics. This is because the concept of sustainability is at its heart so simple that it legitimately applies to all these areas and more. By all accounts, the modern sense of the word entered the lexicon in 1987 with the publication of *Our Common Future*, by the United Nations World Commission on Environment and Development (also known as the Brundtland Commission after its chair, Norwegian diplomat Gro Harlem Brundtland). The Brundtland Report defined sustainable development as: *"Development that meets the needs of the present without compromising the ability of future generations to meet their own needs"*.[1]

The Brundtland Report was primarily concerned with securing a global equity, redistributing resources towards poorer nations whilst encouraging their economic growth. It also recognised that achieving this equity and sustainable growth would require technological and social change. Three fundamental components where highlighted in order to achieve a sustainable development: environmental protection, economic growth and social equity. This implies that the environment should be conserved and our resource base enhanced, by gradually changing the ways in which we develop and use technologies. Developing nations must be allowed to meet their basic needs of employment, food, energy, water and sanitation. If this is to be done in a sustainable manner, then there is a definite need for a sustainable level of population. Economic growth should be revived and developing nations should be allowed a growth of equal quality to the developed nations.[2]

This study mainly focuses on the environment component of sustainable development. Many people often associate sustainable development with how we should solve our energy needs without depleting natural recourses or negatively affect our world. One of the solutions to a more sustainable development could be the use of *renewable energy sources*. We currently rely heavily on fossil fuels like oil and natural gas for its energy. Fossil fuels are considered to be *non-renewable*, that is, they draw on finite resources that will eventually dwindle, become too expensive or too environmentally damaging to retrieve and use. In contrast, *renewable energy* resources, such as wind, solar and biomass energy, are constantly replenished and will never run out. Since biodiesel is made from biomass like vegetable oil it is defined as a renewable energy source.[3]

[1] Scientific American.
[2] Atmosphere, Climate & Environment Information Programme.
[3] National Renewable Energy Laboratory.

1.1 An Overview of the Field

1.1.1 Biodiesel

Biodiesel is an alternative fuel for diesel engines that is produced by chemically reacting vegetable oil or animal fat with an alcohol. Since the carbon in the oil or fat mostly originates from carbon dioxide in the air, biodiesel is considered to contribute much less to global warming than fossil fuels and is thus often referred to as a renewable energy source. Diesel engines operated on biodiesel also have lower emissions of carbon monoxide, unburned hydrocarbons, particulate matter and air toxics than when operated on petroldiesel.[4]

The idea of using vegetable oil for fuel has been around as long as the diesel engine. Rudolph Diesel, the inventor of the engine that bears his name, experimented with fuels ranging from powdered coal to peanut oil. In the early 20th century, however, diesel engines were adapted to burn petroleum distillate, which was cheap and plentiful. In the late 20th century the cost of petroleum distillate rose which renewed the interest in biodiesel. Commercial production of biodiesel began in the 1990s.[5]

Blends of biodiesel and petroleum diesel are designated with the letter *B* followed by the volumetric percentage of biodiesel in the blend: B20, the blend most often evaluated, contains 20 percent biodiesel and 80 percent petroleum diesel; B100 is pure biodiesel. By several important measures biodiesel blends perform better than petroleum diesel, but its relatively high production costs and the limited availability of some of the raw materials used in its production continue to limit its commercial application.[6]

1.1.2 Singapore

Stretching over an area of only 707.1 km^2, Singapore is one of three remaining true city-states in the world and the smallest nation in Southeast Asia. It lies close to the equator at the southern most tip of the Malay Peninsula surrounded by the neighbouring countries Malaysia and Indonesia. The population of Singapore is approximately 4.59 million and although Singapore is highly cosmopolitan and diverse, ethnic Chinese form the majority of the population. English is the administrative language of the country.[7]

Singapore is located in South East Asia.[8]

[4] Van Gerpen, 2005. Biodiesel processing and production.
[5] Energy Information Administration.
[6] Energy Information Administration.
[7] CIA – The World Fact Book.
[8] Getting Around.

Prior to European settlement, the island now known as Singapore was the site of a Malay fishing village at the mouth of the Singapore River. Several hundred indigenous *Orang Laut* people also lived along the nearby coast, rivers and on smaller islands. In 1819 the British East India Company established a trading post on the island, which was used thereafter as a strategic trading post along the so called Spice Route. Singapore would become one of the most important commercial and military centres of the British Empire, and the hub of British power in Southeast Asia. The city was occupied by the Japanese during World War II but reverted to British rule immediately post war in 1945. Eighteen years later the city, having achieved independence from Britain, merged with Malaya, Sabah and Sarawak to form Malaysia. However, less than two years later it seceded from the federation and became an independent republic on the 9th of August 1965.

Since independence, Singapore's standard of living has been on the rise. Foreign direct investment and a state-led drive to industrialization have created a modern economy focused on electronics manufacturing, petrochemicals, tourism and financial services. Singapore is one of the top ten wealthiest countries in the world in terms of GDP per capita. [9]

Singaporean politics have been dominated by the People's Action Party (PAP) since the 1959 general election when Mr Lee Kuan Yew became Singapore's first prime minister. Foreign political analysts and several opposition parties have argued that Singapore is a *de facto* one-party state. Many consider the form of government in Singapore to be closer to authoritarianism rather than true democracy. Some classes Singapore as a "hybrid" country, with authoritarian and democratic elements.[10]

1.1.3 Alpha Biofuels

In 2004 the company Alpha Biofuels was created and has since then worked with a sustainable fuel option by using *waste vegetable oils* (WVOs) to produce biodiesel. In contrast to Europe, biodiesel is not commonly used in Singapore. There exists for example no biodiesel from crude palm oil, making Alpha Biofuels biodiesel quite unique in Singapore. The company is considered to be a small/medium producer of biodiesel by international standards.

Pure biodiesel and untreated waste vegetable oil. [11]

They estimate that if all the waste vegetable oil in Singapore would be transformed into biodiesel it should cover 0.1 % of the country's total fuel need.[12]

[9] Country Studies.
[10] Country Studies.
[11] Biodiesel-fuel.co.uk.

The waste vegetable oil for biodiesel production is collected from restaurants, catering- and food processing companies all over Singapore. The biodiesel is then sold to fleet customers and smaller companies that operate diesel vehicles. An important part of the relationship Alpha Biofuels has with WVO-providers and customers is to spread knowledge on how to work and operate more environmentally friendly, hopefully contributing to an increased awareness of sustainable living.[13] Alpha Biofuels believe that a carbon footprint conscious community can only be created in an environment where people know how they can contribute. The core philosophy is to change perceptions and empower individuals and communities to make a difference.[14]

1.2 Study Aim

When making biodiesel from waste vegetable oil the process includes not only the environmental benefits of replacing a petroleum-based fuel with a biofuel, but also the effects from the recycling process itself: Recycling can encourage greater awareness on sustainability as well as reducing the harmful effects waste vegetable oil can have if left un-recycled.

By many means, Alpha Biofuels biodiesel can contribute to a more sustainable living on more than one level and can therefore be a good inspiration for future development in Singapore. The company's motto is "changing perceptions" which Allan Lim, one of Alpha Biofuels founders, explains as: *"One of our goals with the company is to contribute to make Singapore more sustainable. We can not be the solution, but perhaps a part of the solution. Singapore needs a success story to inspire."*[15]

What impacts biodiesel and a company like Alpha Biofuels can have is further regulated by the context it operates in; in this case Singapore. The context shapes implementation possibilities and thus also impacts from technology. Summing it up the aim for this study will focus on which role biodiesel made from waste vegetable oil can play in moving Singapore towards sustainability. The main questions are as follows:

- What are the impacts from biodiesel, compared to other fuels, for our environment and health?
- What shapes biodiesel implementation in Singapore?
- What are the possibilities for Alpha Biofuels to contribute to a more sustainable development?

After analysing these issues I will also try to give a few suggestions on additional efforts Alpha Biofuels could carry out and on further studies related to this study.

1.3 Delimitations

The study aim is quite extensive so the limiting factor has foremost been the time constraint and furthermore limited information resources. Time spent on this study is 20 weeks, as directed for this type of exam project. Concerning resources, information on

[12] Lim, 18.08.2008.
[13] Lim, 18.08.2008.
[14] Alpha Biofuels. *Main*.
[15] Lim, 18.08.2008.

biodiesel emissions has for example been extensive, but the selection on information about biodiesel implementation related to Singapore has been very slim.

A case study can either be made on a single case or use two or more cases to compare between (as further explained in Chapter 2.1.1). This is a single case study, but would be suited for multiple-cases as well; like for example a comparison between biodiesel implementation in Singapore and Sweden. Both time limitations, and the fact that SIMTech wanted a local viewpoint on the "social aspects" of biodiesel in Singapore, made this a single case study.

1.4 Disposition

Chapter 2 introduces the reader to theory on case- and technology studies.

Chapter 3 focuses on research methodology

Chapter 4 is about the impacts from biodiesel production and usage.

Chapter 5 is an overview of the Singaporean context trying to explain areas related to sustainable development in Singapore.

Chapter 6 presents Alpha Biofuels along with their WVO-providers and customers.

Chapter 7 analyzes previous chapters through discussions and presents conclusions as well as suggestions.

2 Theory

This chapter introduces the reader to Case Study Theory which is then applied in the research structure in the following chapter. The focus will also be on Social Shaping of Technology studies which encompass a large variety of theories, viewpoints and methods when trying to explain how technology development is shaped in our society.

2.1 Case Studies

In general, case studies are the preferred strategy when *how* or *why* questions are being posed, when the investigator has little control over events, and when the focus is on a contemporary phenomenon within some real-life context. The case itself is an account of an activity, event, or problem and usually gives a detailed analysis of a limited number of events or conditions and their relationships. It is important that the case is written in a nonbiased way so the readers can have access to all the information and draw their own conclusions. A good case is generally taken from real life and includes the following components: setting, individuals involved, the events, the problems, and the conflicts.[16]

Researchers have used this research method for many years across a variety of disciplines, but in general it does not lend itself well to generalization or prediction. That means that the researcher who makes a case study is usually interested in a specific phenomenon and wishes to understand it completely, not by controlling variables but rather by observing all of the variables and their interacting relationships.[17]

Since case study research is a method that can bring us understanding of a complex issue, it is suitable in pursuing the aim of this study. Biodiesel itself is well studied as a product, but its implementation and use are hard to generalize from place to place. Therefore a case study on biodiesel in Singapore is fitting for a better understanding of these special conditions.

2.1.1 Case Study Design – Single or Multiple

A case study can either focus on one single case, or use multiple cases for comparison. The single case is the most common and is in general very justifiable when the case for example represents:

- A critical test of existing theory
- A rare or unique circumstance
- A representative or typical case
- A first time encounter
- A comparison over time

[16] Yin, 2003. Pages 1-15.
[17] Dooley, 2002.

Within the single case there may still be incorporated subunits of analyses, so that a more complex, or embedded, design is developed. The subunits can often add significant opportunities for extensive analysis, enhancing the insights of the single case.[18]

Multiple-case designs have distinct advantages and disadvantages in comparison to single-case designs. The evidence from multiple cases is often considered more compelling, and the overall study is therefore regarded as being more robust. At the same time, the "raison d'être" for single-case designs usually cannot be satisfied by multiple cases. Moreover, the conduct of a multiple-case study can require extensive resources and time beyond the means of a single student or independent research investigator.[19]

2.1.2 Case Study Steps

Case study research has well-defined steps and can employ various data collection processes such as participant observation, document analysis, surveys, questionnaires, interviews etcetera. The power of case study research is the ability to use all methodologies within the data-collection process and to compare within case and across case for research validity.

Case study research, like all other forms of research, must be concerned with issues such as methodological rigor, validity, and reliability. This is accomplished through the six steps below:[20]

- Determine and define the research questions
- Select the cases and determine data-gathering and analysis techniques
- Prepare to collect data
- Collect data in the field
- Evaluate and analyze the data
- Prepare the report

- Determine and Define the Research Questions

The first step in case study research is not that different from any other research study: to establish the focus or the intent of the project. The focus or intent is established once an intensive literature review has been completed and the problem has been well identified. This should be something that the research can refer to as grounding during the process of the study. The research object of the case is often a program, a group, or team, or may even be a person. Each object is usually associated with political, social, historical, and personal issues, making the case much more complicated than at first glance. The object is then investigated by using varying data-gathering techniques; both qualitative and quantitative in nature, all intended to supply the necessary information to address the research questions.[21]

[18] Yin, 2003. Page 45.
[19] Yin, 2003. Page 47.
[20] Dooley, 2002.
[21] Dooley, 2002.

- Select the Cases and Determine Data-Gathering and Analysis Techniques

A major strength of case study research is the ability to use multiple sources and techniques. Tools used in this type of data collection are usually surveys, interviews, document analysis, and observation, although standard quantitative measures such as questionnaires are also used. The study must be well constructed to ensure construct validity, internal validity, external validity, and reliability. To pass these tests of validity and reliability, explicit attention must be paid to the design of the research study and to the processes used in the collection of the data, the analysis of the data, and the reporting of the findings. Construct validity requires the researcher to select the correct tool or method for the concepts being studied. Internal validity demonstrates that the conditions being observed will necessarily lead to other conditions and is discovered by triangulating various pieces of evidence. A credible line of evidence that can be followed to these conclusions must be established. External validity usually determines if the findings can be generalized beyond the one or multiple cases being studied. Relating findings back to the literature also helps in external validity. Reliability refers to how well the procedures are documented to ensure that the research can be replicated.[22]

- Prepare to Collect the Data

A case study will typically begin by using only one method of data collection and will add others as the situation warrants it. The added benefit of this process is that it can enhance the validity of case study findings through triangulation. Preparation for the vast amounts of data prior to collection will save much time and frustration later. Due to the nature of case study research, it will generate large amounts of data from multiple sources. Time taken to plan prior to the research will allow one to organize multiple databases and set categories for sorting and managing the data. Finally, it is important to acknowledge the personal involvement of the researcher in case study research data collection. A question of validity will always arise if the reader considers the researcher too close to the content to be subjective.[23]

- Collect Data in the Field

Data collection is an evolving process in case study research. This means that what is learned from the data collected at one point in time often is used to determine subsequent data collection. The researcher therefore must collect and store multiple sources of data, in a systematic manner. The storing of the data is critical so as to allow for patterns and themes to emerge. The decision when to end the data-collection stage of case study research involves both practical and theoretical considerations. Time and budgetary constraints are of course important factors, but also an exhaustion of sources or when continuing data collection produces only tiny pieces of new information can close the process.[24]

[22] Dooley, 2002.
[23] Dooley, 2002.
[24] Dooley, 2002.

- Evaluate and Analyze the Data

The data is finally analyzed using an array of interpretations to find any and all relationships that may exist with reference to the research questions. The discovery of constructs in qualitative data can be a significant outcome to a case study. The case study method, with its many different data-collection and analyzing techniques, allows researchers opportunities to triangulate data to strengthen the findings. An important evaluation is to structure the data for the purpose of identifying patterns inherent in interviews, texts, events etcetera. It is important to sort data in as many ways as possible to seek unintended outcomes that may not be apparent in the beginning.[25]

- Prepare the Report

The goal of the report is to present the conclusions to the questions posed by the research in a way that the reader can understand. Two types of reports are popular for case study researchers. Reflective reporting; where the writer will use literary devices to bring the case alive for the reader and the strong presence of the researcher's voice is apparent, and analytic reporting; which notes an objective writing style (the researcher's voice is either silent or subdued). In the analytic style, the report generally has a conventional organization: introduction, review of the literature, methodology, results, and discussion.

Case studies are complex because they generally involve multiple sources of data, may include multiple cases within a study, and produce large amounts of data for analysis. Researchers from many disciplines use the case study method of research to build on theory, to produce new theory, to dispute or challenge theory, to explain a situation, to provide a basis to apply solutions to situations, to explore, or to describe an object or phenomenon.[26]

2.2 The Social Shaping of Technology

My conceptual inspiration in this case study is the notion that society and technology interact in complex ways; the very central idea covered in studies of the so called *Social Shaping of Technology*. The Social Shaping of Technology (SST) is an emerging field concerned with explaining how social processes, actions and structures relate to technology; and is concerned with the developing critique of *technological determinism*.

Technological determinism is the notion that technological development is independent and excluded from society; it shapes society, but is not equally influenced back. Rather, it exists outside society, but at the same time influences social change. In more extreme varieties of technological determinism, the technology is seen as *the* most significant determinant of the nature of a society. Studies within the Social Shaping of Technology field find technological determinism unsatisfactory because technologies do not, in practice, follow some predetermined course of development. Research and development decisions, for example, are significant determinants of the sorts of technologies which are developed. Also, although technologies clearly have impacts, the nature of these is not built into the technology but depends on a broad range of social, political and economic factors. The SST approach "serves as a needed corrective" and

[25] Dooley, 2002.
[26] Dooley, 2002.

"an antidote to naïve technological determinism". Although SST does not deny that technologies have social effects, the focus is rather on the social forces which give rise to particular technologies.[27]

2.2.1 Origin – The Critique of Technological Determinism

SST stands in contrast to post-Enlightenment traditions which did not problematise technological change, but limited the scope of enquiry to monitoring the social adjustments it saw as being required by technological progress. SST emerged through a critique of such technological determinism to show that technology does not develop according to an inner technical logic but is instead a social product, patterned by the conditions of its creation and use. Every stage in the generation and implementation of new technologies involves a set of choices between different technical options. Alongside narrowly *technical* considerations, a range of *social* factors affect which options are selected - thus influencing the content of technologies, and their social implications.

Inspired by a range of academic traditions, SST research investigates the ways in which social, institutional, economic and cultural factors have shaped: [28]

- The direction as well as the rate of innovation.
- The form of technology: the content of technological artefacts and practices.
- The outcomes of technological change for different groups in society.

It thus goes beyond traditional approaches, concerned merely to assess the "social impacts" of technology, to examine what shapes the technology which is having these "impacts", and the way in which these impacts are achieved.[29]

The critique of technological determinism is perhaps less controversial today than when the SST banner was first erected. The challenge now is to go beyond simple critique, and elaborate a model for analyzing processes of technological change.[30]

2.2.2 The Social Construction of Technology

Probably the most well known theory within the SST field is the Social Construction of Technology (SCOT) formulated by Bijker & Pinch in the 1980s. One of the reasons to why it is so influential in the SST arena might be that it is quite straight forward with a number of steps to follow for anyone who wishes to explore the development of a certain technical artefact; thus making it easy to adopt. SCOT has often been taken to be synonymous with the Social Shaping of Technology approach, something not always that popular because of the limitations many consider SCOT theory to have. But it could be said that SCOT is kind of a corner stone in SST. Therefore it is a good starting point when considering the relationship between technology and society; especially if the criticism on SCOT is considered as well because it is a way to understand the factors of technology development.[31]

[27] Mackay & Gillespie, 1992.
[28] Williams & Edge, 1996.
[29] Williams & Edge, 1996.
[30] Williams & Edge, 1996.
[31] Winner, 1993.

As originally presented by Bijker & Pinch, SCOT's conceptual framework consists of four related components. The first is *interpretive flexibility*. This idea suggests that technology design is an open process that can produce different outcomes depending on the social circumstances of development. Some sociologists of science argue that the very entities of physics, such as the particles studied in particle physics, are the products of intergroup negotiations over the interpretation of observations. SCOT scholars, in turn, apply the concept of interpretive flexibility to technological artefacts to show how artefacts are similarly the product of intergroup negotiations.

The concept of the relevant social group is a second component of the SCOT approach. Relevant social groups are the embodiments of particular interpretations: "all members of a certain social group share the same set of meanings, attached to a specific artefact". For example, groups may have different definitions of a working technology, so development continues until all groups come to a consensus that their common artefact works. Design ceases not because the artefact works in some objective sense but because the set of relevant social groups accepts that it works for them.

The third component of the SCOT framework is closure and stabilization. A multigroup design process can experience controversies when different interpretations lead to conflicting images of an artefact. Design continues until such conflicts are resolved and the artefact no longer poses a problem to any relevant social group. The multigroup process achieves closure, no further design modifications occur, and the artefact stabilizes in its final form. Somehow a final decision, or at least a cessation of further decision, occurs. Pinch & Bijker see this as occurring through closure mechanisms.[32]

Fourth, there is the wider context. This is the wider sociocultural and political milieu in which artefact development takes place. This plays a minor role in Pinch and Bijker's original conception of SCOT. The background conditions of group interactions, such as their relations to each other, the rules ordering their interactions, and factors contributing to differences in their power, remain largely invisible.[33]

2.2.2.1 Critique and Considerations

Most critique and questioning of SCOT theory has been within the so called forth component; the wider context. Many have pressed the importance of factors in the wider context that have effects on technological development, as well as how it can affect social groups and their perceptions of, and use of, an artefact. In fact, how it can shape all other components of SCOT. Other critique concerns for example a lack of viewing impacts from technology itself as well as considerations about components in SCOT like the relevant social groups.

- The Impacts from Technology Itself

The most obvious lack in SCOT writing is an almost total disregard for the social consequences of technical choice. One tries to show why these particular devices, designs and social wills prevail within the range of alternatives available at a given time. But the consequences of prevailing are seldom a focus of study. What the introduction of new

[32] Klein & Kleinman, 2002.
[33] Klein & Kleinman, 2002.

artefacts means for people's sense of self, for the texture of human communities, for qualities of everyday living, and for the broader distribution of power in society these are not matters of explicit concern.

There is also no desire to weigh arguments about right and wrong involved in particular social choices in energy, transportation, weaponry, manufacturing, agriculture, computing, and other sometimes controversial technologies.[34]

- Structures in the Wider Context

SCOT tends to disregard the possibility that there may be other factors in technological change beyond those revealed by studying the immediate needs, interests, problems, and solutions of specific groups and social actors. One of the key claims in philosophical writings is that, if one looks closely, one sees basic conditions that underlie the busy social activities of technology making. Marxists, for example, argue that a key condition is the phenomenon of social class: [35] That technological change was designed to appropriate and displace workforce skills, and thus to enhance the control of capital over the production process.[36]

Others argue that technologies are not neutral, but are fostered by groups to preserve or alter social relations; they are "politics pursued by other means". For example Langdon Winner pursued this notion in his essay "Do artifacts have politics?" with an example of bridges built in New York during the beginning of the 20th century: The bridges to Long Island was built too low for busses to enter, so it was typically only people with cars who could travel out to the nice parks on the island. That meant black people, who mostly travelled by public busses, were basically shut out. This was according to Winner a reflection of underlying racism when designing and constructing the infrastructure in New York. Similarly, the studies on gender and technology argue that technology can be designed to preserve male dominance.[37]

Besides trying to structure the wider context through the eye of ideologies there are other things that are considered to influence technological change and design like for example marketing, laws, economics and political pursuits.[38]

- Social Groups

There are some annoying questions concerning social groups that can be considered as a problem in SCOT methodology: how can one decide which the relevant groups are? What about groups that have no voice but that, nevertheless, will be affected by the results of technological change?

Furthermore, what happens in cases where social groups can not agree on the design of an artefact or technological system? The idea of interpretive flexibility seems to work especially well in cases in which all social groups agree; which probably is unusual in real life.[39]

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[34] Winner, 1993.
[35] Winner, 1993.
[36] Williams & Edge, 1996.
[37] Winner, 1993.
[38] Mackay & Gillespie, 1992.
[39] Winner, 1993.

2.2.3 Present SST Research

Present research in the SST area combines ongoing empirical case studies with more general questions about the modernization of society, the politicization of technological culture, and the management of innovation. It has become increasingly difficult (and unfruitful) to observe the boundaries between the various approaches within the broader social construction of technology. Research collaboration and conceptual combinations have emerged between, for example, the actor-network approach, SCOT and gender and technology studies. Connections are developing with studies in the social sciences more generally, including politics, economics, and law.[40]

Many have also questioned the artificial gulf between the "social" and the "technical" - and thus between the social sciences and natural science and engineering. It may well be that a "success" of SST, in the long run, will turn out to be its undoing. Perhaps it will ultimately undermine the concept of "technology" as a separate area of social activity.[41] One of the most prominent researchers in society and technology studies, Langdon Winner, has stated the following on SST-studies and technology development:[42]

"In the late 20th century, a great many people – scholars and ordinary people alike – have begun to realize that the key question is not how technology is constructed but how to come to terms with ways in which our technology-centred world might be reconstructed. Faced with a variety of social and environmental ill, there is growing recognition that what is needed is a process of redirecting our technological systems in ways inspired by democratic and ecological principles."

[40] International Encyclopedia of the Social & Behavioral Sciences, 2001. *The Social Construction of technology.*
[41] Williams & Edge, 1996.
[42] Winner, 1993.

3 Research Method

This chapter presents research structure and data collecting methods. The research format follows case study technique with the underlying thought is that technology and society interacts and shapes each other in countless ways. Data collecting methods include interviews and written sources.

3.1 A Method for This Study

Traditionally, SCOT and related theories within SST studies are used to study historical development of technology; that is, why a particular artefact looks like it does today or why a certain technology was chosen over another. That can be reflected in the methodology were there is a step called closure. In retrospect it is easier to see how closure, or stabilization of the technology, came about. Of course, if you study the emerging of a technology that is happening right now it is impossible to study the closure because it has not yet happened. For example, when petrol run automobiles were introduced they where considered to be the more clean and green alternative to horse carriages. Horses left a lot of faeces on the roads, smelled bad, etcetera, thus considered a dirtier mode of transportation. So a vehicle that did not leave any apparent trace was back in the beginning of the 1900s considered to be very clean indeed. As more and more people realized that cars were a faster and more efficient way of transportation as well as clean, a kind of closure was reached that the automobile was the best way to transport oneself. Today we know better, and petrol driven automobiles are mostly not considered "clean and green" at all. Still people in general seems to agree on that the automobile itself is still the preferred ground transportation artefact, but what kind of fuel or energy source should it be run on? Some think we should stick with petrol, but perhaps make cars more fuel efficient. Others want electricity or biofuels. Perhaps what is going on right now is a process of trying to reach a new closure. Nowadays there are a lot of alternatives to petrol, but it is hard to tell which will be the winning alternative or when we will reach a new closure. Maybe in 20-30 years we will know if it is biodiesel, ethanol, electricity, hydrogen and/or some other energy source, and why this alternative was chosen. Trying to find the process behind closure can thus not be a part of this study but it can benefit from ideas on different social groups and their interpretations, as well as the larger context.

Originally impacts from technology itself were not considered in SST studies. Later Bijker himself has expressed that:[43] *"An important, though negative, starting point for SCOT was to criticize technological determinism"*, thus giving some credit to the relevancy of studying technological impacts in the SST field as well. SCOT offers only a framework for studying different people perceptions of the technology, not the technology itself. It is more focused on their subjective view on how this technology could benefit themselves or what kind of problems they see with it.

[43] International Encyclopedia of the Social & Behavioral Sciences, 2001. *The Social Construction of technology.*

In this study there will be one part on biodiesel properties and impacts. I find this especially important for an artefact like biodiesel because its "user-design" resemble the already well known fuel petroldiesel, but it is instead what kind of positive (or negative) impacts the use itself can have that people are concerned with.

3.1.1 Structure

This will not be a study in trying to prove that biodiesel development in Singapore is socially shaped; I take for granted that it is and thus focuses on how it is shaped. Rather it is a case study on biodiesel from waste vegetable oil in Singapore. Therefore I need a structure to go about when looking for factors that shape this particular development. As mentioned earlier, there may be incorporated subunits of analyses within a single case study, so that a more complex, or embedded, design is developed. In an attempt to structure this study it will be divided into three main subunits. These subunits will hopefully add significant opportunities for extensive analysis:

Subunit 1: Biodiesel properties and impacts
Subunit 2: The Singaporean context
Subunit 3: Alpha Biofuels

As explained in Figure 1 below; biodiesel is of course the artefact in question. It is surrounded by the three "main social groups": Alpha Biofuels, WVO Providers and Customers. Alpha Biofuels can also be viewed as a part of the relationship between Customers & WVO Providers and Biodiesel. The Singaporean Context is the ever present background for "rules of play", concerning both social groups and artefact.

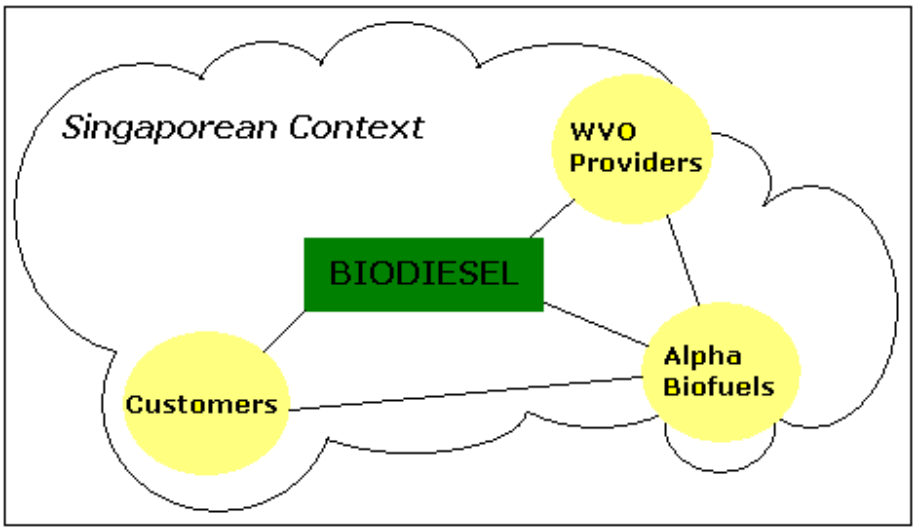

Figure 1 - Research structure.

My purpose with the first subunit, biodiesel properties and impacts, is to find important impacts from using and producing biodiesel. These impacts will foremost be those I consider to be related to Singapore and to a "social context" like for example health. That can answer the question on what impacts biodiesel from waste vegetable oil has compared to other fuels. The ambition with the second subunit, about Singapore, is to get

to know Singapore's environmental work, Singaporeans perception on their environment and regulations related to biodiesel. This will help in understanding how biodiesel implementation is shaped and how Alpha Biofuels work can affect general perceptions. In the third subunit I will look at Alpha Biofuels, their customers and WVO-providers to understand their actions and how they relate to each other.

Together these three subunits can give an understanding on how Alpha Biofuels' biodiesel can play a role in moving Singapore towards sustainability.

3.2 Data Collection

3.2.1 Interviews

All the conducted interviews have been semi-structured. This technique is used to collect qualitative data by setting up an interview that allows a respondent the time and opportunity to talk about their opinions on a particular subject. It uses open-ended questions, some suggested by the researcher and some arise naturally during the interview. The researcher tries to build a report with the respondent and the interview is like a conversation. Questions are asked when the interviewer feels it is appropriate to ask them. They may be prepared questions or questions that occur to the researcher during the interview. The wording of questions will not necessarily be the same for all respondents.

Semi-structured interviews are helpful when complex questions and issues needs discussion or clarification since the interviewer can probe areas suggested by the respondent's answers and pick up information that had either not occurred to the interviewer or of which the interviewer had no prior knowledge. On the other hand these types of interviews might not be very reliable because they are non-standardized; it is difficult to repeat questions and answers exactly. In addition, the researcher has no real way of knowing if the respondent is lying. The respondent may not consciously lie but may have imperfect recall or answer in a way that puts his or hers own interests first.[44]

3.2.1.1 Conducted Interviews

Interviews have foremost been conducted with people in charge at Alpha Biofuels like for example the Chief Executive Director or the Chief Operations Officer. Since the company is quite small, the four people representing Alpha Biofuels in this study is a big part of the company's total staff. Because written information about Alpha Biofuels is limited to a brief overview at their web site, the interviews have been a very valuable source of information.

One interview, with a researcher in the biodiesel field at the National University of Singapore has been conducted as well, giving a good understanding of the Singaporean context.

[44] Sociology Central.

3.2.2 Written Sources

I have scanned and read a lot of written information. Much of this information comes from scientific papers, internet pages and also some newspaper articles. Properties of biodiesel are plentiful represented in scientific papers; a trustworthy source of information.

3.2.3 My Role

Since this study is carried out in a culture I am not familiar with, it is important to keep this in mind during interviews and interpretation of information because it might lead me to draw wrongful conclusions. The variation in pronunciation, the way a delicate issue is phrased or motives behind texts and answers differs from culture to culture. What is important to acknowledge is the difficulty with objectiveness when interacting with people in, and from, a different culture. Because of this, semi-structured interviews are for example the preferred interview method since it gives the respondent a chance to elaborate freely on topics that are important to him or her.

It is also important to acknowledge the researcher role in how a case study is shaped and what it results in. The sociologist Irene Molina says that: "*A story is built in to and at the same time a result of power, ideology and socio-economic conflicts in the society. And surely, it matters who gathers the research material, not least because the way questions gets chosen and formulated depends on the researcher's position and starting point.*"[45]

As a researcher, I am also a part of this report and therefore define which voices and opinions that will be heard and perhaps more importantly, which that will be omitted.

[45] Translated from: Molina, 1997. Page 17.
"En berättelse är inbyggd i, samtidigt som den är ett resultat av maktförhållanden, ideologi och socioekonomiska konflikter i samhället. Och visst spelar det roll vem som samlar in forskningsmaterial, inte mist därför att sättet på vilket frågor väljs ut och formuleras beror på forskarens position eller utgångspunkt."

4 Biodiesel

This part of the study mainly goes through some biodiesel impacts, especially social impacts, and gives a comparison between biodiesel- and petroldiesel properties. It also explains differences between various feedstocks for biodiesel production and why making biodiesel from waste vegetable oil is such a good alternative to biodiesel made from crude palm oil. In the end there is also a section on consequences from non-proper disposal of waste vegetable oil.

4.1 The Diesel Engine

A diesel engine is per definition an internal combustion engine which operates using the Diesel cycle (named after Dr. Rudolph Diesel). The defining feature of the Diesel engine is the use self-ignition by compression to burn the injected fuel. This is in contrast to a gasoline engine (which utilizes the Otto cycle) in which ignition is initiated by a spark plug.[46]

Diesel's motivation to develop the diesel engine was not only to improve efficiency but also to bring the benefits of powered machinery to smaller companies. The steam engines used back then were so big that only the largest firms could afford them and Diesel wished to enable smaller firms to compete against the larger, steam-powered firms. He used peanut oil as the fuel for his demonstration engines at the 1900 World's Fair and thought that oils from locally grown crops would be used to power his engines.

The early 20th century saw the introduction of gasoline-powered automobiles. Oil companies refined so much crude oil to supply gasoline that they were left with a great surplus of distillate, which turned out to be an excellent fuel for diesel engines and much less expensive than vegetable oils. Though on the other hand, resource depletion has always been a concern with regard to petroleum, and farmers have always sought new markets for their products. Consequently, work has continued on the use of vegetable oils as fuel. Early durability tests indicated that engines would fail prematurely when operating on fuel blends containing vegetable oil. Engines burning vegetable oil that had been transesterified with alcohols, however, exhibited no such problems and even performed better by some measures than engines using petroleum diesel. The formulation of what is now called biodiesel came out of those early experiments. With the energy supply concerns of the 1970s the interest was renewed in biodiesel, but commercial production did not begin until the late 1990s.[47]

4.2 Biodiesel in the Making

The most important ingredient in a biodiesel recipe is lipids. In general, all greases and oil are classified as lipids. Chemically, greases and oils are classified as triglycerides. However, oils are considered to be liquids at room temperature, while greases and fats are solid at room temperature. Biodiesel is usually produced from food-grade vegetable oils

[46] About.com. Alternative Fuels. *Diesel Vehicle Basics.*
[47] United States Environmental Protection Agency.

but waste vegetable oils, restaurant grease and animal fat are also potential feedstocks for biodiesel.[48]

Biodiesel is produced in a process called transesterification which refers to a catalyzed chemical reaction involving vegetable oil and an alcohol to yield biodiesel and glycerol, as can be seen in Figure 2. When using WVO, like Alpha Biofuels, the oil usually needs to go through a pretreatment to remove occasional food or water spills as well as other contaminants before it is transesterified. By heating up the oil and filter it, the WVO gets ready for the transesterfication.[49]

A Biodiesel processor.[50]

The transesterfication process involves stripping the glycerol from the fatty acids with an acid-catalyst or an alkali-catalyst and then replacing it with an alcohol, which typically is methanol. An excess of methanol is used to shift the reaction to the right side in order to achieve a higher yield of biodiesel, or methyl esters as it is chemically known as.[51] Glycerol is considered to be a by-product but also has its own value as it can be sold to the cosmetics industries which in their turn use it in soaps and creams.

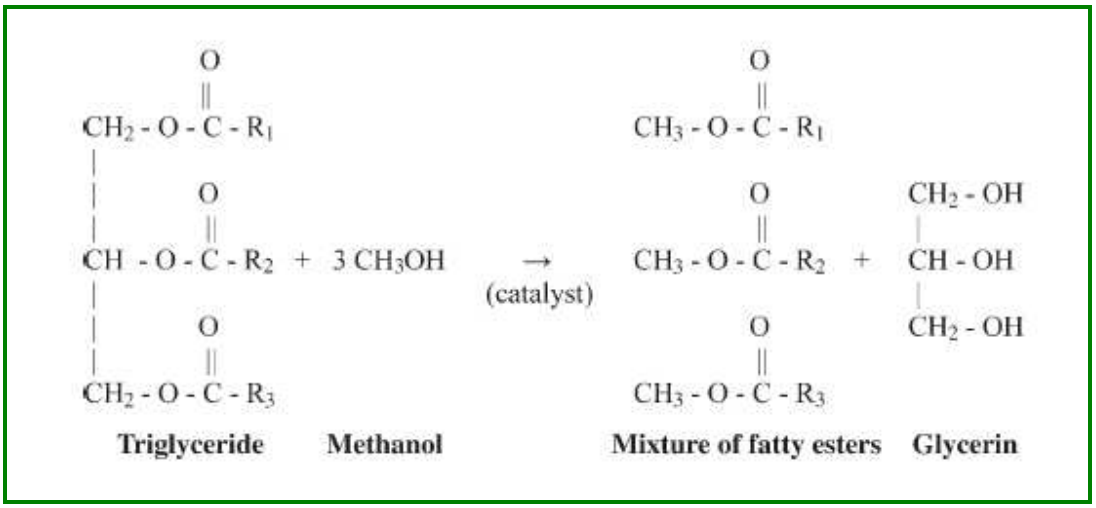

Figure 2 - Transesterfication reaction of triglyceride and methanol to fatty acid methyl esters (biodiesel) and glycerol. Source: van Gerpen, 2005.

[48] Canakci, 2005.
[49] Andrew Xiao Junzhao, 18.07.2008.
[50] Biodiesel-fuel.co.uk
[51] Kasteren & Nisworo, 2006.

Most biodiesel industries use the alkali catalyzed process, with catalyzes such as sodium or potassium hydroxide, because it is the most economical beneficial.[52] Alpha Biofuels use potassium hydroxide to catalyze the reaction between methanol and oil. The amount of catalyst depends on how much free fatty acids (FFAs) there are in the WVO.[53] One limitation though, with the alkali transesterfication, is its sensitivity to both water and FFAs.[54] Special processes are required if the oil or fat contains significant amounts of free fatty acids. Used cooking oils typically contain 2–7% FFAs, and animal fats contain from 5% to 30% FFAs. When an alkali catalyst is added to these feedstocks, the free fatty acids react with the catalyst to form soap and water, as shown in Figure 2:

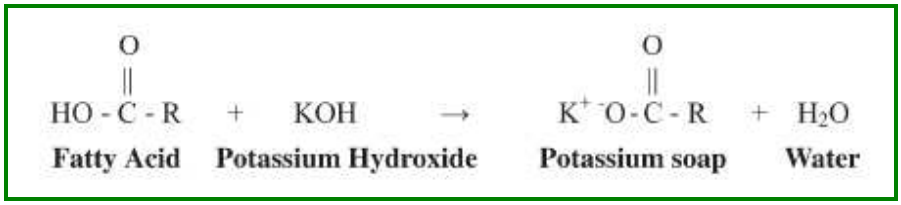

Figure 3 - Soap and water formation during the catalyst process.[55]

With up to about 5% FFAs, the reaction can still be catalyzed with an alkali catalyst, but additional catalyst must be added to compensate for the catalyst lost to soap. Most of the soap that is created during the reaction will be removed at the same time as the glycerol. Remaining soap leftovers has to be washed out later from the final product.

When the FFA level is above 5%, the soap inhibits separation of the methyl esters and glycerol and contributes to emulsion formation during the water wash. In these cases, an acid catalyst, such as sulphuric acid, can be used to esterify the free fatty acids to methyl esters. This process can be used as a pre-treatment to convert the FFAs in high FFA feedstocks to methyl esters and thereby reduce the FFA level. Then the low FFA pre-treated oil can be transesterified, as usual, with an alkali catalyst to convert the triglycerides to methyl esters.[56]

After going through the reaction phase the almost ready to use biodiesel needs a thorough cleanse to remove soap, sulphate and glycerine leftovers. This can either be done by washing the biodiesel with water or using a so called dry wash.

The water wash method needs plenty of water to ensure pure biodiesel, a downside especially in a water scarce place like Singapore. The dry wash method on the other hand is faster and as the name implies; does not need any water. Instead the biodiesel is filtered through cleansing pellets or raisins. There are many different types of dry washers such as ion-exchangers, cellulose based pellets or, like the one Alpha Biofuels use, made from magnesium silicate.[57]

[52] Refaat *et al.*, 2008.
[53] Junzhao, 18.07.2008.
[54] Kastern & Nisvaro, 2006.
[55] Van Gerpen, 2005.
[56] Van Gerpen, 2005.
[57] How to make biodiesel.

4.3 Biodiesel Properties and Emissions

Petroldiesel combustion by-products are a major source of urban air pollution; especially when used in older vehicles. Diesel engines produce significant amounts of nitrogen oxide (NOx), gaseous hydrocarbon emissions (HC) and particulate matter (PM) emissions. However, carbon monoxide emissions are much lower than those from gasoline engines. [58]

A significant expression of diesel combustion fuel quality (among a number of other measurements that determine overall diesel fuel quality) is its cetane number. Cetane numbers are actually a measurement of a fuel's ignition delay; the time period between the start of injection and start of combustion (ignition) of the fuel. Diesel fuels with higher cetane numbers are more environmentally friendly and effective than the fuels with lower cetane numbers.[59]

Compared to petroldiesel, predicting the exact emissions from biodiesel is hard because it is produced from so many different types of feedstock (like WVO, rapeseed oil, soybean oil, grease etcetera). Because lipids are constructed different from one another the resulting emissions vary as well. Especially biodiesel emissions from WVO can be hard to predict because the mixture of lipids depend on types of oils, and in which proportions, that have been used during cooking. In Asia palm oil is by far the most commonly used oil, which means the WVO Alpha Biofuels use for their production of biodiesel mostly originates from palm oil. But then of course the cooking process alters the lipids as well, creating more free fatty acids for example.[60]

Below in Table 1, biodiesel emissions are compared to petroldiesel emissions. It is composed by the United States Environmental Protection Agency and shows the average comparing results from using different types of biodiesel and petroldiesel, in different types of engines. It gives a good picture of the emission benefits given by biodiesel use.[61]

Total amount of Unburned Hydrocarbons, HC	**- 67 %**
Carbon Monoxide, CO	**- 48 %**
Particulate Matter, PM	**- 47 %**
Nitrogen Oxides, NOx	**+ 10 %**
Sulphates, SO	**- 100 %**
Polycyclic Aromatic Hydrocarbons, PAHs	**- 80 %**

Table 1 - Comparison between petroldiesel and pure biodiesel. [62]

[58] Biodiesel Magazine.
[59] About.com. Alternative Fuels. *Cetane Number*.
[60] Woon, 18.08.2008.
[61] United States Environmental Protection Agency.
[62] United States Environmental Protection Agency.

The compiled numbers in Table 1 are mostly based on biodiesel made from soybean oil and rapeseed oil which are the most commonly used oils in U.S. and Europe.[63] That means it probably differences slightly compared with emissions from the biodiesel Alpha Biofuels makes from waste vegetable oil, which is more of a palm oil type. Especially nitrogen oxygen emissions can differ a lot depending on which feedstock is used because they are in relation to the fuels cetane number; and cetane numbers stretch over a wide span from one type to the other.[64]

The most serious emission from diesel engines is particulate matter which consists primarily of soot. These particles are a health concern because they easily reach the deepest parts of the lungs, causing a series of significant health problems. The World Health Organization estimates that in Asia more than 1.5 million people die every year from diseases related to air pollution in areas that are densely trafficked. About half a million deaths each year can be attributed to particulate matter and sulphates in outdoor air. Bringing particulate matter down to safe levels could save between 300,000 and 700,000 lives annually.[65]

Studies show that oxygen atoms present on the biodiesel molecule prevent the carbon atoms that are attached to the oxygen to participate in the formation of soot. Thus resulting in a reduction of soot emissions.[66] Another benefit is that biodiesel does not contain sulphur so no sulphur dioxide can form during burning. Therefore sulphur emissions are essentially eliminated with pure biodiesel.[67]

Other compounds that are harmful to human health and are greatly reduced in biodiesel emissions are polycyclic aromatic hydrocarbons (PAH). These types of compounds are carcinogenic and when measured by scientists for Singapore the levels where distressingly high, carrying a risk of lung cancer for 1 in 10 000. [68]

4.3.1 Palm Oil Biodiesel Properties

Palm oil biodiesel is also known as palm oil methyl ester (PME) and differs from other types of biodiesel in its grade of molecule unsaturation. PME is more saturated, which means it has a lower number of double carbon bonds in its molecules. For diesel engine applications, the degree of biodiesel molecule unsaturation has both positive and negative effects. Saturated fuels such as PME have high-ignition quality. However, they also harden at higher temperatures, making them difficult to use in cold weather.[69]

PME has a short ignition delay, which is represented by its high cetane number. Thus, when compared with fuels that has a lower cetane number, less fuel ignites during pre-mixed combustion. This leads to a lower peak of in-cylinder pressure and temperature. NOx is reduced since it's strongly dependent on the flame temperature. HC emissions

[63] United States Environmental Protection Agency.
[64] Biodiesel Magazine.
[65] China Daily.
[66] Biodiesel Magazine.
[67] National Biodiesel Board. *Biodiesel Emissions*.
[68] Kalaiarasan *et al.*, 2008.
[69] Biodiesel Magazine.

also tend to be reduced when high cetane fuels are combusted.[70] Both NOx and HC are contributing to the localized formation of smog and ground level ozone.[71]

PME oxidation stability has better performance than soy methyl esters and rapeseed methyl esters. Both are because PME has fewer unsaturated molecules susceptible to oxidation through its double carbon bonds. Oxidative stability is important to engine performance because oxidation by-products can cause harmful effects such as filter plugging, deposits and corrosion. On the other hand, saturated molecules harden at higher temperatures. As the biodiesel cools down, solid crystals form which eventually cause fuel filter plugging. The temperature at which this occurs is known as the cold filter plug point (CFPP). This property is the major difficulty facing the use of pure PME (B100) in cold weather conditions, since CFPP of PME is 12 degrees Celsius.[72]

4.4 Problems with the First Generation of Biofuels

The demand for biofuels such as ethanol and biodiesel has increased enormously during the last 10 years. They were rushed onto the market in response to escalating concerns about climate change in Europe, quickly followed by The United States of America where worries grew about energy security. But almost before these biofuels has been properly established they have run into major problems regarding how sustainable they actually are.[73]

4.4.1 The Carbon Debt Problem

As a result from the production of biofuels from food crops such as corn, sugarcane, soybeans, and palms, land in undisturbed ecosystems, especially in the Americas and Southeast Asia, is being converted to biofuel production as well as to crop production when existing agricultural land is diverted to biofuel production.

Soils and plant biomass are the two largest biologically active stores of terrestrial carbon, together containing about 2.7 times more carbon than the atmosphere. Converting native habitats to cropland releases CO_2 as a result of burning or microbial decomposition of organic carbon stored in plant biomass and soils. After a rapid release from fire used to clear the land and prepare it for biofuel crop cultivation there is also a prolonged period of green house gas (GHG) release as roots, branches etcetera decay more slowly. Fargione *et al*. calls this amount of CO_2 released during the first 50 years of this process the "carbon debt" of land conversion. Over time, biofuels from converted land can repay this carbon debt if their production and combustion have net GHG emissions that are less than the life-cycle emissions of the fossil fuels they displace. Until the carbon debt is repaid, biofuels from converted lands have greater GHG impacts than those of the fossil fuels they displace.

Fargione *et al*. has calculated the carbon debt for different types of land areas over the world. Palmoil, which is most often used in biodiesel production, and usually originates from Malaysia or Indonesia gives staggering high carbon debts. Converting lowland tropical rainforest in Indonesia and Malaysia to palm biodiesel would result in a biofuel

[70] Biodiesel Magazine.
[71] National Biodiesel Board. *Biodiesel Emissions.*
[72] Biodiesel Magazine.
[73] Pearce, 2008.

carbon debt of ca 610 Mg of CO_2 per hectare that would take about 86 years to repay. Until then, producing and using palm biodiesel from this land would cause greater GHG release than refining and using an energy-equivalent amount of petroleum diesel. Converting tropical peatland rainforest in Malaysia or Indonesia to palm production incurs a similar biofuel carbon debt from vegetation, but the required drainage of peatland causes an additional sustained emission of ca 55 Mg of CO_2 per hectare and year from oxidative peat decomposition. All and all, turning peatland into palm oil production results in a carbon debt so high it could talk more than 840 years to repay.[74]

4.4.2 The Food vs. Fuel Debate

For decades before 2000, declining food prices have allowed millions of people worldwide to escape from poverty. However, since the turn of this millennium, prices of basic food commodities, such as wheat and rice, have climbed steadily. In 2007 and 2008, price increases of staple foods reached alarming proportions which has triggered concerns of a global food crisis that has been widely reported in the media. During this period, export prices of wheat increased by 130%, rice by 98%, and corn by 38%. Among the most gravely affected are the poor who spend 50-60% of their income on food.

The underlying causes of rising food prices are many and complex. They include factors such as adverse weather conditions that affect crop productivity, speculative or precautionary demand for food commodities and inappropriate policy responses such as export bans. More important are structural factors that include rising energy costs, stagnation in crop productivity, policy inadequacies or failures that constrain agricultural development, climate change, rising demand for higher value and grain-intensive foods (for example meat), and diversion of crops or croplands to biofuel production. Among these factors, biofuels have indeed carried a lot of the blame due largely to the media's sensationalisation of the "food vs. fuel" debate. A popular allegory to illustrate the impacts of biofuels on food equates the grain required to fill the tank of a sports car to grain that could otherwise feed a person for an entire year Although biofuels may have received a disproportionate amount of the blame for increased food prices, it clearly does deserve some of the blame. For example, the use of corn to produce bioethanol in the US has increased from 6% of total corn production to 23% over the last three years and this has undoubtedly contributed to tightening food supplies and rising food prices.[75]

4.4.3 The Threat on Tropical Forests and Biodiversity

Apart from contributing to GHG emissions and affecting food prices, biofuel-driven agricultural expansions can also lead to severe bio-diversity lost. Biodiesel from oil palms are most intensively cultivated in countries with very high biodiversity, such as Malaysia and Indonesia. Any future intensification of oil palm production, without proper mitigation guidelines, will likely further threaten the high concentrations of globally endemic species in these areas.

Even though environmentalists often promote biofuels as environmentally friendly they have become increasingly concerned about the impacts of rapidly expanding

[74] Fargione *et al.*, 2008.
[75] Koh & Ghazoul, 2008.

feedstock agriculture in the tropics. For example, several non-governmental organizations have accused oil palm growers in Southeast Asia of destroying large tracts of tropical forests and threatening the survival of many native species, including the orang-utan. Palm oil producers argue that oil palm cultivation is not a threat to biodiversity because only already disturbed forest or pre-existing croplands have been converted to oil palm. But it is estimated that between 1990 and 2005, 55-59% of oil palm expansion in Malaysia, and at least 56% of that in Indonesia occurred at the expense of forests. Because palm oil is widely used both as food and fuel; two rapidly growing sectors due to population growth and increased bio-fuel demand, the spread of oil palm agriculture is a particularly worrisome threat to tropical biodiversity.

4.5 Second Generation of Biofuels

Even though biodiesel made from waste vegetable oil and animal fats has been in use for quite some time it is considered to be a part of the so called second generation of biofuels. The first (and current) generation of biofuels refers to biodiesel and ethanol made from food crops such as sugarcanes, palm oil, soybean oil etcetera, while the second generation is made from waste or other materials that are not consumed as food by humans. Thus the second generation can be considered to be a truly sustainable alternative to petroleum based fuels.

The hope is that in the future production costs will be lower than those today for biofuels like ethanol from cellulose, or biodiesel from algae, so that it can be commercially interesting and produced in a large scale.[76] In Singapore, research is for example conducted on oil from algae. Algae can produce oil up to half its own weight and be cultivated in sea ponds, thus not taking up any valuable land space or competing with cultivation suitable as human food.[77]

4.5.1 Putting WVO to Good Use

As a part of this second generation of biofuels, Alpha Biofuels makes biodiesel out of recycled materials. Using WVO to make biodiesel is not only good for lowering emissions; there are other advantages as well from reusing WVO in this way, both for the environment and human health.

4.5.1.1 Second Hand Food

With such a strategic position in South East Asia, Singapore has become somewhat of a hub for biodiesel production from crude palm oil. The Palm oil is shipped in from Malaysia and Indonesia and then converted to biodiesel in newly built plants. None of it stays in Singapore though; it is all shipped to and sold in Europe.

The high demand on palm oil has lead to increased prices in the region and as a consequence the interest in selling and reusing WVO for cooking has increased as well. The already used frying oil can be very dangerous to consume again and can be toxic and carcinogenic. There are no quality controls on the used oil which means that if it was

[76] Pearce, 2008.
[77] Obbard, 26.08.2008.

mixed with any toxins by previous users it will be transferred to the new user.[78] Vegetable oil also accumulate toxins naturally when they are heated or reheated, especially at high temperatures and when used during a long time, which often is the case of frying oil. Vegetable-based monounsaturated and polyunsaturated fats are inherently unstable, so when heated a fatty acid-derived toxin called 4-hydroxy-trans-2-nonenal, or HNE, forms.[79] The toxicity arises because HNE is highly reactive with proteins, DNA, RNA or other biomolecules. Reports have related this with several diseases including stroke, Parkinson's, Alzheimer's, heart and liver diseases. Other toxins accumulated in used cooking oil are lipid hydro peroxides which also form during the heating process and can cause diseases and damage to our body systems such as cancer.[80]

Millions of tons of waste cooking oils from fastfood restaurants around the world are exported to Third World countries for further refinement into "fresh" vegetable oil for human consumption. This exploits people of unnecessary harm from whatever previous use they are not aware of. Singaporeans might also be concerned about their own health from consuming WVO since some of the waste cooking oil in Singapore is exported to neighboring countries such as Malaysia to be mixed as poultry feeds. Eventually, these poultry are imported back to Singapore as food. Hence human beings, and especially Singaporeans, are the ultimate recyclers.[81]

4.5.1.2 Oil Blocks in Sewage Systems

One of the main causes of sewer spills are overflows from the sanitary sewer system due to clogs in the sewer piping system from cooking oil and grease. These substances enter the sewage system most commonly through users pouring used oil down a drain or during the cleaning operations at food service facilities.[82]

When poured down the drain, cooking oil and grease do not disappear; they gel as they cool and build up in the sewer lines. This process starts by grease sticking to the top and sides of the pipe and growing inwards. Over time, this reduces the diameter of the pipe and constricts the sewage flow through the pipes, eventually leading to a complete clogging of the lines which causes sanitary sewer overflows. When pipes and manholes overflow during heavy rainstorms, storm water can force untreated sewage water out of the collection system. This raw sewage can reach homes and other facilities, rivers and lakes, and can cause potential health problems. As many as 90 % of the sanitary sewer overflows in certain locations have been attributed to blockages caused by fat, oil and grease.[83]

[78] Woon, 18.08.2008.
[79] Health At Oz.
[80] The Weston A. Price Foundation.
[81] Biofuel Research.
[82] Daphne Utilities.
[83] Pasco County Florida.

5 The Singaporean context

This chapter includes aspects that are considered to be of relevance for biodiesel implementation and sustainability in Singapore. The emphasis is on mindsets and environmental work as well as some of the rules and regulations that are of interest in this case. The section on air quality is related to the previous chapter on biodiesel emissions. Further, the part on taxation of vehicles is needed to understand customer patterns explained in the following chapter.

Despite being a city state, Singapore has through hard work achieved one of the cleanest and greenest environments in Asia. Not surprisingly, most of the natural habitats have been lost in order to make room for the growing population and industry, but there is plenty of aesthetic greenness in the Singaporean urban environment. The severe pollution, constant flooding and associated unhealthy conditions of the past are now no longer a problem in Singapore's modern and highly urbanized society. To make Singapore more ecologically green is a challenging task and one that has not been truly achieved in any Asian city to date. However, Singapore is frequently upheld as a role model by other Asian cities in terms of a conducive and habitable living environment for its citizens.[84]

View of Singapore greenery.[85]

While a well-landscaped and clean urban environment has been achieved in Singapore, the evidence is that even though the environment is obviously considered, it often has to be regarded as a secondary factor in favour of economic, social and technical issues. In the past, the driving force in Singapore has been economic growth, even if that meant that the natural environment would have to be removed or degraded in the process. This was considered necessary to achieve a modern society with a good living standard in what is one of the most densely populated and resource-deficient countries in the world.

In more recent years, there has been a change in attitude towards environmental protection that has arisen from Singapore's regional and international responsibilities,

[84] Briffett *et al.*, 2002.
[85] Urban Photo.

from public awareness and pressure from an improved perceived need to meet the future sustainability agenda.[86]

5.1 General Mindsets and Culture

The Singapore government prefers using law and regulations to enforce policies, adopting a top-down approach in their overall governing. The use of regulatory instruments to enforce Singapore's environmental policies has been administered smoothly over the years. Due to the small size of Singapore and the centralized functioning of ministries and their departments, the Singapore Government is effective in ensuring that policies are effectively implemented within the country. A culture for conformance and compliance pervades much of Singapore's civil service and society. The small size of Singapore and the one-level government may also make it easier to administer, co-ordinate, and manage environmental policies. [87]

Control through fines.[88]

The temperament of Singaporeans is another reason why Singapore government can constantly use regulatory instruments to implement its policies. Singaporeans are generally law-abiding citizens, who are co-operative and supportive of the government. The public generally respects and believes in the country's laws and statutes, which help to reduce the problem of non-compliance.[89]

The Singaporean mentality is to leave initiatives to the government. Singaporeans do not initiate things on their own, but trust in new legislatives and governmental incentives to get what is necessary done. Tan Hai Woon, the Chief Technical Officer at Alpha Biofuels, explains the Singaporean mentality as: *"I take care of my family. Let the government take care of the country."* This might be one of the reasons to why the environmental debate has just started in Singapore compared to other well developed countries. Also, because it is such a young country, the struggle just to survive is close in time and has previously not left much room for thoughts on the environment. In general, Singaporeans seem to always strive for efficiency and economical growth.[90]

There have been a few campaigns in an attempt to make citizens more aware and resource efficient, but they have not been successful and sometimes been met with bad response. For example the Singapore government wishes people to be more energy efficient and recently launched a campaign about air-conditioner use. The hope was that air-cons would be set on no lower than 25 degrees Celsius to save up on energy. But people were not persuaded by the campaign: even though the PR has been immense the

[86] Briffett *et al.*, 2002.
[87] Briffett *et al.*, 2002.
[88] Delirium.
[89] Ho, 2002.
[90] Woon. 18.08.2008.

preferred temperature in offices, shopping malls and homes has stayed around 20 degrees.[91]

Another project that has backfired is the *Bring Your Own Bag Day* drive where grocery shoppers were supposed to bring their own bags to the grocery store (and the stores were not supposed to sell plastic bags on those days as well). The result was that people stopped buying groceries on those days because they could not be bothered to bring their own bags; they just waited with the shopping until the next day.[92]

"Bring Your Own Bag Day" advertisement.[93]

The Singaporean education system has realized the need to include environmental education to the curriculum, or as expressed by The Ministry of Education: *"When our young know and appreciate the features, constraints, values and aspirations of Singapore, they can play an active part in the community and the nation, to mould the kind of society that Singapore desires and needs to sustain her stability and growth"*.

It is expected that the results from this environmental education will show more and more as new generations grow older.[94] Dr. Jeffrey Obbard works as a professor in environmental science at The National University of Singapore and can confirm the changed attitudes in younger generations compared to the older ones. He believes that the younger generations are much more aware of environmental problems and are really enthusiastic about environmental issues. The level of sustainable thinking in general though, is not as high as it could be: what works in other countries might not work in Singapore. For example, Dr. Obbard believe that it is not possible to base environmental thinking by only promoting the importance of sustainable living to save our planet or other more "soft" values. Singaporeans need an economic incitement as well.

So what could make Singaporeans live more sustainable? According to Dr. Obbard there are a few tipping points:[95]

[91] Obbard, 26.08.2008.
[92] Lim, 18.08.2008.
[93] National Environment Agency.
[94] Ho, 2002.
[95] Obbard, 26.08.2008.

- One of the "wakeup calls" has been the threat of a sea level rise caused by global warming; Singapore is one of the countries that would be severely hit by such an event.
- Singapore is a country living way beyond its own natural resources. Because of the great need of imported goods, prices on energy and food are important. A great fuel chock or food chock would get the wheels spinning.
- Other countries in the South East Asian region look up to Singapore thus making it a leading country in many ways. If for example Malaysia or Indonesia would turn to Singapore for help regarding the environment, it would spur Singapore's own development as well.
- Economic incitement: Just doing things because it is good for the environment will not work in Singapore. Possible economic gain from green businesses and green technologies will spur the development.
- The supply chain effect: If Europe asks for green technology and business, Singapore needs to follow that demand. Singapore has a great market in Europe for its products and would loose customers if they could not live up to such demands.

5.2 National and International Frameworks for the Environment

The Ministry of Environment and Water Resources is the main body in charge of formulating environmental policies in Singapore. Additionally, due to Singapore's land scarcity problem, strict planning and building controls are also used to prevent Singapore from land-use, environmental, and transportations problems.

The land scarcity problem and a lack of natural resource are just some of the issues that highlight the fragility of its existence. One could say the survival of Singapore depends on being sustainable, or as the Ministry of Environment puts it: *"Singapore needs to strike the right balance with Nature, giving it care and respect to ensure that it does not give up on us"*.[96]

5.2.1 Singapore Green Plan 2012

The Singapore Green Plan is the government's blueprint for environmental sustainability in Singapore with the ambitious goal of achieving sustainability in ten years. The first Green Plan was launched in 1992, but it was in 2001 the plan was being formed into what it looks like today. At that time the government invited participation from stakeholders from all sectors of society to give their opinions and in 2002 Singapore launched The Green Plan 2012.

The Green Plan is carried out by six Action Program Committees (APCs), each overseeing a functional area: Clean Air, Clean Water, Waste Management, Conserving Nature, Public Health and International Environmental Relations. Within these six functional areas are 155 action programs. The APCs are composed of representatives from government, industry, and the public sector. Regular monitoring and assessment is performed to keep the efforts on track. While Singapore is a very small country, it has

[96] Ho, 2002.

taken on green planning with a dedication that makes it a good model for other small nations as well as for large cities and metropolitan areas.[97]

The Green Plan has been met with praise by many, but also with some critique. Some of this critique has come from The Natures Society's Conservation Committee; an organization in Singapore that works towards nature conservation and environmental awareness as well as reviewing government work related to these topics. Some of their comments regard the claims that are made in the report and what they are based on, like for example: *"What has been dubbed as a "balance", ("a thriving world-class city with a quality living environment"), may supposedly be achieved but our Ecological Footprint may very well cover half the globe. This will be far from a holistic result in terms of global sustainable development. Yet "doing our part for the global environment because environmental degradation knows no boundary" is regarded by the Draft Plan as one of the "three key thrusts in the formulation of SGP 2012"."*

The Nature Society is also sceptical about the claim made in the Green Plan that: *"Singapore can be justifiably proud that it has successfully achieved economic and social growth without compromising the environment".* Their comment is: "*By what measure is this balance supposedly achieved?"*[98]

5.2.2 Kyoto Protocol

In 2006 Singapore acceded to the Kyoto Protocol. Even though Singapore is one of the richest countries in the world it is, perhaps somewhat strangely, classified as a developing country according to the Kyoto protocol. That means it does not have any legally binding agreement on reducing greenhouse gases compared to a "developed country" that has also acceded the Kyoto Protocol. Instead Singapore is trying to lower its *carbon dioxide intensity* (which is calculated using CO^2 per GDP) which they also have succeeded with. But in relative terms the CO^2 emissions have increased; actually more than doubled in the last 20 years.

When Singapore mitigates greenhouse gases they can, in accordance with the Kyoto Protocol, earn carbon credits to sell forward. Something they have benefited from because of a switch from oil to natural gas as the main energy source. Critics claim Singapore only signed the Kyoto protocol to make money from selling carbon credits.[99]

5.3 Recycling

One of the functional areas of the Green Plan is waste management and recycling. As for most parts of the world the amount of solid waste generated in Singapore steadily increases over the years, but the overall recycling rate has increased as well, from 51% in 2006 to 54% in 2007. As showed in Table 2, high recycling rates have been achieved for waste streams such as construction and demolition waste, used slag, and ferrous metals. That is, such waste often generated in industry and building construction. A number of

[97] Resource Renewal Institute.
[98] Conservation Singapore.
[99] Obbard, 26.08.2008.

waste streams like food waste, plastics, wood and glass (typically "household waste") still have low recycling rates and offer potential for further increase.[100]

Waste Stream	Amount of waste generated (million tons/year)	Amount of waste recycled (million tons/year)	Recycling rate (%)
Used Slag	0.53	0.52	99
Construction Debris	0.78	0.76	98
Ferrous Metal	0.74	0.67	91
Scrap Tires	0.03	0.02	86
Non-Ferrous Metal	0.09	0.08	82
Wood	0.25	0.13	52
Paper/Cardboard	1.20	0.62	51
Horticultural Waste	0.22	0.09	41
Plastics	0.66	0.08	11
Glass	0.07	0.01	9
Food	0.56	0.05	9
Textiles	0.11	0.01	7
Others	0.25	0.01	6
Sludge	0.12	0.00	0
Total	**5.60**	**3.03**	**54**

Table 2 - The amount of waste generated and recycled in Singapore during 2007.[101]

Singapore solves the mounting storage problem of un-recycled waste by incinerating what is left. Even though incineration as a waste management system costs six to seven times more to operate than dumping, it can reduce the volume of waste by 90% and weight by 80%. This is an advantage for land-scarce Singapore, who cannot afford more land for landfills. If the amount of solid waste in Singapore is allowed to grow in the trend projected from the current amount of solid waste generated, it is estimated that Singapore will need a new incineration plant every five-seven years and a new landfill site every thirty years. This is expensive and unsustainable, so a further improvement in recycling rates is needed.[102]

To encourage Singaporeans to recycle, 1600 sets of centralized recycling collection sites have been installed in government built living estates where 80-90% of the 4.6 million Singaporeans live. In general, this means that about 2900 Singaporeans have to share each recycling depository. About 50% of the private condominiums have access to recycling and work is in progress to provide recycling facilities in more condominiums.[103]

5.3.1 Recycling Behaviour

The Singaporean waste infrastructure is built for efficient garbage collection, not recycling. Thus Singapore is very clean indeed but the recycling rate is low among its citizens; the strive for efficiency leaves no room for recycling. Tan Hai Woon is the Chief

[100] Ministry of the Environment and Water Resources.
[101] Ministry of the Environment and Water Resources.
[102] Ho, 2002.
[103] Ministry of the Environment and Water Resources.

Technical Officer at Alpha Biofuels and he believes it is important that Singaporeans get to know that recycling is easy. There have been recycling test trials that have worked out fine until the emptying of recycling bins has not been as frequent as is needed. *"If no one collects the things people put out for recycling, they will get fed up and stop doing it",* says Tan Hai Woon. Even though people are positive about these kinds of projects at first, there is no follow up from the government and then recycling is slowly forgotten.

Except from a lacking recycling infrastructure, one of the main boarders is knowledge on why things should be recycled. Even so, Singaporeans that know about the benefits from recycling probably do not know where to find recycling facilities. Another barrier is that it people might need some kind of economic incitement for recycling, something that could be implemented by new legislations according to Tan Hai Woon.[104]

5.3.2 Research on Recycling Behaviour

Research made on recycling behaviour tries to target the factors that differentiate recyclers from non-recyclers with the hope of using these factors to increase recycling behaviour. A study on the relationship between value orientation and recycling behaviour suggested that inconvenience was the key factor for predicting the recycling behaviour of people who were more individualistic or had a lower economic status.

People with higher tendency to recycle were those who had collectivistic value orientation where sharing, duties, and obligations were strongly valued, or for people who had beliefs about the importance of recycling. It was also suggested that people tend to classify environmental behaviour like recycling as a moral responsibility and obligation, especially in affluent industrial societies. Therefore, offering reward programs to encourage recycling behaviours may actually reduce the feeling of obligation, causing negative effects on the targeted behaviour. Instead of feeling morally obligated to recycle, people may start weighing the private costs and benefits of recycling. This may result in a decrease in recycling behaviours, as people realize they can afford to forgo the reward in view of the higher cost they incur when they recycle.[105]

In a study on recycling habits among Singaporeans that lived in Sweden for some time, it was pointed out that these Singaporeans adopted an improved viewpoint on recycling and increased their recycling rate. Their opinions were also that if the same standard of recycling facilities were available in Singapore as well, they would continue to recycle just as much once back in Singapore.

The author further suggested that the top-down approach used in Singapore, when implementing recycling programs, did not internalize the behaviour of recycling in Singaporeans and therefore made people see themselves as passive consumers of a recycling scheme. It was suggested that perhaps Singapore may need to rethink its preferences for using a top-down approach when implementing environmental policies if long-term sustainable result is the goal because the use of regulatory instruments to implement environmental policies might produce passive participants who do not internalize the targeted behaviour.[106]

[104] Woon, 18.08.2008.
[105] Ho, 2002.
[106] Ho, 2002.

5.4 Air Quality

Clean air has for a long time been, besides ensuring enough water, the main area of environmental work in Singapore. In contrast to the water supply which Singapore still struggles to get enough of, the air quality has for many years been astonishing good for such a big city. The concentration of most major air pollutants like sulphur dioxide, nitrogen oxides, carbon monoxide, ozone, and PM10 has consistently stayed within the United States Environmental Protection Agency's (USEPA) standards. However, a pollutant of concern is PM2.5, for which Singapore cannot meet the USEPA standard. The limit is set for 15 μg/m³ but the levels in 2007 reached 19 μg/m³. On of the goals in the Singapore Green Plan 2012 is to reduce this air pollutant so that it is within standard limits.[107]

A pollutant that is not regulated in the Singapore Green Plan but considered hazardous is Polycyclic Aromatic Hydrocarbons, PAHs. There is no standard for PAHs set by USEPA, which Singapore usually compares its air quality against, but the recommended limit for PAHs in U.K. is 0,25 ng/m3 (measured on the reference PAH-compound benzo(a)pyrene).[108] Other countries, like Sweden, tries to reach a target level of maximum 0,1 ng/m³. When measured in Singapore; the mean level was at 1 ng/m³ of this carcinogenic particle.[109]

5.5 Green Technology Development

5.5.1 Support to Renewable Energy Technologies

Singapore's natural limitations constrain production of many types of renewable energies such as geothermal, hydro or wind power. Nonetheless, even though Singapore may not become a significant user of renewable energy apart from perhaps solar energy, it wants to develop renewable energy technologies for export. Singapore has identified environmental and water technologies as key strategic research sectors and set aside 350 million Singaporean Dollars to fund research and development in environmental technologies, including renewable energies. Singapore's accession to the Kyoto protocol may be seen as part of this strategy to position the country as a hub for research and development and eventual marketing of green technologies.[110] Many Singaporeans see an opportunity for Singapore to strengthen its finance, research and manufacturing through the Kyoto Protocol and by hopping on the "renewable energy train". Singapore has been managing its energy better more efficiently than many of its Asian neighbours via better processes and technologies. However, renewable energy forms a relatively new development. With a small home market, the approach is rather that Singapore should regard itself as a distributor of clean or renewable energy instead of a user. For example a

[107] Ministry of the Environment and Water Resources.
[108] Forum for Sustainable Development for German Businesses.
[109] Kalaiarasan *et al.*, 2008.
[110] Lin, 2007.

lot of biodiesel is being made in Singapore from South East Asia's large supply of palm oil. None of it is used in Singapore though but shipped to Europe instead.[111]
Compact as Singapore is, the nation has the ability to implement initiatives, such as research and development, quickly. Thus it is a hope that the island republic can be a renewable energy hub focusing on many sustainable energy-efficient solutions.[112] Also, as a large financial centre, Singapore can help developers find funding for projects, designing and managing projects, supply necessary skill and training people to operate a renewable energy plant. Financers obviously expect returns on their investment, and here carbon trading comes in. Each renewable energy or energy efficiency project creates certified carbon credits tradable in world markets. This emerging business model provides one of the main income incentives for banks, investment companies, and business to look at energy as an area with fast and good returns. Also, as the world's third largest oil trader, Singapore can use this already existing platform for carbon trading and attract green funds.[113]

5.5.2 Is Singapore Ready for Renewable Energy?

Singapore has been putting much effort in attracting renewable energy companies to set up their operations in Singapore to create jobs as well as encouraging research and development in renewable energy technologies. There have been several initiatives and funding to support the renewable energy industry ever since the government decided to focus on clean technologies in 2006.

However, the local adoption of renewable energy lags behind. There are no renewable energy targets by the government to specify the proportion of energy that should be generated by renewable sources within a time period. In addition, the government is not in favour of subsidies and without subsidies the use of renewable energy like for example solar energy is still not price competitive as compared to current electricity tariffs. The Deputy Chief Executive of the Energy Market Authority in Singapore, Mr. David Tan, explains their standpoint on the issue as following: *"We do not subsidize energy. We believe in the right pricing of energy because by pricing energy correctly, that would drive certain behaviour in consumers. As a result of that behaviour, we believe consumers will learn to conserve energy. The government has no plans to implement feed-in tariffs."*

During a seminar on renewable energy in Singapore one of the speakers, Mr. Stefan Mueller, said that the two issues of jobs and research, and adoption of renewable technology should be looked at separately. He also explained that it is important to have local adoption of renewable energy as it is an investment for the future, ensures energy security, and retains talent. Talent retention is relevant because the people who are working in the renewable energy industry would want to be where the market demand is and where their renewable energy technologies are being installed and used.[114]

[111] Lim, 18.08.2008.
[112] Byun, 2007.
[113] Byun, 2007.
[114] Asia Is Green.

5.6 Diesel Vehicles

5.6.1 Private Diesel Cars

Having a car in Singapore is indeed costly. Not that surprising considering the lack of space in such a small area, and with a lot of high income inhabitants that wants to own their own cars. With goals such as clean air and cars that fit the "neat and clean" image that the Singapore government wishes to preserve, the legislations for vehicles owners to follow are strict and costly.

In contrast to for example Europe, Singapore is "anti-diesel" because diesel vehicles are considered to degenerate the air quality. Whilst Europe encourages diesel car ownership with lower taxes and green car rebates, the Singapore government heavily taxes private diesel cars. Because of these very unfavourable tax legislations, not more than 4 private diesel cars currently reside in Singapore, see Table 3 below. Although new generations of diesel cars can be much more environmentally friendly than petrol cars, Singapore does not yet support them fully. [115]

Cars	Petrol	513 375
	Diesel	4
	Hybrid (petrol/electricity)	1057
	Bi-fuel (petrol/CNG) & CNG	248
	Electric	1
	Total	**514 685**

Table 3 - Number of cars in 2007.[116]

5.6.1.1 Tax structures

First a soon-to-be car owner needs a Certificate of Entitlement, a COE. This entitles a person the right to own a car and is a way for the government to limit the amount of cars in Singapore. CEO-auctions are being held twice each month with prices ranging from 7.589 to 19.501 Singaporean Dollars (S$) in 2008.[117]

Upon registration the car owner has to pay a registration fee of S$140 and an additional registration fee of 110% of the cars open market value. That is; if a person buy a car for 40 000 S$ the *additional* price to be paid for registration is S$44140. Some of this registration fee is returned to the car owner when he or she sells the car; the amount depending on how old the car is. For example, if the car is no more than 5 years old when it is sold the owner will get a 65% refund. After 10 years there is no refund at all, hence there are mostly new cars on the streets of Singapore. There is also an "exercise duty" fee of 20% of the cars open market value to be paid before the car owner can traffic the streets. To promote electric cars or cars run by compressed natural gas, a 40% discount on the additional registration fee is given.

Every six months a road tax is paid. For a medium sized car it mounts up to S$372. For a non-Euro IV diesel car this tax is 6 times than the regular amount. For a Euro IV diesel car the tax was recently changed from 4 times the regular amount to an additional

[115] Ling, 09.10.2008.
[116] Land Transport Authority. *Annual Vehicle Statistics 2008*.
[117] One Shift.

S$1000 in the medium sized car case. This shows a slight improvement in the government's attitude against diesel cars, but it is not sufficient to make Singaporeans drive diesel cars.[118] Some analysts estimated that one would need to drive 70,000km per year just to offset this tax. It is understood though, that the government is studying the possibility of reversing the prohibitive taxes currently levied on privately owned diesel-powered cars.[119] The signs are that the government is waiting for Euro V vehicles to be more widely available after 2009.[120] If the diesel tax were removed it would make these cars cheaper to run than similar petrol-driven models and a more attractive alternative in this era of high fuel prices.[121]

5.6.2 Other Types of Diesel Vehicles

Busses, trucks, etcetera are often diesel driven, see Table 4: what Singapore lack in private cars they make up for in company owned vehicles, at least when it comes to diesel. It is not as costly to operate a vehicle commercially as it is to own a private car because the system is meant to rather spur businesses instead of discourage them. Despite a slightly higher road tax on diesel compared to petrol, it is more profitable to operate commercial transportation with diesel vehicles. Especially for companies with several vehicles that can buy the less expensive industrial diesel in bulk.

The government has research projects on running fleets with biodiesel which are mostly focused on what effects biodiesel can have on engines. There is a demand for cheaper fuels due to the ever rising prices on petroldiesel, especially in the construction industry because of the big diesel engines used in trucks and working machines which are costly to operate. If biodiesel would be more cost efficient than petroldiesel it could be used in these kinds of vehicles as well[122]

Taxi	Petrol	1
	Diesel	24 224
	Bi-fuel (petrol/CNG) & CNG	221
	Total	**24 446**
Goods & Other Vehicles	Petrol	11 569
	Diesel	127 031
	Bi-fuel (petrol/CNG) & CNG	4
	Total	**136 604**
Busses	Petrol	392
	Diesel	13 788
	Bi-fuel (petrol/CNG) & CNG	12
	Total	**14 192**

Table 4 - Number of commercial vehicles in 2007.[123]

[118] Land Transport Authority. *Motoring.*
[119] Wild Singapore.
[120] Star Bamboo Singapore.
[121] Wild Singapore.
[122] Obbard, 26.08.2008.
[123] Land Transport Authority. *Annual Vehicle Statistics 2008.*

5.7 Citizens View on Sustainability

In the beginning of 2008 the Singapore government set up a committee called the Inter-Ministerial Committee on Sustainable Development. The purpose of this was to *"formulate a clear national framework and strategy for Singapore's sustainable development in the context of the emerging domestic and global challenges"*. One of the workings has been to set up an online forum for Singaporean citizens where they can give their view and suggestions on sustainability in Singapore. Close to 700 Singaporeans have so far given their thoughts on what they are concerned about, and which problems and solutions they see, related to the environment. All these comments can be read on the website.[124]

The main issue seems to be transportation. People in general would like fewer cars and better public transportation. The subway trains are considered too few and too crowded to give people the pleasant ride they wish for when going to work etcetera. An expansion of the subway network would make public transportation more convenient because people think busses are to slow and not as environmentally friendly because of the emissions. Also a lot of suggestions are given on biking routs along roads. People argue that since Singapore is so small and flat the best way to transport oneself is on a bicycle.

Quite a lot of comments are about "green cars" including hybrid cars and cars running on compressed natural gas. People want more green cars on the roads, or would like to buy one their selves, but since they are more expensive than regular cars they feel it would be to costly. Therefore they request subsidies and further tax regulations to promote green cars in Singapore. For example a young Singaporean comments the following on his family's attempt to buy a green car*: "People know about climate change and other environmental issues - like my parents, but it was all down to cost and value for money in the end. While we did not manage to get a hybrid this round, I have strong faith our next could well be one."*[125]

Another much commented issue is how recycling of household waste works, or perhaps does not work at all, in Singapore. Many of the comments seems to be from people that have experienced recycling abroad and refer to these countries when requiring better recycling facilities and education about recycling and resources. One comment reads:
"I must say on one hand, people are not fully equipped with knowledge and the greater good of recycling, and on the other hand, the bigger environment is not conducive for them to practice it. Recycling bins are not readily accessible by residents. They are too far and few in between. Ask how many Singaporeans are willing to walk a few hundred meters under the scorching sun to recycle their trash? I dare say so few that they are insignificant. So to start with, we need an up-down approach. It has always been so in Singapore, isn't it? This work has to begin somewhere and needs something or someone to kick-start it."[126]

[124] Sustainable Singapore.
[125] Sustainable Singapore.
[126] Sustainable Singapore.

6 Alpha Biofuels

This part focuses on some of the things that are directly related to Alpha Biofuels such as areas of engagement, the product, WVO-providers and customers. It is also explained why the quality of biodiesel and its distribution infrastructure is important to consider.

6.1 Areas of Engagement

Alpha Biofuels produce and sell both biodiesel and biodiesel plants. In Singapore there are two plants: one "main" plant where essentially all biodiesel is made and one "showpiece" at the National University of Singapore's campus. The showpiece plant operates on cocking oil used in canteens at the university campus, whilst the larger one is for WVO from providers all over Singapore. At the moment there are no expansion plans on running more biodiesel plants in Singapore; the city state is considered to be too small to supply enough WVO for additional plants.[127]

Another important part in Alpa Biofuels work is to engage communities to reduce climate change effectively, and to empower communities through the benefits of turning their WVO into biodiesel. In 2007, Alpha Biofuels worked alongside *Friends Without a Border* to empower the community of Ang Kor Hospital for Children in Siem Reap, Cambodia. The collection of waste cooking oil in the community helped to generate income for the locals, and the biodiesel microprocessor provided the locals with an independent source of sustainable clean energy.[128]

Alpha Biofuels has also set up a small plant in Phnom Pen. Compared to Singapore, setting up biodiesel microprocessors in less developed countries generally works better because petroldiesel can be hard to come by. Therefore the incitement is greater in such areas, whilst in Singapore petroldiesel is abundant and easy to buy wherever. Another aspect is that manpower is cheaper in for example Phnom Pen compared to Singapore.[129]

Besides working with community empowerment, Alpha Biofuels tries to spread knowledge on sustainability, as well as building a reputation, through various charity and PR projects. For example, one of the ongoing projects is sponsoring of a biodiversity research in seawaters. It includes a sail boat driven by, apart from the wind, biodiesel. The boat travels through biodiversity dense areas to conduct research and collect samples. In each village the boat makes a stop, 5 liters of biodiesel are given to the inhabitants.[130]

They also work on spreading the knowledge in Singapore through educational green programs, teaching students and school children about making biodiesel from waste vegetable oil.

[127] Lim, 09.10.2008.
[128] Alpha Biofuels. *Community Projects*.
[129] Lim, 09.10.2008.
[130] Lim, 09.10.2008.

6.2 Product Quality

To ensure that biodiesel producers make fuel that will not cause unnecessary harm to engines and fuel systems there are certain quality standards that a fuel has to live up to. Requesting producers to live up to quality standards is also a good way to make sure biodiesel is known as a safe and clean fuel option instead of petroldiesel among consumers. There are different standards that can by applied; in Europe for example the EN 14214 is often used, while U.S. call their equivalent standard used ASTM D6751. Engine manufacturers want users to use biodiesel labelled as quality standard fuel in order for engine warranties to be valid.

To further help biodiesel producers there are voluntary programs, such as the BQ-9000 Quality Management Program in the U.S., that help producers with storage, sampling, testing, blending, shipping, distribution, and fuel management practices.[131]

The U.S. Department of Energy's National Renewable Energy Laboratory did a quality study in the end of 2007 as a part of an effort to help the biodiesel industry obtain warranty approval from engine manufacturers for the use of biodiesel blends. The study showed that a lot of biodiesel producers do not live up to quality standards that are set for biodiesel. Larger producers often meet specifications, but small and medium producers indeed have more problems. The results of that study showed that 59% of the biodiesel samples collected failed to meet ASTM D6751 standards.[132] Large producers and producers enrolled in the BQ-9000 program almost always met the property specifications. Small and medium producers not participating in the BQ-9000 program experienced more difficulty in meeting the specification limits. Samples from the small producers met the specifications 28% of the time. Sixty-eight percent of the medium producers failed to meet specifications.[133]

The emergence of quality problems suggests that many newly set-up companies may not be adopting stringent quality-control checks and that this potentially dangerous trend might scare investors away.[134]

Since there are no standards in Singapore regarding biodiesel the quality of Alpha Biofuels is not regulated by any national standards. They compare their biodiesel with standards within for example EU or U.S. (like the ASTM D6751), but do not do all the tests that these standards require. It would be too expensive for them to do all of the tests so they only do about 5-6 different quality tests. Alpha Biofuels tries to create their own standards for Singapore, by doing a lot of tests on different vehicles, to come up with proper safety limits for different kinds of compounds in biodiesel. The American tests are mostly done on soybean oil, and the European on rapeseed oil, in contrast to the used oil in Singapore that mainly consists of palm oil.[135]

To further insure biodiesel quality it is important that the WVO does not contain too much FFAs. Alpha Biofuels educate their providers on FFA contents and when to change frying oil in order to not accumulate too much FFA through the repeated heating. Restaurants are also provided with ph-measuring sticks for an easy control of FFA

[131] The National Biodiesel Accreditation Program.
[132] National Biodiesel Board. *Results of the 2007 B100 Quality Survey.*
[133] National Biodiesel Board. *Results of the 2007 B100 Quality Survey.*
[134] The Hindu Business Line.
[135] Woon, 18.08.2008.

content in frying oils. As mentioned in Chapter 4.2 WVO can be pre-treated to remove excess FFAs, but this is so far not a step in the Alpha Biofuels process. If they included this pre-treatment they could produce biodiesel from lower quality oil or grease, but it is of course an extra treatment step that costs a lot of money.[136]

6.3 WVO Providers

Alpha Biofuels approximates the amount of waste oil in Singapore to about 1500 tones/month. If all that WVO would be turned into fuel it would result into 1350 tones biodiesel, since 1 litre of WVO gives 0.9 litre of biodiesel. The old biodiesel plant had a capacity of 40 tones biodiesel per month, whilst the new one will have a 360 tones/month capacity. It can be expanded to twice as much though, if needed.

Even if the amount of WVO in Singapore is enough to cover Alpha Biofuels capacity, the problem is rather trying to collect it all since there are other possible ways to dispose WVO than just making biodiesel from it. A vegetable oil user, like a restaurant, normally has the following three options:[137]

1. Pour it down the drain. Even though it is not allowed, some restaurants still do this because it is often difficult to trace back the oil in the sewage system to a specific restaurant. Especially if many restaurants share the same main sewage line, like food courts do, it is hard to tell exactly who clogged it with cooking oil.
2. Put it in sealed containers and throw it away as solid waste.
3. Sell it to biodiesel producers or for further consumption, as mentioned in Chapter 4.5.1.1. The money either goes directly to the staff, in small establishments, or it can also be used as a good contributing income for larger users of cooking oil like food manufacturers.

Many of the WVO providers are restaurants that Alpha Biofuels visit weekly to empty the barrels where used cooking oil is kept after use. The collection barrels are usually stored inside the kitchen because there are risks of thefts if they keep them outside. A problem though, with keeping the barrels inside, is that they attract cockroaches and rats; and rats can lead to a shut down of the restaurant if visited by a health inspector.

Restaurants usually change their oil every 1-2 days, and the less it is used the easier it is to make biodiesel from it. The quality of the oil lessens the more it is used because repeated heating increases the content of free fatty acids. One restaurant normally produces circa 50-100 kg of waste oil per week.

Alpha Biofuels also has about 10 larger providers like caterers and food manufacturers, with the largest one providing them with 20 tones of WVO per month. [138]

Just as the more traditional oil collectors (that sell WVO forward instead of making fuel out of it) Alpha Biofuels offers restaurants and other establishments money for their waste oil. Even if oil collectors might pay more for the oil, they are not interested in "bidding wars". They offer their oil providers a so called *green wash* instead, as a part of the oil exchange. A green wash means that Alpha Biofuels helps the company acquire a

[136] Ling, 09.10.2008.
[137] Ling, 09.10.2008.
[138] Ling, 09.10.2008.

more environmentally friendly image. For example the restaurant gets publicity on Alpha Biofuels' website or during events and other public outings. The oil providers can also put symbols on their products to let customers know that they make use of cooking oil in a sustainable way. Sometimes Alpha Biofuels also hold PR events at partnering restaurants. WVO can also be traded against some of the resulting biodiesel, or for environmental friendly packaging for their take away food in order to further boost the image as a restaurant that uses resources in a sustainable way.[139] The goal for Alpha Biofuels is to help restaurants do business differently, not only focusing on profit but at the environment as well.[140]

Food manufacturers are harder to recruit as WVO providers because they do not care about PR or having a "green" image as much as restaurants do. They are more concerned with at what price they can sell their used oil. Especially smaller manufacturers are not very interested in PR and image because they produce the more "no-name" brand food. The larger manufacturers though, producing well known brands, are more interested in obtaining a greener image and should be easier to recruit because they see a marketing value in it, according to Alpha Biofuels' Chief Operations Officer Jack Ling.[141]

Alpha Biofuels do not collect any household waste cocking oil but has had campaigns to encourage students to collect oil from their homes and bring it over in plastic bottles. Such a system can help spreading the green thinking not only to students but their parents as well. Alpha Biofuels hopes that a positive effect from collection of WVO could be to change people's mindsets and thus promote other recycling as well.[142]

6.4 Customers

6.4.1 Customer Strategies

In other countries like the U.S., attempts to introduce alternative fuels and green vehicles have largely been focused on a "fleet" approach. Fleets are traditionally intended as a good way to create a seed for the development of an alternative fuel market by stimulating the production and purchase of alternative-fuel vehicles, thereby creating a demand for the alternative fuel. In the initial stages of introduction for any alternative fuel, fleet markets have some advantages that make them attractive as market seeds. One advantage is that fleet vehicles tend to be able to refuel in a centralized location (as compared with private consumers who require a large number of geographically dispersed refuelling stations), making it easier to create a supporting fuelling station structure. However, previous attempts at introducing alternative fuel and green vehicles have not been very successful, if success is measured for instance by displacement of petroleum based fuels. The potential "spill-over" effect has not worked as well as anticipated. For a station to be considered a seed for a (private) consumer market, the average consumer must both know about the station (or easily be able to find that

[139] Ling, 09.10.2008.
[140] Lim, 18.08.2008.
[141] Ling, 09.10.2008.
[142] Woon, 18.08.2008.

information) and have access to it. The stations that fleet vehicles use might be inaccessible to the regular consumer or located in hard to reach or hard to know areas like in the back of industrial facilities, thus limiting the effectiveness for the station as a seed for a consumer market. On the other hand, a primarily consumer-driven approach that excludes any fleet component must still find a way to initially seed the positive feedback.[143]

Refuelling stations and vehicle demand tend to concentrate near metropolitan areas. Another way to think of this phenomenon is that metropolitan areas have a lower tipping point than more rural areas, which also have implications for transition strategies and policies. A larger part of trips are taken closer to a vehicle owner's residence, and a smaller percentage of trips are taken farther away. This benefits urban areas because of these areas being closer to more people's homes, and thus gives a lower tipping point for alternative fuels because there are larger market potentials in urban areas. The larger the potential market is; the greater risk a business owner is generally willing to take in hopes of capturing sales in that market. This potential market mechanism also contributes to clustering of refueling stations and vehicle demand in metropolitan areas.[144]

6.4.1.1 Alpha Biofuels' distribution infrastructure

At the moment Alpha Biofuels has two fuelling facilities, or pumps, in Singapore; one in their factory facility and one at a fleet company called Bedok. Bedok both use biodiesel themselves and also works as a retailer. Alpha Biofuels prefers when customers fuel up at Bedok because it is too time consuming to have customers coming by their own facilities to pump biodiesel: then they have to help customers with the pump and answer a lot of questions which sometimes can take up valuable time otherwise spent on the actual production of biodiesel.

Besides using pumps to distribute fuel, they also provide larger customers like fleet companies with containers holding up to 1000 litres of biodiesel. Fleet customers are considered as preferable because they require less work in biodiesel distribution [145]

6.4.2 Prices

In general biodiesel is more expensive to buy than petroldiesel. This is because the process of making biodiesel is costly and also adding to the price is the cost of raw material like crude palm oil or WVO. Thankfully though, biofuel consumers are often willing to pay more for biofuels because it is for a good cause.

Due to the present economy recession, Alpha Biofuels has decided to emphasize more on cost instead of environment due to peoples concern about keeping expenses low. They try to keep the cost of their biodiesel below the cost of petroldiesel bought in regular gas stations, like Shell for example. There is also the type of diesel that is called *industrial diesel* which can be bought by larger companies in bulk. The price on industrial diesel is much lower thanks to the large amount that has to be bought at same

[143] Welch, 2006.
[144] Welch, 2006.
[145] Ling, 24.10.2008.

time as well as being of lower quality. The prices at the 24th November 2008 were as follows:[146]

- Alpha Biofuels Biodiesel 1,35 S$/l
- Shell Diesel 1,45 S$/l
- Industrial Diesel 0,85 S$/l

By keeping the price on biodiesel low Alpha Biofuels hope that people will get to know biodiesel without worrying about the high cost, even though it gives them only small profit margins at the moment.[147]

6.4.3 Current Customers

Alpha Biofuels' customers are both smaller and larger companies that use trucks or busses with diesel engines. They do not have any private customers, but would like to have, since private customers probably would pay more for a "green image". The customers stated below are those mentioned during an interview when the Chief Operations Officer at Alpha Biofuels was asked to list all their customers. The company is ever expanding and adds new customers regularly so it is important to remember that the clientele is dynamic.[148]

At the moment Alpha Biofuels has one fleet customer; Bedok Transport. They run a fleet of 70 busses to cater schools, events, exhibitions etcetera.[149] From the old facilities Alpha Biofuels could deliver Bedok 10 tonnes/month, making them the largest client. With the improved capacity in the new plant Alpha Biofuels can now meet Bedok's wish to deliver even more biodiesel.

Bedok use biodiesel in their older buses to extend their lifespan. As a bus gets older they produce more and more so called *black smoke*; that is emissions with a lot of soot from particulate matter and other pollution. The black smoke makes it hard for old busses to pass the mandatory yearly testing on vehicle emissions. To repair and change engine parts in order to improve emissions is very expensive, so by running these older busses on biodiesel the emissions improve without going through costly engine modifications. Even though the industrial diesel that the busses usually run on is much cheaper, it is still less expensive to run the older busses on biodiesel than replacing engine parts. Besides helping Bedok to pass their busses through emissions testing, customers do not complain about black smoke when getting on and off the bus if it is run on biodiesel. Sometimes it is also used in newer busses in a 50/50 biodisel and petroldiesel blend.[150]

By using biodiesel Bedok also get some good PR through the events Alpha Biofuels host, something they are very pleased with and that is good for their business.[151]

Alpha Biofuels has three catering companies and some other smaller business as customers which run their trucks on biodiesel. These companies are too small to buy

[146] Ling, 24.10.2008.
[147] Ling, 24.10.2008.
[148] Ling, 09.10.2008.
[149] Bedok Transport.
[150] Ling, 24.10.2008.
[151] Lim, 18.08.2008.

industrial diesel in bulk so they use biodiesel because it is cheaper than petroldiesel from gas stations. They can also use it for PR reasons; like when advertising themselves as a company that uses eco-friendly fuel for deliveries. Another benefit similar to Bedok Transport is that emissions are cut by using biodiesel thus making it easier to pass emissions testing.

Alpha Biofuels also has one car workshop owner that buys biodiesel; but no more than 50 l/week. He offers his customers, with problems passing emissions testing, to first clear out their fuel tanks and then fill it with biodiesel before he takes their vehicles to emissions testing.[152]

[152] Ling, 24.10.2008.

7 Analysis

This chapter sums up the study with discussions on previous chapters as well as a conclusion part. There is also a section with suggestions on further studies on those subjects I find to be the most important and interesting.

7.1 Discussion

7.1.1 Impacts from biodiesel made of WVO

7.1.1.1 Properties and Emissions

Even though a displacement of petroldiesel with biodiesel from WVO could only be on a small scale due to the limited supply of WVO, it is important to look at emissions related to human health because even small improvements can save human lives. Especially decreases in emissions like PM and PAHs, that are troublesome in city areas like Singapore, is interesting to notice on a small scale as well. There are probably both human lives and medical costs to spare from turning Singapore's WVO into biodiesel in order to displace some of the petroldiesel used.

As shown in Table 1, biodiesel in general seems to increase NOx emissions. But according to studies on pure palm oil biodiesel the higher saturation in palm oil gives the resulting fuel such short ignition delay that NOx emissions are actually decreased instead. Therefore there should be no concerns about Alpha Biofuels' biodiesel because WVO from Singapore is mostly composed of palm oil. If the WVO would, for example, be from Sweden there would be an issue of increased nitrogen emissions because other types of cooking oils are used in Sweden.

Other concerns about biodiesel, like its cold flow properties, is yet again not a problem in Singapore: With a tropical climate it is not likely temperatures will reach as low as 12 degrees Celsius, thus fuel clogs in engines is not a concern.

Another good reason to evaluate biodiesel emissions is the possibility of a future increase in biodiesel use. That increase would probably not come from WVO, but perhaps from algae or some other oil source that could be a truly sustainable option compared to palm oil. The tropical climate would be perfect for algae cultivation and Singapore's already well developed biodiesel production plants, which are now used for crude palm oil, would come in handy. With the home market that Alpha Biofuels is building at the moment there would be interested customers and a demand for biodiesel.

7.1.1.2 First and Second Generations of Biofuels

Since Singapore has not adopted biodiesel on a larger scale like many countries in Europe, it can not be accused of acquiring a first generation biofuel without a second thought. Thus Singapore can learn from others mistakes and not implement biofuels unless they are truly sustainable. Being a country in South East Asia, a region with

problems of increasing land losses to feedstock for biodiesel, it could be important to try to develop second generations of biodiesel where such knowledge is needed the most. WVO is in general not that abundant to support a production of biodiesel meant for export, but the development of second generations of biodiesel could in time help countries in the region to switch from older cultivation and production methods.

Others more direct positive impacts from not supporting palm oil biodiesel is the effects that land clearing, in Indonesia and Malaysia, can have on Singapore. Many forest fires are a consequence of logging and land clearing and the smoke and haze from these fires easily travels via winds to Singapore.

7.1.1.3 The Use of WVO

Probably the most important positive impact Alpha Biofuels' biodiesel has, is that it is made from waste vegetable oil. Putting good use to WVO could actually be more important than the end product biodiesel, especially concerning social impacts and human health:

- Proper disposal of WVO lower the risk of oil clogging sewage pipes; thus cutting costs from repairs and cleansing of pipes, and risks from the spreading of untreated sewage water. With Singapore's heavy rain falls this should be of great value.
- Making biodiesel from WVO eliminates health problems associated with its further consumption. By using WVO for biodiesel instead of risking it ending up on the second hand market, Singapore can be a role model for other countries that have an unregulated disposal of WVO, thus influencing ethical practices beyond its own borders.
- Giving a value to WVO might spur people to change their oil more frequently and thus produce more healthy food.
- The collection of WVO promotes recycling of other waste streams as well.

7.1.2 The Wider Context: Singapore

7.1.2.1 Environmental Work

After many years of focusing on economical and social growth Singapore is now in the throws of trying to focus on a more "green" development. The government first and foremost wants to develop green technology that can spur further economical development but also to implement a more resource efficient attitude among the citizens. But projects on energy efficiency etcetera have backfired thanks to what many consider is a behaviour focused on efficiency and the lack of economic incitement. One suggested solution to get Singaporeans more involved is by enforcing environmental work through legislations.

According to the Green Plan 2012 there are six areas of important environmental work in Singapore. An example of an area heavily regulated by law is emissions and air pollution, another important area of environmental work is recycling which in contrast to air quality, is mostly motivated by economic gain in the reuse of valuable materials. Both air quality and recycling are in direct connection to biodiesel use:

- Air Quality

Although the supply of WVO can only result in a small supply of biodiesel, compared to how much petroldiesel Singapore actually use, the thorough work on ever improving Singaporean air quality will benefit from its implementation. Strictly regulating emissions is very understandable being such a greatly urbanized area that easily could suffer from air-quality problems. Looking at statistics over measured air pollutants, as mentioned in Chapter 5.4, the main concern seems to be particulate matter. The goal is to reduce PM 2,5 from 19µg/m³, to within the recommended amount of 15µg/m³, by 2014. Biodiesel reduces PM emissions with about 50 % which would contribute to reaching the goal.

- Recycling

WVO is part of the food category that has a recycling rate of 9 %. Hence there is a lot that can be done, and should be done, to increase that number. With the present access of recycling facilities (only 1 per 2900 Singaporeans) there are no wonder recycling rates tend to be low.

That Singaporeans would recycle more if there were better facilities seems to be what Singaporeans themselves believe when reading their comments on the sustainable Singapore forum. This is also supported by the study on Singaporeans living in Sweden which showed that Singaporeans adopted improved recycling behaviour much thanks to better recycling facilities in Sweden.

It was also suggested that an internalization of values behind recycling is to prefer instead of using state-led regulations. At same time a top-bottom approach might be good in Singapore because that is the way it has always been, and was also requested by Singaporeans in the Sustainable Singapore Forum.

7.1.2.4 Renewable Energy Technologies

The Singaporean government wants the market to decide which technology should be used. That is they do not want to favour any technology over the other by using subsidies but instead let supply and demand decide pricing. This notion is considered logic and fair, but it could be argued that green technology should be considered as a part of the "greater good" instead of only one player competing with others in the market place. The government task is to cater for the greater good; otherwise there would be no need for a government. Even though there are good arguments on why it could be useful to use subsidizes to shape markets according to the greater good, it is not a method used by the Singapore government and is thus nothing to hope for. As it is today in Singapore the market can to some extent be controlled through taxes, which is a good alternative to subsidies but works more in a way of punishing things that are conceived as "bad" instead of encouraging usage of the "good". Since vehicles are already heavily controlled by taxes it should not be too difficult to shape these in order to favour green cars, without using subsides as an alternative. Compared to for example solar panels that many would like to see as a favoured technology, but which is part of the energy market that is not subject to taxes, introducing greener transportation alternatives is easier.

7.1.2.5 Green Vehicles Implementation

There are no biofuel cars in Singapore. The green cars that exist are either run on compressed natural gas or electricity. Natural gas is after all still a fossil energy source and that goes for electricity as well; electricity in Singapore is made from either oil or natural gas. This leaves all transportation in Singapore dependent on fossil fuels which are both unsustainable and limited fuel sources.

Despite the bad reputation biofuels tend to have these days concerning land and food issues, it should still be considered as an important fuel for the future. Especially with new generations of biofuels emerging and because it is an alternative to fossil fuels. With both the energy and transportation sector totally dependent on foreign fossil fuel imports, it leaves Singapore quite vulnerable. Therefore it is probably good to spread the risks, or as the saying goes: "do not put all your eggs in one basket".

Compared with for example ethanol that needs special ethanol-compatible engines, biodiesel should be much easier to implement because no special "bio"-engine is needed. The new diesel engines are considered more environmentally friendly than petrol engines because they are much more fuel efficient. That means that even though they are not run on biodiesel it is still a better option. With the already existing diesel fuel infrastructure the implementation would be much smoother than for ethanol cars. Ethanol cars can be run on petrol as well but then it would not be considered a green car thus a supporting infrastructure of ethanol pumping stations is needed. A diesel car can be a green vehicle whether it is run on bio- or petroldiesel. It is just more "green" with biodiesel.

7.1.3 Important Groups: Alpha Biofuels, Customers and WVO-providers

7.1.3.1 WVO Collection

With a WVO collection that mainly targets larger users of cooking oil, Alpha Biofuels' collection unfortunately does not include households except from engaging students to bring it from their homes in plastic bottles, and with the plant located in an industrial area it is very inconvenient for people to drop by with their small amount of oil if they wish to contribute. Household recycling needs to be enforced by communities collecting it from all participants or by government incentives like placing recycling bins out for oil. Otherwise it would be too costly and almost impossible for Alpha Biofuels' to collect.

7.1.3.2 How Customers Relate to Biodiesel vs. Alpha Biofuels Goals

For understandable reasons it is hard to tell customers for which means a product should be used. For example a pharmacist selling a customer paracetamol (like Panadol or Alvedon) can only hope that he or she follows the instructions on taking 1-2 pills to ease headaches, but the customer on the other hand might as well take 50 pills in an attempt to commit suicide. So when a company like Alpha Biofuels has goals other than just making money from selling its product it is important to choose the right customers in order to fulfil the ambition.

Biodiesel itself is better for the environment because of its properties that, if correctly used, would improve air quality and lessen environmental impacts compared to petrol diesel. But in the way it is sometimes used today it might actually have the totally

opposite effect: If a diesel vehicle owner uses it on one occasion each year during mandatory emissions testing only to run it on petrol diesel the rest of the year, the effect is indeed non-exisisting. If the same vehicle owner passes emissions' testing only because of the tank is filled with biodiesel that means this vehicle will exhaust emissions during the rest of the year that otherwise would not have been allowed. Then the effect on the environment is much worse than if biodiesel had not been used at all.

There is also the issue on profitability; the ideal customer is of course the one that will pay the most. Customers can thus be arranged, as in the figure below with two scales. The environment scale is on how high customers classify environmental benefits as a reason to use biodiesel. The higher it goes; the more important positive environmental effects from fuel use are. The price scale is on how much customers are willing to pay for biodiesel compared to the diesel type they normally use. The higher the scale goes; the more expensive biodiesel can be and still be worth its price.

- *The Bus Company*

Use biodiesel to prevent bad emissions. Not for environmental reasons but more to pass emissions testing and to circumvent customers' complaints, thus the environmental concern is not that high. Even though the price on biodiesel is higher than what they normally pay, biodiesel use is still considered to save money in the end. Will be categorized in the *Low Environment High Price* quadrant.

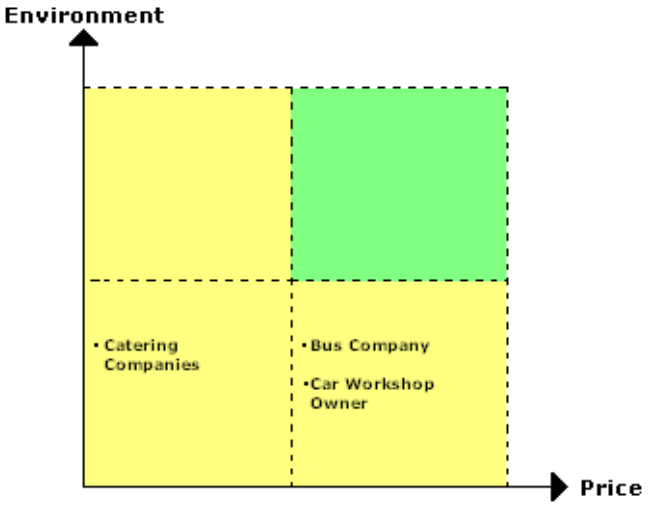

Figure 4 – Environment vs. Price.

- *Catering Companies*

Buy biodiesel because it is less expensive than diesel on petrol stations. The positive environmental effect itself seems not that important unless used for PR reasons. They will be categorized in the *Low Environment Low Price* quadrant.

- *The Car Workshop Owner*

Buy it in small amounts because of concerns about emissions testing, thus pricing is not a big issue, but neither are positive or negative environmental effects. Will be categorized in the *Low Environment High Price* quadrant.

None of the existing customers fit criteria's on *High Environment High Price* which would be, in my opinion, the preferable customer for Alpha Biofuels. The company's intention is of course to offer an environmental friendly alternative to petrol diesel but they can not control to which means biodiesel is being used. Private diesel car owners would, due to Singapore's favorable system for new cars, have the latest diesel engines and would not need biodiesel to pass emissions testing. So their motivation would instead be a more environmentally friendly fuel all year around instead of a quick fix on too high

emission levels. Also a private diesel car owner would pay more for a “green image” thus seeing an additional value in biodiesel that goes beyond it being just another fuel. The result would be a customer in the *High Environment High Price* quadrant.

7.1.3.3 Fuel Quality

Depending on the production rate in the new facilities, Alpha Biofuels can be classified as a small to medium producer of biodiesel. Studies have shown that especially smaller producers have problems meeting quality standards. In an emerging market like biodiesel usage, quality problems can be extra troublesome because it can scare of customers from trying and using the new product. When dealing with long known products on the other hand, people can relate to experience if something fails and realize that the cause of failure was an exception. The general idea of quality standards is of course to ensure customers that they are buying a product that will not cause failure, regardless of a new or old product.

As mentioned by Alpha Biofuels, making these kinds of quality tests are costly and is not something they do or have plans on doing. But with a possible future customer base in private diesel car owners, concerns about the quality of the fuel they run their new expensive car on have to be considered. If customers know there are international quality standards on biodiesel they would probably want Alpha Biofuels’ biodiesel to be tested according to these on order to use it.

7.1.3.4 Distribution Infrastructure

Since selling biodiesel to single buyers is to inefficient and take to much effort to do at the biodiesel factory the idea of using pumps installed at fleet customers as a retailing spot is indeed good. One problem of having pumps where fleets are located is that it is often out of sight for people; fleet fuelling stations are often located in industrial areas and inside the confinements of the fleet property. It is not as easy to pass by these pumping stations and notice them, as it is with a regular petrol station like Shell or BP. And as the saying goes: “out of sight, out of thought”. That means it is hard for people to get to know about Alpha Biofuels biodiesel because it is not likely they will pass by the place that sell this fuel. So by limiting distribution to pumps at fleet companies Alpha Biofuels looses the attention that more visible pumps can give. How will people get inspired to getting a diesel car if they can not find the kind of fuel they want it to run on?

7.1.4 A Note on Research Method

7.1.4.1 Structural Difficulties

In this study I have been using the categorization of Alpha Biofuels/WVO providers/Customers operating in the Singaporean context, and in relation to biodiesel. This has been a good way to structure the presentation in this report but as a research method it lacks some more defined structure, and especially delimitations, making it hard to know exactly what to consider and where to limit the collection of information. The aim can be considered a bit too general as well since the time frame on doing a study according to my structure can range from very short to very long.

This is not a case study on theory testing, so a deeper analysis on which factors might be more important than others when presenting and evaluating facts is missing. Although I guess that trying to range such things might be hard due to people's subjective perceptions in ranging what should be important. The Social Shaping of Technology field itself is very broad with almost endless considerations when it comes to what shapes technology and its implementation. Trying to build a structured research method from that can thus be complicated. The SCOT method, as described in Chapter 2.2.2, has an easy-to-use frame but its flaws would make it hard, if not impossible, to make a sufficient analysis like this on biodiesel in Singapore. As an example there is the difficulty with relevant social groups and their view on biodiesel usage: The current consumers appear to have about the same view on biodiesel use, but it is not commensurable with Alpha Biofuels goals on sustainability. Customers seem fine with viewing biodiesel as a fix for their old engines and of course Alpha Biofuels is happy to sell it, but they do not share the same view on their role in environmental work. This means that one relevant group's *use* of the artefact might not coincide with another group. So how should groups be defined when there is more than just design usability involved? Like in for example built in values the interpretive flexibility might not diminish at all. It also leads to an interesting dilemma in terms of reaching "closure" because it is hard to tell if it is reachable at all when the interpretive flexibility gets more complex. This might be a thing to consider for future SCOT analyses.

7.1.4.2 The Sources Objectivity

A main source of information, particularly information related to Alpha Biofuels, has been interviews with chiefs at Alpha Biofuels. So it should be in their best interest to portrait their company in a good light. After several interviews I decided the information to be credible because they pointed out both positive and negative things, and ups and downs, in their work and with the biodiesel. For example how and why their customers use biodiesel is information that in my opinion is negative for Alpha Biofuels environmentally friendly reputation. But they were still open about discussing the difficulties with customers' environmental concerns versus profitability.

Another difficulty was information related to Singapore and their national agenda on environmental work. Singapore is not a democracy with freedom of speech, but instead more controlled; especially concerning national governance. I got the impression that the main reason with information from governmental sources was not to present objective facts, but rather to make a good impression.

7.2 Conclusions

7.2.1 Biodiesel Impacts

Benefits derived from biodiesel made of WVO compared to petrol diesel can be categorized into two phases: the "production" phase and "user" phase; where the main positive impacts from production is its use of waste vegetable oil, and from the user phase, some of the emissions.

7.2.1.1 Giving a Different Value to WVO

WVO used to be considered as waste or be sold for further consumption by either humans or animals. With the demand of biodiesel the value of WVO has been on the rise all over the globe. By not pouring it out as a part of liquid waste, the risk of clogging sewage systems, and the costs for repairs, is reduced by an estimate of 90 %. The most important impact though is that it does not end up for further consumption because of the toxins WVO accumulate during repeated heating.

Further, biodiesel made from WVO does not struggle with issues like the food vs. fuel dilemma as biodiesel made from crude palm or rapeseed oil would do. Using waste for fuel is truly sustainable.

7.2.1.2 Emissions

Comparing air pollution measurements for Singapore in Chapter 5, with measured improvements in emissions from biodiesel use in Chapter 4, the major health benefits from biodiesel use in Singapore seems to be its effect on PM and PAHs. Singapore in general has very good air quality but can not quite reach the recommended levels for these two pollutants, as shown in Table 5 below. Since Singapore works very hard to gain and preserve good air quality even small positive impacts, like from biodiesel use, is important to recognize. The positive effects on air quality are also important to keep in mind if further biodiesel use should be relevant in the future.

Pollutant	Singapore Level	Standard Level	Biodiesel Compared to Petroldiesel
PM 2,5	19 µg/m3	15 µg/m3 (U.S. recommendation)	- 47% (both PM 10 & PM 2,5)
PAHs (BaP)	1 ng/m3	0,25 ng/m3 (U.K. recommendation)	- 80%

Table 5 - A compilation of significant pollutants.

7.2.2 How the National Agenda Shapes Biodiesel Implementation

Through the Green Plan 2012, Singapore has shown a great dedication to environmental work within the country. I do not personally believe that the claim *"Singapore can be justifiably proud that it has successfully achieved economic and social growth without compromising the environment"* is truthful considering the large amount of resources Singapore uses to sustain its standard of living and economic growth. The ecological footprint Singapore leaves is probably one of the largest in the world compared to its size. But Singapore is still the leading country in environmental work in its region and much more dedicated than others.

The S$ 350 million set aside for R&D in environmental technologies is of course good for a company like Alpha Biofuels, but it could be further helped by a local adoption of green technologies. If the government would give greater incitement to for example private diesel cars the demand for biodiesel would be greater. Alpha Biofuels'

biodiesel seems to be a great way towards a more sustainable Singapore but is unfortunately at the moment not completely supported in its implementation phase. An implementation of biofuels should be important because of the current total dependency on imported fossil fuels for both electricity and transportation. Another more altruistic view on adoption of the more expensive environmental technologies is that if every country reasoned like Singapore (that green technologies should be cost compatible first, not creating an "artificial demand") we would have had no development what so ever in this area. Thanks to countries and people that believe that even if it costs more, it is important to support it, there is a market today.

The conclusion is that even though Singapore shows a great interest in environmental technology like renewable energy, the implementation lags behind. Right now the government does nothing to encourage the use of biodiesel.

7.2.3 Alpha Biofuels Contribution to a More Sustainable Singapore

Alpha Biofuels contribution to a sustainable development can roughly be divided into two different areas: the actual impacts from production and biodiesel use, and the work on changing perceptions.

7.2.3.1 Biodiesel Use

The impacts from biodiesel itself are concluded in Chapter 7.2.1, but there are also the impacts from the way biodiesel is used. As explained in Chapter 6.4.3 the way biodiesel is used by current customers is not always with the environment's best interest in mind, like in the extreme case of biodiesel usage only during emissions testing. Therefore I believe a lot of work is still left on achieving positive effects from biodiesel use; work that at the moment is limited by current rules and legislations. The more "suitable customer" for Alpha Biofuels should be a private diesel car owner, something not at all abundant in Singapore at the moment but it is suggested that a change in tax structures will soon be implemented thus stimulating a market for diesel cars. Then they could try to attract a customer base more in line with the positive impacts biodiesel use could have. The other positive effect is that of pricing; where corporate interests are more concerned about prices whilst a private consumer would pay more accordingly to a product suiting his or hers personal values or image.

7.2.3.2 Internalize Values on Sustainability

The main perception of Singaporeans is that they are very economically driven. Weather it comes to recycling or choosing more environmentally friendly products and technologies the main incitement is considered to be financial gain. Other from that, Singaporeans are used to a government and system that implements rules regarding "the greater good" through law, and hard punishments if these are neglected. Therefore it is implied that environmental work has to be executed in a top to bottom approach in Singapore. But research also suggests that to gain truly environmental thinking and a sustainable system it is important to internalize the values gained from living more sustainable; to make them important to people. That is where education and the kind of work Alpha Biofuels do can play an important part. They have an extensive agenda on spreading knowledge through educational programs, charity and community work. Right

now a lot of effort also goes into providing WVO providers with a "green wash" to make their businesses more environmentally friendly. Internalizing values on sustainability is indeed the strongest part of Alpha Biofuels work towards a more sustainable Singapore.

7.3 Suggestions

7.3.1 Suggestions for an Improved Customer Base

One of my conclusions is that the way biodiesel is used by current customers is not always with the environments best interest in mind, like in the extreme case of biodiesel usage only during emissions testing. Therefore I believe a lot of work is still left on the sustainable use of biodiesel. At the moment the number of biodiesel customers is limited due to unfavourable tax regulations, as mentioned in Chapter 5.6, but there have been some improvements this year and more are expected next year. There will probably be a new market for fuel to support diesel car owners in a near future when it no longer is an economic disadvantage to drive a diesel car in Singapore. To fulfil goals on both positive environmental impacts and good profitability, a suggestion for Alpha Biofuels would be to reach out to these private diesel car owners and be a part of the new fuel market.

The further advantage with a private customer approach when implementing a new fuel is the visibility because the distribution needs to be of a more open and accessible kind compared to fleet companies; private consumers need to find fuel at petrol stations whilst fleets can fuel up at a closed industrial facility. To spread the word on environment and sustainable living, like Alpha Biofuels wishes, customers are an important step and use among private diesel car owners will more likely have a significant impact on people's perceptions. By keeping biodiesel use limited to fleets it will contribute to only a "closed loop" where few new people get introduced to the positive properties of biodiesel. To prepare for private consumption of biodiesel some suggestions would be:

- Evaluate Car Manufacturers' Demands on Biodiesel Blends and Quality

Depending on production rate in the new facilities, Alpha Biofuels can be classified as a small to medium producer of biodiesel. Studies have shown that especially smaller producers have problems meeting quality standards. In an emerging market like biodiesel usage, quality problems can be extra troublesome because it can scare of customers from trying and using the new product. Also vehicle manufacturers have regulations regarding fuel quality/fuel type and engine warranties because they, as well as their customers, are concerned about which proportions petroldiesel/biodiesel should be used in and that the producers can meet fuel quality standard. As mentioned by Alpha Biofuels, making these kinds of quality tests are costly and is not something they do or have plans on doing. But with a possible future customer base in private diesel car owners, concerns about the quality of the fuel they run their new expensive car on have to be considered. If customers know there are international quality standards on biodiesel they would want Alpha Biofuels biodiesel to be tested according to these in order to use it.

- Plan and Prepare for How to Improve the Distribution Infrastructure

In other countries like USA, attempts to introduce alternative fuels and green vehicles have largely been focused on a "fleet" approach. Fleets are traditionally intended as a good way to create a seed for the development of an alternative fuel market by stimulating the production and purchase of alternative-fuel vehicles, thereby creating a demand for the alternative fuel. In the initial stages of introduction for any alternative fuel, fleet markets have some advantages that make them attractive as market seeds. One advantage is that fleet vehicles tend to be able to refuel in a centralized location (as compared with private consumers who require a large number of geographically dispersed refuelling stations), making it easier to create a supporting fuelling station structure.

However, previous attempts at introducing alternative fuel and green vehicles have not been very successful, if success is measured for instance by displacement of petroleum based fuels. The potential "spill-over" effect has not worked as well as anticipated. It is not as easy to pass by these pumping stations and notice them, as it is with a regular petrol station like Shell or BP. And as the saying goes: "out of sight, out of thought". That means it is hard for people to get to know about Alpha Biofuels biodiesel because it is not likely they will pass by the place that sell this fuel. For a station to be considered a seed for a (private) consumer market, the average consumer must both know about the station, or easily be able to find that information, and have access to it. The stations that fleet vehicles use might be inaccessible to the regular consumer or located in hard to reach/hard to know areas like in the back of industrial facilities, thus limiting the effectiveness for the station as a seed for a consumer market. So by limiting distribution to pumps at fleet companies Alpha Biofuels looses the attention that more visible pumps can give. How will people get inspired to getting a diesel car if they can not find the kind of fuel they want it to run on?

Alpha Biofuels can probable not provide several petrol stations with biodiesel so it must therefore be limited to stations with the most strategic advantage. Such advantage could for example be stations in areas where a lot of potential customers live. Probably there are demographic patterns which point to certain areas where people in general are more aware, or have greater financial means, and can be found by for example looking at sales statistics on new cars. When the unfavourable tax system on diesel cars comes to an end the sales on diesel cars will be on the rise especially in some areas. To evaluate which petrol stations would have a strategic advantage over others in terms of number of possible private customers in the area and product visibility is an important preparation.

- Spread Recycling to a Household Level

To further increase recycling and build knowledge, WVO collection should include households as well. Moving beyond collecting WVO from only larger commercial users is important in the process of changing perceptions, but it is hard to implement because of the small amounts. Going around collecting WVO from single households would not be possible for Alpha Biofuels. But they could have a centralized location where people could drop of their used cooking oil; by a petrol station selling biodiesel for example. There could be a recycling container for WVO where people could pour their used oil at the same time as they fuel up their cars. By choosing to run the car on biodiesel they are

probably interested in contributing to the environment in other means as well, like recycling. The knowledge that the oil they used for cooking today a few days later could be brought back in their fuel tank would probably excite people about bringing their WVO.

7.3.2 A Suggestion on Further Studies

Probably one of the most interesting things about Singapore is its governance with both democratic and authoritarian elements and how citizens' behaviour is shaped by this. How to shape a more environmentally aware society is an important thing to evaluate in Singapore (and in other countries as well of course). When it comes to sustainable behaviour and thinking, what is the best way to implement this in Singaporeans and Singapore's already existing system?

So far projects on increased environmental awareness like "bring your own bag day", or trying to get people to set their air conditioners on a more energy efficient temperature, has not been that successful leaving the question on what the best approach might be to implement sustainable behaviour. Should it be stricter regulations using the top-down approach as many suggests and that has worked in other cases in Singapore. Or does sustainability need more of an internalization of values in order to work in the long run? Perhaps what is needed is economical incitement or a more convenient system. With the dedication Singapore usually goes about things this should be an important step in achieving the nation's goals on sustainability.

As mentioned earlier on the relationship between value orientation and recycling behaviour, it is suggested that inconvenience was the key factor for predicting the recycling behaviour of people who were more individualistic or had a lower economic status. For people who had collectivistic value orientation where sharing, duties, and obligations were strongly valued, or for people who had a more internal locus of control, like beliefs about the importance of recycling were positively related to the tendency to recycle. It was also suggested that people tended to classify environmental behaviour as a moral responsibility and obligation, especially in affluent industrial societies. Therefore, offering reward programs to encourage environmental behaviours may actually reduce the feeling of obligation, causing negative effects on the targeted behaviour. Instead of feeling morally obligated to contribute, people may start weighing the private costs and benefits of doing environmental work.

In Singapore's case perhaps a mix of different approaches is needed. People are used to a behaviour, in accordance to the greater good, enforced through legislation and fines. To encouraging the not mandatory behaviour, a solution that is efficient and easily accessible seems needed to make it worthwhile, as well as economic incitement. Also the government has implemented environmental education in the Singaporean school system. It seems that the following factors are important to consider:

1. Control through legislations and fines.
2. Giving economical incitement.
3. Creating solutions that are easy and efficient.
4. Increase environmental awareness and values.

The suggestion would be to find a balance between these for a long-term sustainable development in Singapore. Trying to find an approach for Singapore might be useful for other countries in the area as well. It can probably be implemented in other nations' environmental agendas, especially in countries with backgrounds and values similar to Singapore.

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