KTH Industrial Engineering and Management

Setting the seeds for a green growth

-A Study of biofuel development in Indonesia’s transport sector

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Abstract

Climate change poses as one of the major environmental issues on a global scale today, with one of the largest contributor to the climate change being the greenhouse gas (GHG) emissions. GHG emissions in turn is known to a large extent originate in anthropogenic energy use, especially fossil fuel usage. This leads to almost a quarter of the global emissions today being emitted from the transport sector as the sector is primary fueled by fossil fuels.

Biofuels have been promoted as a strong candidate for fossil fuel substitution as it has similar properties while being renewable. However, even as biofuels have been increasing annually since 2008 globally, there are still concerns associated with the usages that have hindered its replacement of fossil fuels.

Indonesia, one of the most populated countries in Southeast Asia, is projected to be one of the world's leading economies in 2050. In 2030, Indonesia in projected to have doubled its energy consumption since 2014, indicating that the decisions and actions taken today in Indonesia will have a significant impact on the future fuel consumption. This, in combination with being the largest producer of palm oil in the world, gives it a great potential to be in a leading position in the future production of biofuels, especially biodiesel from palm oil. Additionally, Indonesia has set mandatory targets for biofuel share in the transport sector which indicates that the country also seeks to promote the usages of biofuels.

This thesis intends to investigate Indonesia's potential for biofuel development in the transport sector and which factors that could hinder it. More specifically, this study answers the two questions: (i) *Which factors are hampering the development of biofuels in the Indonesian transportation sector from a multi-level perspective? and (ii) What is the projection of the Indonesian transport sector by 2030 in terms of fuel consumption and global warming potential (GWP) and what role could biofuels play in reducing those?*

The data used were collected by interviews with stakeholders in Indonesia and a literature study, which afterwards was processed with the tools Multi-Level Perspective (MLP) and Long-range Energy Alternatives Planning (LEAP). MLP is a concept aiming to describe how system transitions happens with the help of an examination of the linkages in between technology and society, whereas LEAP is an energy modeling tool used in order to create energy projections in different policy scenario options. In this research, MLP were used to capture and analyze the factors that influence the future implementation of biofuels in Indonesia from a socio-technical perspective, putting forward key barriers for biofuel implementation in Indonesia. LEAP was used to construct a model of the Indonesian transport sector to project the future fuel consumption and GWP emissions. This was used to examine biofuels importance as a fuel through scenarios where different Indonesian policy actions were appraised. Together, these two methods will provide an enlightening and concluding remark on the future possibilities for biofuels in Indonesia's transport sector in this thesis.

The major finding of the first research question were that biofuels in Indonesia were being introduced in Indonesia as the government saw economic benefits and a solution to the increased energy demand in Indonesia and an increased energy security in going towards a domestic produced energy source. The need for biofuels were also increased due to an increased global sustainability awareness, which also reached Indonesia.

Today, biofuels in Indonesia is in a socio-technical transition pathway to go from a niche innovation to a technology in the regime level, but in order for a breakthrough, a number of barriers needs to be addressed. The most mentioned barriers were the institutional and regulatory barriers, which mainly lays in a lack of cooperation amongst the regulatory institutions and a low rate of success of biofuel laws and regulations. Other barriers were the market barriers, closely connected in a subsidization of fossil fuels in Indonesia and a need for further subsidization of biofuels for the market for biofuels to exist in Indonesia. Furthermore, a technical barrier with the vehicle engine were seen as the engine needs improvements in order for a higher blending of biofuels in the fuel. There was also a concern of the perceived sustainability of biofuels in general (e.g. water scarcity and pollution) which was identified as a hindrance. It was also clear a social change is needed in order to push the biofuel breakthrough and enable it to reach its full potential. Today, the interviewees mainly see a development for the biofuel biodiesel and not for the biofuel bioethanol in Indonesia, which they mainly concluded as there is currently none or very little production and demand for bioethanol in Indonesia, and as well a lack of governmental support for bioethanol development.

For the second research question four scenarios were used; Business as Usual (a continuation of current trends), Improved Standards (an investigation of higher emissions standards and an increasing fuel efficiency), Biofuel Mandate (a mandatory biofuel share in fuels) and the Low Carbon scenario (a combination of the previous two as well as introduction of electric vehicles, changed car preferences and higher biofuel blending targets). Cars represents a tenth of the vehicle fleet and the share of diesel car amongst the cars are 5% while gasoline stands for 95%, the rest of the vehicles are gasoline driven motorcycles. The main findings were: the total vehicle fleet will have doubled by 2030. This rapid increase could cause stress on the domestic fuel supply, as the yearly fuel consumption is expected to grow from 770 million GJ in 2014 to 1850 million GJ in 2030, an increase by 140%. In the projection the fossil fuels are blended with biofuels, diesel is mixed with biodiesel while gasoline is blended with bioethanol. The annual diesel fuel consumption is projected to increase from 350 million liters to 1100 million in the Business as Usual scenario where the current trend was expected to continue. The implementation of biodiesel and bioethanol in the Biofuel Mandate scenario. Additionally, the Biofuel Mandate scenario resulted in a 12.6% reduction of GHG emissions during the projected period. The cumulative GHG emissions in the projection is estimated to be 1630 million tonnes of carbon dioxide equivalents in 2030 for the Business as Usual scenario. In the transport sector, gasoline is projected to increase from 23 billion liters to 54 billion liters over the period. In the Improved Standards scenario, where the emission standards are increased from Euro2 to Euro6 in 2030 for cars and Euro4 for motorcycles in 2025 as well as an annual fuel economy improvement of 2%, the total fuel consumption is reduced with 20% and GWP by 18%. It was found that the annual GWP could be reduced by almost 31% below the 2014 level, at 47 million metric tonnes of CO_{2Eq}, if the actions of the Low Carbon scenario were achieved.

The barriers associated with the Improved Standards scenario were technical, institutional and regulatory while the Biofuel Mandate scenario also had financial, market and distribution barriers. The Low Carbon scenario had barriers from all of the identified barrier categories. The institutional and regulatory barrier was the most prevailing barrier for all of the scenarios.

The recommended actions based on the content of this thesis is to firstly promote collaboration between governmental institutes, stakeholders and authorities and include all stakeholders in the decision progress, this way, frameworks and regulations will have a chance to improve and increase the knowledge about biofuels in all levels. It is also important to implement a stronger biofuel R&D culture, promote a more sustainable biofuel development and increase the public awareness of biofuels. The implementation of biofuels will have a reducing effect on the total GWP and fossil fuel consumption. Gasoline is projected to remain the predominant fuel in the transport sector. Therefore will actions targeting the reduction or substitution of gasoline be more impactful than those towards diesel. However due to the availability and current production capacity of biodiesel there is still potential for higher share of biodiesel in fuels.

Keywords: Multi-Level Perspective, Long-range Energy Alternatives Planning, Biofuels for transport, Indonesia, Barriers.

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List of Abbreviations

EU - European Union

MLP - Multi-Level Perspective

LEAP - Long-Range Energy Alternatives Planning

NGO - Non-Governmental Organizations

R&D - Research and Development

GHG - Greenhouse Gasses

CPO - Crude Palm Oil

GWP - Global Warming Potential

CO_2 - Carbon Dioxide

CO_{2eq} - Carbon Dioxide Equivalents

CO - Carbon Monoxide

HC - Hydro Carbon

NO_x - Nitrogen Oxides

N_2O - Nitrous Oxide

1. Introduction

1.1 Research Problem

Today the world is facing a number of critical environmental issues, one of the most urgent being the climate change. Greenhouse gas emissions (hereafter GHG) emissions, mainly arising from the vast anthropogenic usage of fossil fuels, is one of the largest contributors to climate change (Food and Agriculture Organization of the United Nations [FAO], 2013; Intergovernmental Panel on Climate Change [IPCC], 2007).

Currently, the transport sector stands for 23% of the global energy related CO_2-emissions and is also the second largest energy consuming sector in the world, causing as much as 35.9 Gigaton CO_2-emissions in 2014 (International Energy Agency [IEA], 2014; IPCC, 2007; Le Quéré et al., 2015). This makes the transport sector one of the main contributors to GHG emissions, due to CO_2 being one of the largest GHGs (IPCC, 2007). IEA (2014) predicts the vehicle fleet in the transport sector to be twice as large in 2040, something that will increase the fuel consumption almost as much. The most consumed fuel in the transport sector today is the fossil fuel, some of its benefits being its high energy content and accessibility, but it is also associated with environmental and local health issues (FAO, 2013).

Climate change, being regarded as a '*wicket problem*' (Levin et al., 2007; Chakrabarty, 2012), needs a complex solution to be solved. An alternative to fossil fuel is therefore often stated as biofuels, as it has potential to solve issues related to energy security, pollution of land and water, rural development and GHG emissions while in the same time, maintaining similar properties as fossil fuels; such as easy to store and use, a high energy content and enough similar physical properties to be used in already existing vehicles (Cordes and Schutter, 2011; FAO, 2013; Vasudevan et al., 2005). These reasons are why the world biofuel consumption, mainly made up by the biofuels bioethanol and biodiesel, increased from 2008 to 2016, and are predicted to continue doing so up to 150 billion liters in 2020, almost doubling the production from 2008 (IEA, 2015a).

Indonesia, with a rapid increase in both population and economic growth since the Asian financial crisis in 1997, is today considered as one of the countries that could be a leading producer of biofuels in the future (International Renewable Energy Agency [IRENA], 2017). Indonesia is already the current largest export of biodiesel from palm oil and produced more than 50% of the world palm oil biodiesel production in 2016 (BpGlobal, 2017; IRENA, 2017). Indonesia were also in the top three largest biodiesel producers in the world together with Argentina and Germany in 2016 (Ren21, 2017).

IEAs (2014) projection of a three times larger energy consumption in 2030 from 2000 for Indonesia, together with a declining of Indonesia's' national fossil fuel reserves, is raising questions of future GHG emissions and energy security, especially as Indonesia in 2015 stated in their Intended Nationally Determined Contribution (INDC) that they by 2030 would do an unconditional GHG reduction of 29% with Indonesia's total emissions (Ministry of Energy and Mineral Resources [MEMR], 2015; Ministry of Environment and Forestry [MoEF], 2015). As 77.6% of Indonesia's primary energy supply came from fossil sources in 2015, Indonesia can be considered as heavily dependent on fossil fuels, putting a strain on Indonesia's energy security (Wright and Rahmanulloh, 2016). The Indonesian transport sector was the largest energy consumer and accounted for 40% of the final energy consumption in 2013 (MEMR, 2016). For the same year it was the third largest emitting sector with 17.5% of the non-Land-Use Change and Forestry GHG emissions (World Resources Institute, 2017).

Environmental and energy concerns have made the Indonesian government promote renewable energy sources, biofuels being one of these (MEMR, 2015; IRENA, 2017). Indonesia has set a goal of 23% renewable energy sources until 2025, where 10% is expected to be from bioenergy with a significant portion being from biofuels (International Civil Aviation Organization, 2017). To further implement biofuels on the domestic market, a regulation for a biofuel blending mandate was prepared by Indonesia's Ministry of Energy and Mineral Resources in 2008. This regulation (MEMR regulation 12/2015) decides the minimum blending percent of biodiesel in diesel and bioethanol in gasoline to be 30% and 20% respectively until 2025 for the transport sector (Wright and Rahmanulloh, 2016). To assist in establishing this, a biofuel subsidy was implemented, largely financed by a levy on palm oil and palm oil production export (Wright and Rahmanulloh, 2016). This subsidy has been deemed important in fulfilling the goals, but since the subsidy has proven expensive, cuts in the funding has been made, affecting the prices of biofuels in Indonesia and spreading market insecurity (Kharina et al., 2016). This, in combination with the fuel blending mandate from 2015 falling short of the yearly targets, has raised a concern whether the mandate and goal of 2025 is achievable and affected the establishment of biofuels in the transport sector (Kharina et al., 2016; Wright and Rahmanulloh, 2016).

Indonesia turned towards biofuels as a solution to their future energy problems, emitting less GHG emissions and increasing their energy security, but biofuels has also raised questions about both deforestation, farming practices and the food-water-energy nexus, causing its sustainability to be questioned and adding further uncertainty of the future development of biofuels in Indonesia (Janda and Stankus, 2017).

In order for Indonesia to fulfill its national goals and promote the further development of biofuels in Indonesia, the issues stated above are necessary to address due to being a hindrance for the development. In light of this, this thesis intends to investigate Indonesia's biofuel potential for fuel consumption and global warming potential (hereafter GWP) reduction in the transport sector and which factors that could hinder the development of biofuels in Indonesia and be possible barriers. Furthermore, this could also bring forward recommendations in how to best develop the biofuels in Indonesia's transport sector. As the direction Indonesia heads for now will have a significant impact in the future, it is important to consider the alternatives and possibilities. Given the fact that Indonesia also is the largest producer of palm oil, it has a unique position to frontline the biofuel advancement.

1.2 Research Significance

Indonesia is in focus in this study due to its large contribution to the energy consumption in the world, making its transport sector one of the most interesting in terms of problems such as high GHG emissions, pollutions and high energy consumption. Indonesia had the highest vehicle sale of the region in 2014 and is supposed to almost double its total energy consumption in Indonesia until 2030 (Gaikindo, 2015a; Wijeratne and Lau, 2015). Indonesia as well stands for the largest contribution of energy in Association of Southeast Asian Nations (ASEAN) with nearly 40% of the total energy use in the region (IRENA, 2017).

The vehicle fleet of Indonesia consists mainly of two-wheelers which made up more than 81% of the entire road vehicle population in 2014 with buses and trucks making up almost 8% together and passenger cars accounting for the remaining 11% see Figure 1. For the total vehicle population, the annual growth rate has been 9.13% with the two-wheelers being the largest contributor to the motorization. As the total vehicle population reached over 114 million in 2014, the total motorization rate were almost 450 vehicles per 1000 inhabitants. (BPS, 2015)

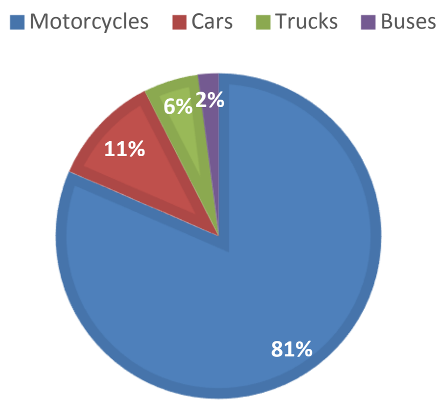


Figure 1. Indonesia's road transport. Compilation by authors based on data from BPS (2015).

Even though Indonesia is still mainly dependent on fossil fuels for the vehicles and motorcycles in the transport sector, the Indonesian government is trying to increase the consumption of biofuels domestically, imposing several regulations, laws and policies regarding the consumption and production of biofuels in Indonesia. Having a rapidly increasing energy sector, combined with a wish to increase the national energy security and being one of the fastest growing economies in the world, gives a unique case for studying a development of one of the most discussed renewable energy sources today. As the transport sector stands for the majority of the biofuel consumption in Indonesia (IRENA, 2017) it's thereby the most vital area for investigation, therefore this thesis will focus solely on Indonesia's transport sector. Biofuels in the Indonesian transport sector is also vital to investigate, as Indonesia relies greatly on fossil fuels and is deemed to need more fossil fuels in the future (see chapter 1.1). Due to biofuels being one of few fuels suiting as a replacement for fossil fuels (see chapter 1.1), biofuels need to be further examined. In the energy sector, several other renewable energy sources already exist on the market, but as a replacement for fossil fuels, biofuels are one of few.

By identifying the barriers for the development of biofuels in the transport sector, these key areas could be addressed for intervention, leading to possible solutions for the problems stated in chapter 1.1 in further research. It is also important to evaluate the possible impacts of biofuels in the transport sector as to determine the significance of introducing them as a solution to the issues of chapter 1.1.

This area is also further relevant to examine since few previous studies have investigated biofuels in Indonesia or more specifically, the transition towards a development of biofuel in the Indonesian transport sector. They have either been angled towards the sustainability issues of biofuels in Indonesia (Dillon et al., 2008; Obidzinski et al., 2012), biofuel implementation in Indonesia's transport sector (Jupesta, 2010), palm oil production and biofuels (Paltseva et al., 2016; Petrenko et al., 2016) or biofuel development policies in Indonesia and their implementations (Kharina et al., 2016; Sorda et al., 2010; Zhou and Thomson, 2009). Just a few studies have also looked at bioethanol in Indonesia, e.g. Khatiwada and Silveira (2017) or Khatiwada et al. (2016). The research exists regarding biofuels in Indonesia, but it is only looking at parts of the biofuel sector or from a certain perspective, e.g. sustainability. More studies are needed regarding both bioethanol and biodiesel in Indonesia, focused on an overall development in the transport sector. No study before has likewise investigated the entire scope of both current barriers as well as the projected impact of implementation of biofuels in Indonesia's transport sector, as this thesis strives to do. As this concludes in recommendations for the development of biofuels in Indonesia's transport sector, it further distinguish it from before mentioned studies.

1.3 Research Objective and Questions

The main objective of this report is to investigate current barriers and project future potential of biofuels in terms of fuel consumption and global warming potential (hereafter GWP) in Indonesia's transport sector. From this, recommendations can be derived for the development of biofuels in Indonesia's transport sector. The objective is approached by using two different tools, the Multi-Level Perspective (hereafter MLP) and Long-range Energy Alternatives Planning System (hereafter LEAP).

This publication uses the term '*biofuels*' for liquid biofuels that are used as fuel in the transport sector. In this case, the liquid biofuels in the Indonesian transport sector are bioethanol and biodiesel. '*Biofuels*' also include the biofuel sector in Indonesia.

The objective is achieved by answering the two main research questions;

1. **Which factors is hampering the development of biofuels in the Indonesian transportation sector from a Multi-Level Perspective?**

To answer this question, a list with barriers of the development of biofuels in the Indonesian transport sector is presented. The barriers are derived from already existing literature on barriers regarding renewable energy penetration and used in combination with the tool MLP, where the MLP is used as a conceptual guide to explore the barriers for biofuels. This thesis is looking at biofuels in Indonesia from a MLP, obtained by doing both a theoretical examination (both technical and social) of biofuels in general and by linking actors and their perspective on the industry to this.

Based on these findings, recommendations how to further successfully develop biofuels in Indonesia's transport sector is then presented. Possible factors affecting the biofuel development, such as the Indonesian transport sector and Indonesia's laws and regulations regarding biofuels, is also presented.

2. **What is the projection of the Indonesian transport sector by 2030 in terms of fuel consumption and GWP and what role could biofuels play in reducing those?**

An energy model is used to determine projections for the development of the Indonesian transport sector until 2030 as well as perform energy policy analysis for different policy scenarios. For the transport sector only motorcycles and private passenger cars are considered and are assumed to be either fueled by gasoline or diesel (see chapter 3). The impacts of biofuels are evaluated in terms of its share to the sector total activity of fuel consumption and GHG emissions. The GHGs will be examined for the total global warming potential (hereafter GWP). This will result in providing data on how the fuel consumption and GWP changes depending on the different policy actions and behavioral changes, which in turn can be useful for shaping steering policies as well as evaluating current mechanics. Recommendations of how to further develop biofuels in Indonesia's transport sector is presented based on the findings. In order to assess the different policy actions scenarios are used, where a reference case scenario following the business as usual trend is compared to the implementation scenario for each of the actions.

1.4 Structure of the Thesis

The thesis is divided into seven chapters.

The first chapter aims at presenting the problem and the general outline of the thesis purpose; research problem, research significance and the thesis's objective and research questions.

The thesis continues in chapter two with a general introduction to both the biofuel technology and the case site Indonesia, to lay a foundation to the study. The biofuel technology is examined both from a technical and a sustainable perspective, also in order to identify already possible existing technical and sustainable barriers for biofuels. The section about Indonesia as a country is presenting a general overview of the country with some sections covering biofuels in Indonesia and certain laws, policies and regulations concerning biofuels in Indonesia.

The third chapter describes the methods used in order to reach the objective. The main methods here are the MLP and LEAP, used separately to answer the research questions.

The fourth chapter describes the data used in this thesis.

The result, chapter five, is divided in two parts, 5.1 and 5.2. Chapter 5.1 focuses on analyzing the Indonesian biofuel sector from an MLP perspective, and barriers that hinder the further development of the biofuel sector will also be identified with an extended part of the sustainability aspect of the technology as a possible barrier. It ends with a part focusing on how the participants perceived the further development of the biofuel sector in Indonesia. The second part (5.2), will present the finding of the energy model constructed with LEAP for each of the different policy scenarios. The outcome of the scenarios is compiled together to offer an overview of the variation in terms of fuel consumption and GWP.

In chapter six, the development of the biofuel sector in Indonesia is discussed, from why the sector were introduced until how it may look like in the future. The findings of the report were further discussed as well as their accuracy.

Chapter seven, the conclusion, ends the thesis by concluding the main results as well as suggested recommendations for how to develop the biofuel sector in Indonesia.

2. Background

2.1 The Biofuel Technology

Chapter two describes biofuels from a technical perspective in order to gain an understanding of the biofuel technologies and its possible drawbacks and benefits from a technical perspective. These may also serve as a clue to already acknowledged problems in Indonesia with the biofuel technologies, which later on can be taken into consideration in the barrier analysis, giving a greater understanding of the biofuel development in Indonesia. It will also provide a starting point in modeling with the LEAP tool as it provides current conditions of the fuel usage and important characteristics of the fuel.

The sustainability issues are known to be one of the most discussed problems with biofuels, which could serve as a drawback for the biofuel technologies development in Indonesia and is therefore discussed in more detail in this chapter (Food and Agriculture organization of the United Nations [FAO], 2015). What more to acknowledge in this assessment is that it is limited to the first and second generations of biodiesel and the first generation of bioethanol, as these are the only biofuels currently occurring in Indonesia and therefore the ones who will be discussed more in detail (see chapter 3.4).

2.1.1 Biofuels

Biofuels are liquid fuels coming from different kinds of biomass, as for example soybean, palm oil or jatropha and produced through biological processes using the direct product or its byproducts (FAO, 2013). Example of byproducts could be organic waste or logs (Biofuel Indonesia, 2007) but what kind of product used is heavily connected with the probability to grow it in the area, for example is this why biofuels from palm oil is heavily exported by Asia (FAO, 2013).

Biofuels has been known as a replacement for crude oil for many decades, but as crude oil was seen as both cheaper and easier to produce, the biofuels has always come as a second choice, resulting in the already established fossil fuel sector working as a barrier for biofuels to come through (Biofuel Indonesia, 2007). As environmental concerns and the concept of peak oil came up on the agenda, biofuels has started to be regarded with more interest (Figure 2) (Biofuel Indonesia, 2007). This led to an increased production of biofuels from 80 billion liters in 2008 to 140 billion liters in 2016 (IEA, 2015a).

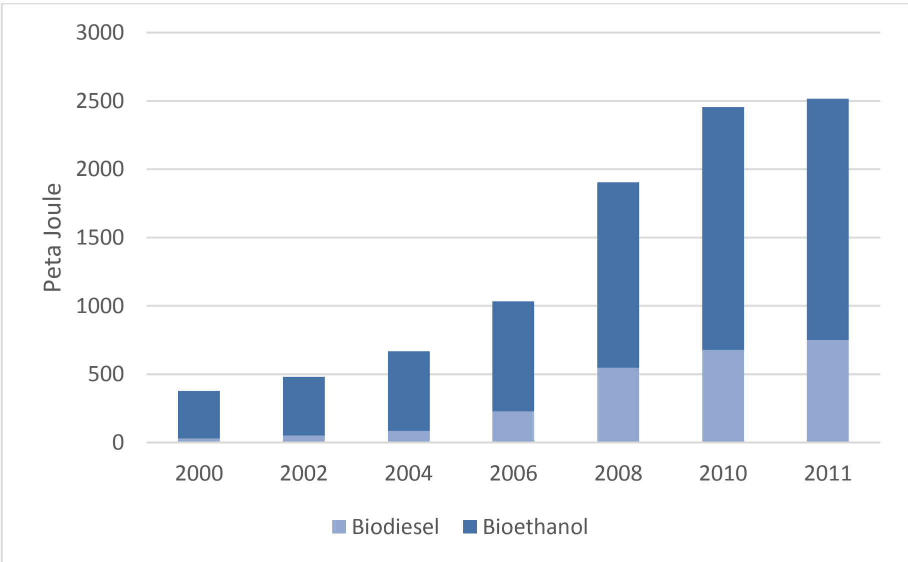


Figure 2. World biofuel and bioethanol production 2000-2011. Compilation by authors based on Timilsina (2014).

Generally, biofuels can be referred to three different types of plant-based liquid fuels; biodiesel, bioethanol and bio-oil (Vasudevan and Shamra, 2005). What kind of biofuel are depending on mainly three different characteristics; from what it is produced, how it is produced and what kind of fuel molecules that emerge from the production (Janda and Stankus, 2017). Biofuels can from this be categorized into three different generations;

- 1st generation; biofuels produced from sources like starch, vegetable oils, animal fats and sugar products.
- 2nd generation; biofuels made from cellulosic products, usually used to feed livestock, mainly wastes, energy crops or agricultural leftovers.
- 3rd generation; biofuels made from algae, which can give arise to both biodiesel and some components of gasoline. (Beyene, 2016; Janda and Stankus, 2017)

Biofuels are according to Kazamina and Smith (2014) usually produced as following: farming of the feedstock by plantation, harvesting and processing, crushing and extracting oil from the feedstock, transportation of extracted oil to the production factory where the biofuels is produced, transportation and storage of extracted fuel and finally the usage of the fuel (see Figure 3). As seen, the production process of biofuels consists mainly of the agriculture and the processing sector, where the agricultural sector produces the feedstock for biofuels and the processing sector turns the feedstock into biofuels and consumes them (Vasudevan and Shamra, 2005).

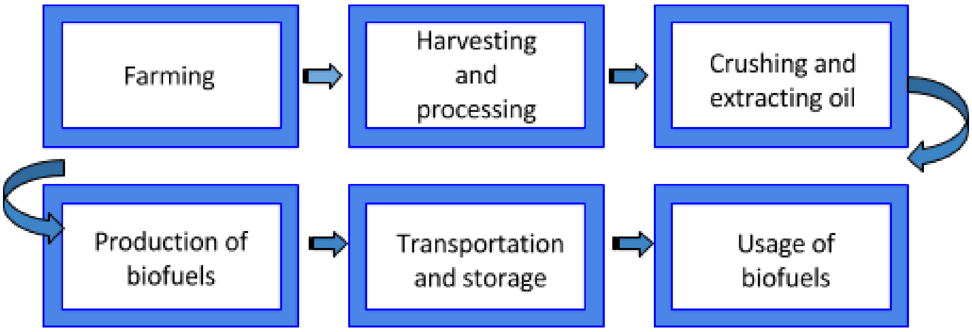


Figure 3. Biofuel production stages. Compilation by authors as perceived from Kazamina and Smith (2014).

Biodiesel

Biodiesel or green diesel that some call it, can be produced by combining alcohol with different oils from plants, fat from animals or greases, such as for example palm oil, soybean oil or jatropha carcass (Beyene, 2016; Janda and Stankus, 2017). It is generally used as a substitute for diesel oil (Cordes and Schutter, 2011). Biodiesel blending is a common trait around the world, with everything from 5% to 20% biodiesel blending with diesel.

Biodiesel has similar properties as crude-oil based diesel as seen in Table 1.

Table 1. Properties of diesel and biodiesel. Compilation by authors Diffen (2017), Eriksson and Ahlgren (2013) and Vasudevan et al. (2005).

Properties	Diesel	Biodiesel
Usages	In diesel engines	In diesel engines
Made from	Petroleum/ crude oil	Alcohol and oils
Energy content	43.3 MJ/kg	38.0 MJ/kg
GWP (CO_{2eq})	87.4 g/MJ	40.8 g/MJ

Generally, biodiesel can only use a diesel engine but some blends can go directly into heat and power operators. In older engines, Biodiesel can be used up to a blend rate of 20% without necessary improvements, which is especially interesting in countries with older cars still in usage. Studies have shown that including it in mix with diesel could increase the safety in warmer countries as the flash point for ignition increases and increase the lifetime of various engine components due to the greasing effect (Agarwal, 2006;

Vasudevan et al., 2005). However, one drawback could be that the same properties can lead to ignition problems in colder countries and the clogging of fuel filters (Agarwal, 2006). The requirement for newer engines is sometimes seen as the largest technical barrier for implementing biofuels (Janda and Stankus, 2017).

Bioethanol

First generation bioethanol, is made by doing bioethanol from the alcohol coming from fermented agricultural crops containing sugar, such as sugarcane or corn (Beyene, 2016). The second generation bioethanol is cellulosic bioethanol, where a range of different materials' cellulose (e.g. solid waste or wood) can be used to make the bioethanol, making it relatively easy to obtain (Janda and Stankus, 2017). Bioethanol is generally used as a substitute for gasoline (Cordes and Schutter, 2011). For more information, see Table 2.

Table 2. Properties of gasoline and bioethanol. Compilation by authors based on Diffen (2017), Eriksson and Ahlgren (2013) and Vasudevan et al. (2005).

Properties	Gasoline (Petrol)	Bioethanol
Usages	In gasoline engines	In newer gasoline engines
Made from	Petrolium/ Crude oil	Agricultural crops containing sugar
Energy content	~44.8 MJ/kg	~26.7 MJ/kg
GWP (CO_{2eq})	87.2g/MJ	56.2 g/MJ

Traditional motors can run on E5 (5% bioethanol and 95% gasoline) as well as E10 but E85 and E100 is only used in motors with a flex-fuel engine. Gasoline also contains more energy per volume compared to bioethanol or in other words, the same amount of bioethanol as gasoline generate less energy to the motor. This makes it harder to sell and a possible market barrier (Janda and Stankus, 2017)

Additionally, this will require the vehicles to have larger fuel tanks or be limited to shorter distances (Agarwal, 2006). However, studies have found that the inclusion of bioethanol will increase performance of engines in terms of torque at lower levels (Thakur et al., 2017).

2.1.2 The Sustainability of Biofuels

The sustainability perspective in this report is a central perspective in many parts, especially when talking about the sustainability of biofuels. The sustainable development concept is famously defined in the report *Our Common Future - Brundtland Report* as; "*Sustainable Development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs*." (United Nations 1987, p. 41). This definition serves as this reports view on sustainable development.

There are also a number of other different factors to consider in order to touch the three different pillars of sustainability; the economic, the environmental and the social sustainability (FAO, 2013). To be deemed truly sustainable, biofuels has to be able to meet all of these three pillars. These sustainability aspects in relation to biofuels are therefore discussed below, especially as biofuels for long has gained negative attention in relation to a number of sustainability aspects which are discussed below.

Due to Indonesia being an "*emerging economy*", Tukker (2005) deemed it's important for Indonesia to be careful with new technologies in relation to sustainable development and not repeat the sustainability 'mistakes' already developed economies have done in regard to new technology. With this in light, the biofuel technology in Indonesia should be carefully monitored in relation to the sustainability concept, particularly as many emerging technologies also have a close relation with social issues (FAO, 2013). Indonesia's sustainability issues related to biofuels are discussed more in detail below. These sustainability issues have been chosen due to their occurrence in Indonesia and they were the most frequently mentioned during the interviews with stakeholders in the biofuel sector (see chapter 4 and 5.1).

Main Sustainability Issues with Biofuels in Indonesia

Biofuels has during a long time been considered sustainable, mainly from the fact that biofuels are considered to release none or a low amount of GHG emissions into the atmosphere. The GHG emissions is one of the largest sources for climate change and therefore it is an important metric to consider regarding sustainability (FAO, 2013; IPCC, 2007). Nowadays, biofuels such as bioethanol and biodiesel is not considered CO_2-neutral, but are considered to reduce the emissions in a larger extent than crude-oil based fuels (Janda and Stankus, 2017; Petterson and Grahn, 2012; Zaimes et al., 2017).

When talking about the farming of biofuels, a number of sustainability issues arise. Two of the most spoken about in Indonesia is the loss of biodiversity and land degradation which mainly occur when land has to be altered in order to farm biofuels, putting pressure to turn forest land into a farming area (Beyene, 2016; Cordes and Schutter, 2011). What type of land you alter is also deemed important, as for example rainforest have a higher environmental impact than forestland due to its rich biodiversity (Hidayatno et al., 2011).

According to Beyene (2016), another problem is the high amount of water used in the farming and conversion stages of biofuel production, affecting Indonesia's water security. Cordes and Schutter (2011) state that bioethanol conversion is twice more water consuming than gasoline. The increased farming of biofuels also causes an increased amount of fertilizers and pesticides used, triggering problems with polluted land and water and eutrophication, affecting both humans and animals (Cordes and Schutter, 2011).

Another problem related to the farming of biofuels is the food-water-energy nexus, which refers to the interlink in between food, water and energy and that scarcity in one of these areas, is heavily linked to the others and always affect each other (FAO, 2013). The increasing food and water demand, mainly due to an increasing population in Indonesia, causes a food and water vs biofuels problem (Rulliet et al., 2016).

Energy security is indeed one of the biggest benefits talked about today with biofuels, which is especially appreciated on the political agenda (Kazamia and Smith, 2014). An improvement of energy security with biofuels for Indonesia would mean less reliance on foreign energy import (e.g. oil import) and more reliance on energy the country can produce by itself and be less influenced of the global market. It could through also make the country more sensitive to environmental phenomena like drought or diseases affecting the harvest as supplies can be volatile (Cacciatore, 2012).

2.2 Study Context

In this chapter, the case context of Indonesia will be presented with specific information on the country and its current trends and future projections. This chapter also gives a background to do an adequate study with the tools MLP and LEAP as it gives insight how historic trends has resulted in the current situation. Biofuel related policies, laws and regulations in Indonesia is presented in the end of this chapter, to give insight in what have been done to implement biofuels nationally in Indonesia and what have been done to develop the biofuel sector.

2.2.1 General Information about Indonesia

Indonesia is a lower middle-income country located in east Asia with a GDP of 942 billion USD[1] ranking it as the 9th largest economy worldwide in 2014 (Hawksworth and Chan, 2015; World Development Indicators [WDI], 2017). For the last 25 years the average GDP per capita have grown by 3.44% annually and were around 3700 USD/capita[2] by 2014 (WDI, 2017). Projections in Figure 4 suggests that the GDP per capita will pass 5000 USD/capita in 2020 and reach 8350 USD/capita in 2030 if the recent high economic growth continues.

[1] In USD from year 2010s currency in dollar.

[2] In USD from year 2010s currency in dollar.

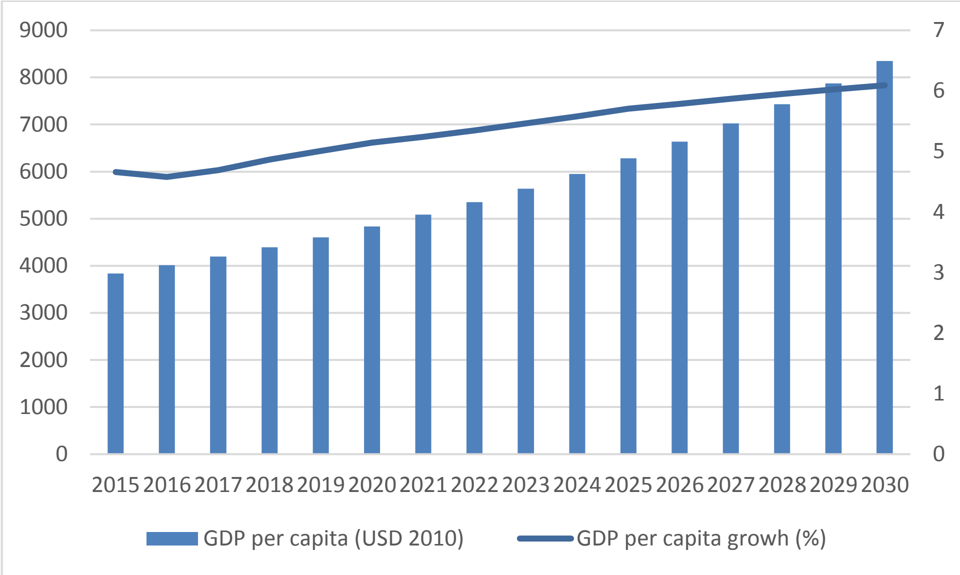


Figure 4. Indonesian GDP per capita forecast. Compiled by authors based on trends by Knoema (2017).

The population of Indonesia reached over a quarter billion in 2013 making it the 4th populous nation in the world (MoEF, 2015; WDI, 2017). The historic population growth rate has been decreasing until it stagnated in the early 2000s and remained so for the following decade, in the recent years it has showed a trend of further reducing its speed as shown in Figure 5. Indonesia's population growth is expected to follow the current trend of decline as it is estimated to drop below 1% in 2020 and decreasing to 0.7% in 2030. In 2030, it is projected that Indonesia's population will have reached 295 million as can be seen in Figure 6. There is an ongoing urbanization in Indonesia and since 2011, more than half of the population is living in urban areas (WDI, 2017).

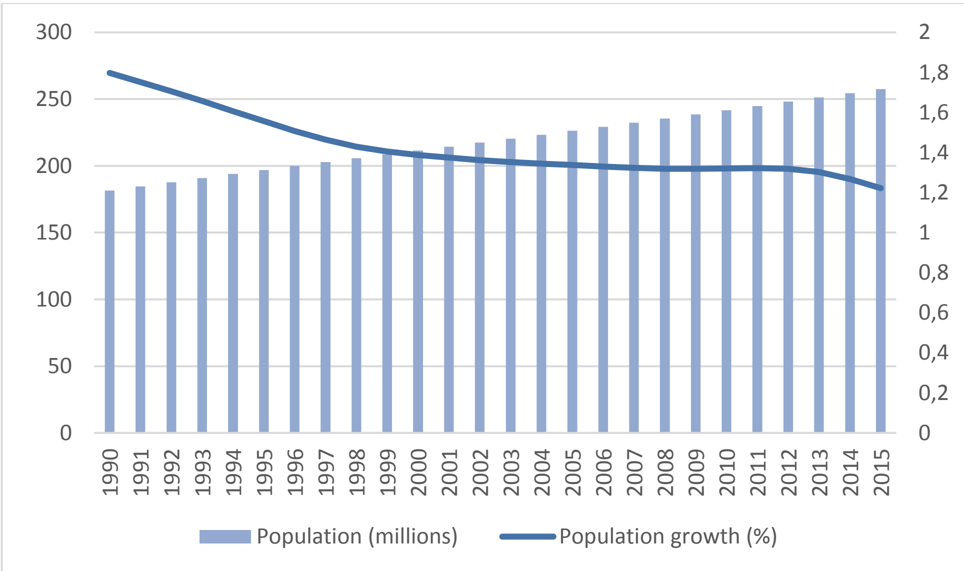


Figure 5. Indonesian population trend 1990-2015. Compilation by authors based on data from UN (2015).

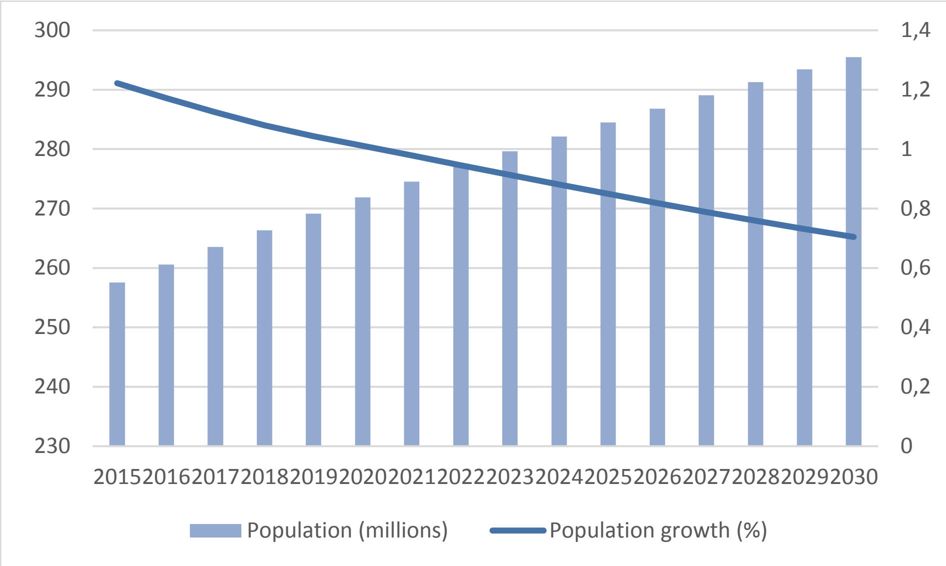


Figure 6. Indonesian population forecast 2015-2030. Compilation by authors based on data from UN (2015).

More than 75% of the national primary energy supply came from fossil fuels in 2014, indicating a high reliance on fossil fuels (MEMR, 2016a). As of 2011, Indonesia has been exporting more energy than it uses domestically and have been seen a net energy exporter for decades (WDI, 2007). Due to its large energy consumption increase the last decade, it went from being a net oil export to a net oil importer in 2004 and is today the second largest oil importer in the region, making it want to increase its national energy production due to energy security improvements (IEA, 2015b). Moreover, in terms of fuels for transportation, more than half is directly imported while over a fifth is indirectly imported through crude oil (MEMR, 2016a). Since the transport sector accounted for 47% of the final energy demand in Indonesia 2014 (Figure 7), it plays a major role in terms of energy self-dependence.

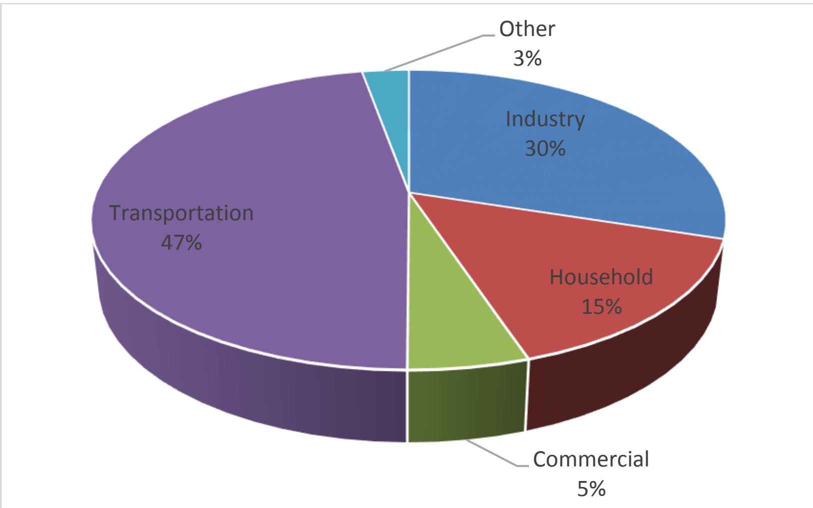


Figure 7. Share of final energy consumption by sector 2014. Compilation by authors based on data from MEMR (2016a).

Indonesia's final energy demand have grown rapidly in the past decades and is projected to continue doing so in the future (Agency for the Assessment and Application of Technology [BPPT], 2016). It is expected to have doubled in the period from 2000-2015 and is projected to grow with 150% in 2030 compared to 2015 (Figure 8).

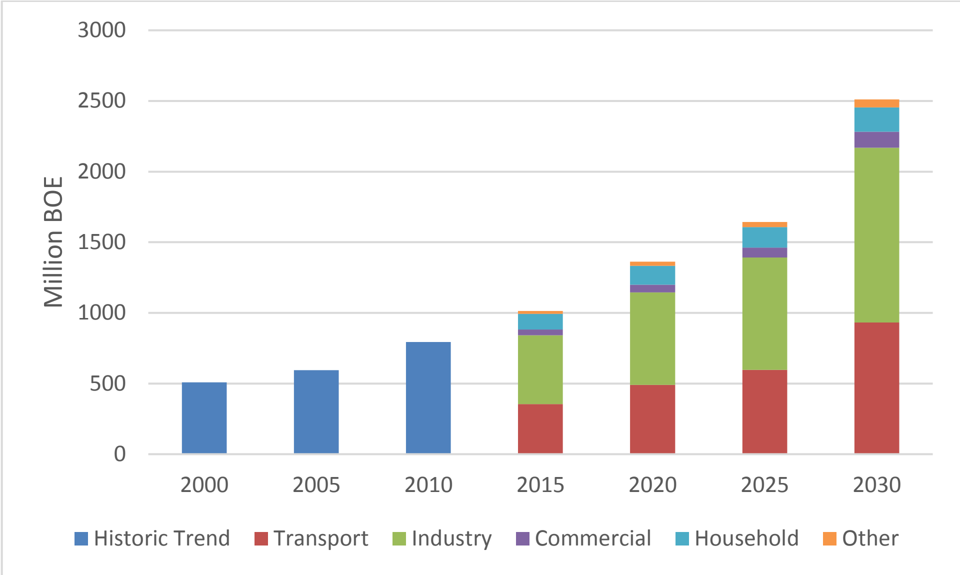


Figure 8. Indonesia's final energy demand. Compilation by authors for historic trend data is based on MEMR (2016a) and for Projection the data is based on BPPT (2016).

According to Presidential Regulation No.79/2014 the energy consumption in 2025 should consist of at least 30% gas, 22% coal, less than 25% petroleum and 23% from new energy and renewables, new energy can be sources as nuclear and coal bed methane (Presidential Regulation, 2014). These shares should change to be minimum 25% gas, 24% coal, less than 20% petroleum and at least 31% new energy and renewables in 2050 (President of the republic of Indonesia, 2014). The regulation has been formed as a push to make Indonesia completely self-sufficient in energy (IEA, 2015b).

Agriculture have historically been an important sector in Indonesia as it accounted for 56.2% of the total employment and 23.4% of the GDP in 1989. Even though its significance has declined somewhat it still accounted for 34% of the employment in 2014 and 13.3% of the GDP, making it one of Indonesia's largest sectors. The area used for agriculture purposes have continued to grow from a quarter of Indonesia's 190 million hectares in 1989 to 31.5% in 2014 (WDI, 2017). Even though Indonesia has a large agricultural sector, it is still a country that is plagued with food security issues and have experienced increased food security problems since 2008. An Asian Development Bank [ADB] study identified grains, horticulture and livestock as some of the major food imports in Indonesia (Quincieu, 2015).

Indonesia's Vehicle Fleet

In Indonesia, road transport is the dominant form of transportation with almost 85% of the passenger activity (Leung, 2016). However, the settings of the current infrastructure are lacking. More than half a million km of road 34.5% is either damaged or severely damaged which have been identified as a limiting factor to the economic growth but also a safety issue (Badan Pusat Statistik (BPS), 2015; Leung, 2016; Smith et al., 2015). Furthermore, there is an undeveloped road capacity which leads to regularly occurring traffic jams and low traveling speeds, which have been linked to increased fuel consumption (Deedarlianto et al., 2017; Ministry of Transportation, 2015; Leung, 2016). Another concern is the local pollution associated with the road traffic and the diseases with strong correlation to those (Leung, 2016).

Indonesia have also experienced an increasing motorization rate in terms of passenger cars over the recent years with an average annual growth rate of 9% between 2011 and 2015 (BPS, 2015). This have led to car ownership increasing by over a third during that period, as can be seen in Figure 9. A bolstering factor on the influx of passenger cars have been identified as the strong economy (Titikorn, 2016) as well as the introduction of the low-cost green car (Titikorn, 2016; Scherer et al., 2016).

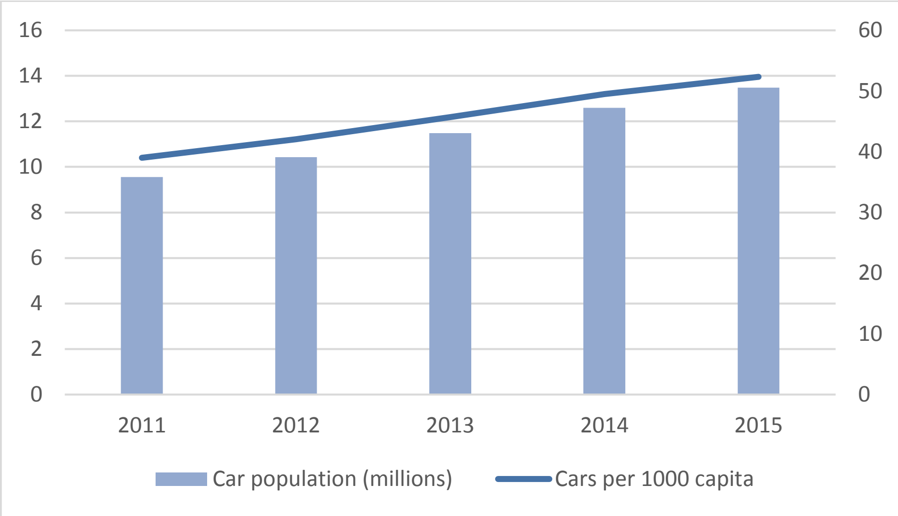


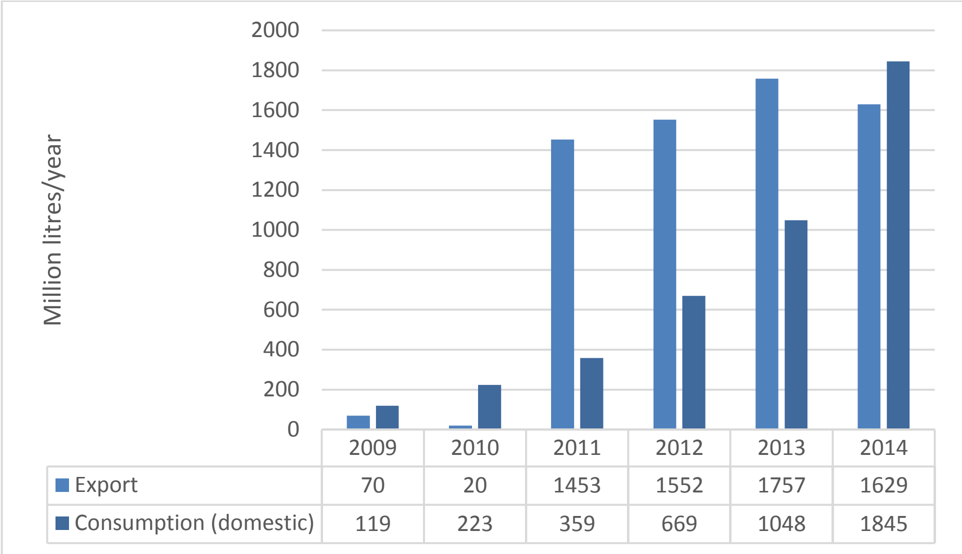
Figure 9. Car motorization rate. Compiled by authors based on data by BPS (2015).

2.2.2 Biofuels in Indonesia

Since the beginning of the 2000 century, the increased Indonesian living standards in combination with a stronger economic development and an increasing number in population has caused a higher energy demand in line with the increase in GDP. This fact in collaboration with Indonesia as a large net importer of fossil fuels such as oil, coal and gas, caused Indonesia in 2006 under the government of president Susilo Bombang Yudhoyono to steer its sight towards renewable energy sources, mainly biofuels which could be produced domestically (The Business Watch Indonesia [BWI], 2007). The biofuels biodiesel and bioethanol is both produced in Indonesia, where biodiesel is standing for almost all domestic production.

As stated, biofuel production has developed differently when looking at the production rate for biodiesel and bioethanol. The biodiesel production has increased steadily, as have the domestic consumption and the export of biodiesel (Figure 10). The bioethanol production is though still small in comparison (Wright and Rahmanulloh, 2015). According to Wright and Rahmanulloh (2015), this is closely connected with the nonappearance of subsidy support for bioethanol, that ended in 2010 due to infrastructure shortcomings, low feedstock production and insufficient results from the economic support given by the government. A small production still exists in Indonesia, but it's mainly exported (Wright and Rahmanulloh, 2015).

When it comes to export of biodiesel, the European Union has long been a key trade partner, but due to increased import taxes, China is now the number one importer with 55% of Indonesian export market of biofuels in 2014 (Wright and Rahmanulloh, 2015). The increased biofuel production and utilization in Indonesia is supposed to increase Indonesia's energy security, create job opportunities, reduce GHG emissions and thus, boost Indonesia's economy in the long run and decrease poverty (Mukherjee and Sovacool, 2014).



	2009	2010	2011	2012	2013	2014
Export	70	20	1453	1552	1757	1629
Consumption (domestic)	119	223	359	669	1048	1845

Figure 10. 2009-2014 domestic consumption and export of biodiesel. Compilation by authors based on data from MEMR (2016b).

The biodiesel in Indonesia is produced from palm oil and to some extent, jatropha carcass whereas bioethanol is mainly made from sugarcane molasses (Wright and Rahmanulloh, 2016). BPPT, a non-ministerial government developing biofuels in Indonesia since 2000, is stating that palm oil and jatropha are the most important crops for developing the biofuel industry in Indonesia, but Indonesia currently also uses sugarcanes molasses to produce biofuels (BWI, 2007). Both the sugarcane molasses and jatropha carcass has been deemed as having lower extraction yield than palm oil and thus needing larger production areas to come up to the same extraction yield as palm oil, something that has shown to be problematic and thus decreasing the chances for these crops market to expand (Wright and Rahmanulloh, 2015).

Palm oil is today Indonesia's most used source for biodiesel and according to Wright and Rahmanulloh in a study from 2016; the only competitive option in the Indonesian market. Indonesia is one of the world's leading producer of palm oil with 25 billion liters palm oil produced/year (Mukherjee and Sovacool, 2014), which is also expected to increase up to 35 billion tonnes in 2016, which is the largest production in the world with more than half of the world's palm oil biodiesel production (Indexmundi, 2016). According to FAOs statistic division for food and agriculture (FAOSTAT, 2016), more than 70% of the palm oil products is being exported, while the rest was used domestically with 73% used for food products and 12% was used to produce biofuels, accounting for one million metric tonnes fuel. This gives Indonesia plenty of room to use CPO for producing more biodiesel if Indonesia exported less (Figure 11) (Indonesia-Investments, 2016; Wright and Rahmanulloh, 2016).

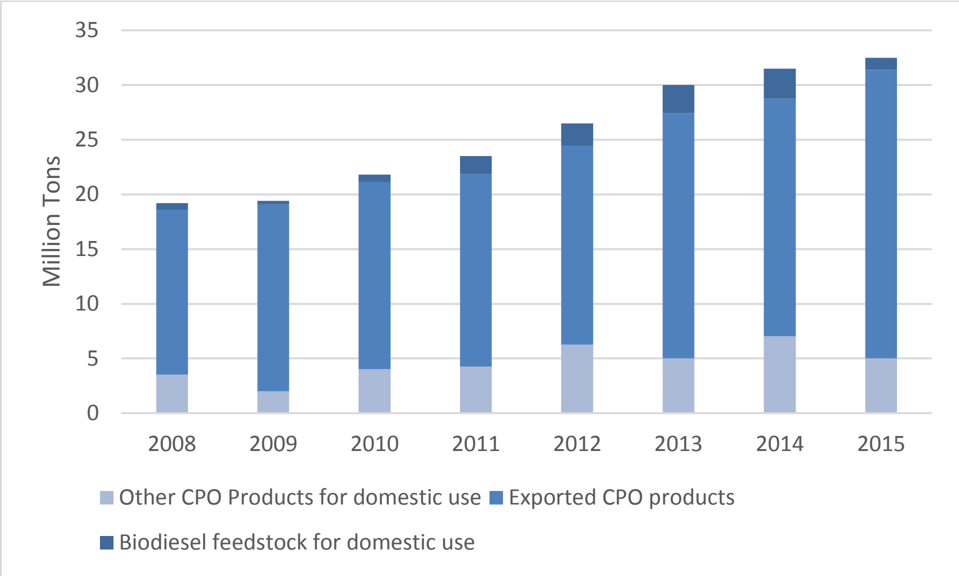


Figure 11. Products made from CPO. Compilation by authors made by data from Indonesia-Investments (2016) and Wright and Rahmanulloh (2016).

During the last couple of years, there has been an increased interest in expanding palm oil plantations in Indonesia, suggesting an interest in expanding the biofuel palm oil industry, see Figure 12. Today, 15 million hectares is used for oil palm production in Indonesia, making it almost 10% of its total land area (Colchester et al., 2006; Ministry of Agriculture, 2015). The growth in demand for biofuels has caused the government to allocated 20 million more hectares towards palm oil productions, more than doubling the palm oil plantation area and an increase of the present land area of cultivation by 330% (Petrenko et al., 2016). Permission is needed from the government both to be able to farm the feedstock used for biofuels as well as to work the land (IRENA, 2017).

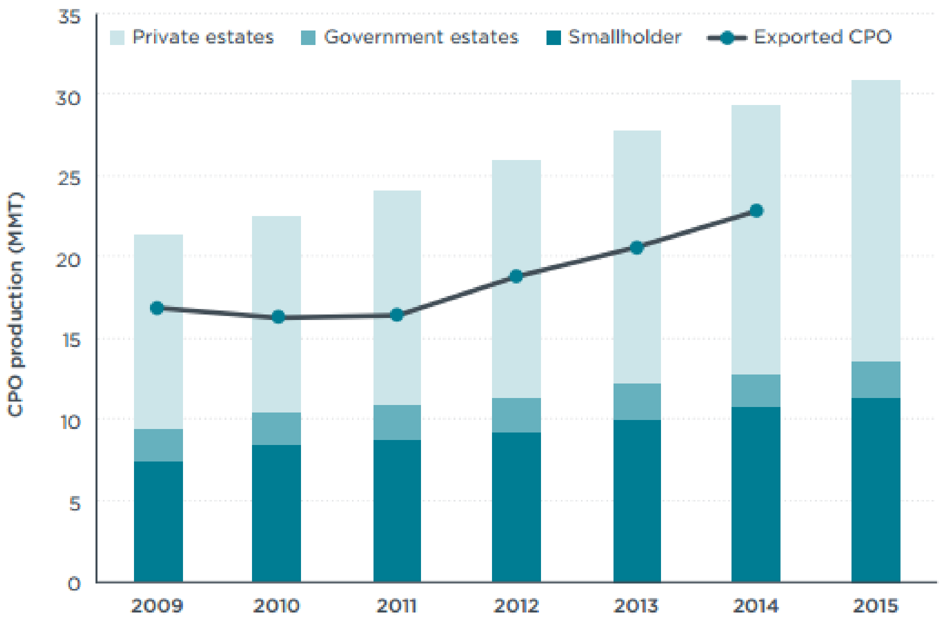


Figure 12. Palm oil plantation area from 2009-2015 divided in owner of estate (Statistics Indonesia, 2015).

Biofuel Related Policies, Laws and Regulations in Indonesia

In 2006, Presidential Regulation No.79/2014 established Indonesia's future outlook for biofuel goal in utilization and development; a “5% biofuel in national energy consumption mandate by 2025” (Kharina et al. 2016, p. 8). From 2008, MEMR issued a regulation for a biofuel blending mandate (MEMR Decree

32/2008) during 2008-2025, stating the biofuel mix in diesel oil and gasoline (BPPT, 2016). This mandate, domestically called 'the B20 program', has since then changed several times throughout the years. In the latest regulation, MEMR regulation 12/2015, the government implemented B20 for the biodiesel in the transport sector, which mixed biodiesel with 15% April 2015, 20% 2016 and will be 30% in 2030 (BPPT, 2016) (Table 3 and Table 4). The responsible actors for meeting this target is deemed to be end usage companies as well as companies who is licensed to sell fuels to end users, e.g. Pertamina (Indonesia's national energy company) or Shell (Kharina et al., 2016).

Until this date, the goal of this regulation has varying opinions whether it is being fulfilled. According to Wright and Rahmanulloh (2016) and New, Renewable Energy and Energy Conservation (2014), the mandate targets was not fulfilled in 2014, leaving the blending target at 73% fulfillment for Pertaminas's fuel (subsidized fuel) and from 9-35% fulfilled for other non-subsidized companies, with no penalties issued to august 2016 according to Kharina et al. (2016). It is also a discussion whether the domestic fuel consumption is enough in order to reach the blending quotes stated (Kharina et al., 2016).

In order to be able to fulfill the blending mandate, the government issued subsidies in order to erase the gap in between the prices for petroleum and biodiesel fuels, as the biodiesel fuels is generally pricier than petroleum fuels. According to IEA (2015b), the fuel subsidies goes up to three times more in money spending than the spending on infrastructure, causing Indonesia to have one of the world's lowest net import oil prices. These subsidies have in recent years been up for discussion since they have put a burden on the national budget. In consideration to this, most of the subsidies was abandoned from 2015, as for example fuel subsidies for gasoline. The government still subsides biodiesel through selling by the companies Pertamina and AKR Corporindo (Kharina et al., 2016).

In 2015, in continuation to the debate regarding subsidies for biofuels, it was decided the subsidy for biofuels was to be financed by a levy on palm oil and palm oil production export (Wright and Rahmanulloh, 2016). The palm oil export levy is collected by the Indonesian Oil Palm Estate found (BPDP) who manage it, and redistributes it as a subsidy to biofuel producers who manage the B20 mixing. As the sum of the levy is based on the difference in price between diesel made from fossil fuel and biodiesel, most of the sum collected by BPDP goes to support of the production of biofuels (Kharina et al., 2016). In 2016, the palm oil levy was at $1.2 billion, only accounting for a subsidy support for on average up to 15% biofuel blending, less than the 20% national blending goal for 2016 (Kharina et al., 2016).

The development of palm oil has in recent years been overshadowed by the growing environmental concern surrounding biofuels, as uncertainty about CO_2 emissions and land use impacts is questioned (Mukherjee and Sovacool, 2014). This has led to governmental intervention, as a policy was issued with Presidential Regulation No. 61/2015, which stated that funds are to be used to encourage sustainable palm oil plantation (hereafter POP) (BPPT, 2016). To regulate the palm oil industry to go in a more environmental direction, a palm oil export tax was for the first time issued in 1994 (Rifin, 2010), stating that when exporting any palm oil product, either pure or in goods, you are subjected to pay a tax. From July 2015, further changes were; the tax money should be used for research and promotion of the (BPPT, 2016).

Even though this fee and policy is in place, Elliot stated in 2015 there is a lack of sustainability perspectives in the regulation surrounding the handling of biofuels in Indonesia, especially biodiesel. According to Interviewee A[3] (see chapter 4), even though there seem to be an increased awakening in the sustainability issues regarding biofuels, there is yet no explicit regulation, policies and laws concerning for example the production of biofuels regarding deforestation. Indonesia has though expressed an interest in combating climate change and done several commitments to reduce GHG emissions nationally (Kharina et al., 2016). Moreover, a Roundtable of sustainable Palm Oil (RSPO) certification is also occurring in the palm oil industry voluntarily while an Indonesian Sustainable Palm Oil (ISPO) certification is mandatory for the palm oil plantations but voluntarily for the palm oil smallholders (Khatalina et al., 2016).

[3] Interviewee A, Personal communication, 10 April, 2017.

KEY REGULATIONS IN NUMBERS

National mandates for biodiesel (Table 3) and bioethanol (Table 4):

Table 3. Biodiesel mandate B20 as stated in MEMR regulation 12/2015. Compilation by authors based on data from BPPT (2016).

Sector	April 2015 (%)	January 2016 (%)	January 2020 (%)	January 2025 (%)
Transportation, Public Service Obligation*	15	20	30	30
Transportation, nonpublic service obligation**	15	20	30	30
Industry	15	20	30	30
Electricity	25	30	30	30

*Public service obligation is vehicle fuel sold through Pertemina, as a state-owned company. **Nonpublic service obligation refers to fuel sold by private owned companies.

Table 4. Bioethanol mandate as stated in MEMR regulation 12/2015. Compilation by authors based on data from BPPT (2016).

Sector	April 2015 (%)	January 2016 (%)	January 2020 (%)	January 2025 (%)
Transportation, Public Service Obligation*	1	2	5	20
Transportation, nonpublic service obligation**	2	5	10	20
Industry	2	5	10	20

*Public service obligation is vehicle fuel sold through Pertemina, as a state-owned company. **Nonpublic service obligation refers to fuel sold by private owned companies.

3. Methodology

3.1 Research Approach and Strategy

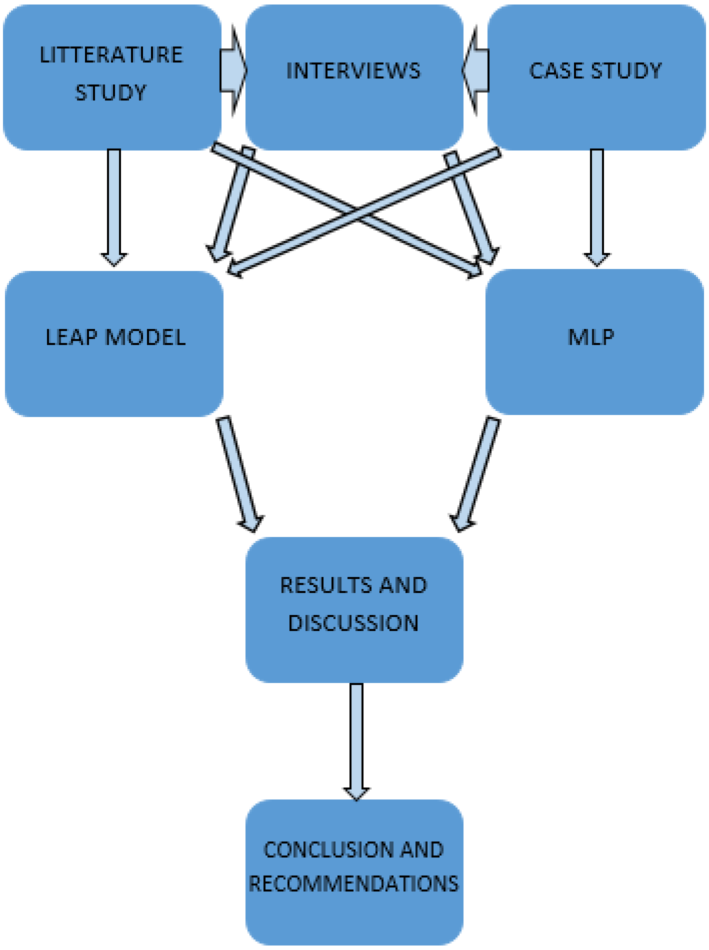


Figure 13. The conceptual framework and methodological approach of the study. Compilation by authors.

This study uses two tools, MLP - Multi-Level Perspective and LEAP - Long-Range Energy Alternatives Planning. The first one, the MLP analysis, is qualitative top down model, focusing on attacking the objective from the top to down and provide an analysis on the different barriers and the conditions for future development from a socio-technological perspective. The second one, the LEAP is a quantitative energy model for projecting future trends for biofuels in the transport sector, attacking the objective from the bottom and up. The resulting projections from the LEAP model also brings attention to possible barriers and possibilities from a technical perspective. In an integrated perspective, these two methods will provide an enlightening and concluding remark on the future possibilities for biofuels in Indonesia's transport sector in this thesis. The MLP analysis was used to identify the prominent barriers that prevents the different policy options of the LEAP scenarios from being achieved. The conceptual workflow of the thesis is presented in Figure 13. The tools will be further presented in chapter 3.2.

Moreover, the research approach to identifying barriers for renewable technology, were chosen in consideration of Painuly's report "*Barriers to Renewable energy penetration*" published 2001 (Painuly, 2001), where he recommends three approaches to identify suitable barriers in a selected country:

- Literature survey - search literature about the site, technology and surrounding complementing information.
- Site visits - visit the site and learn about important socio-economic matters and other important factors concerning the technology. A field study can be important when identifying barriers.

- Interaction with stakeholders - Interact with the stakeholders to obtain their perspective.

In compliance with this, this thesis is built upon integrating document analysis with empirical field work where interviews were conducted. After performing a literature survey on the subject, the authors visited Indonesia for two months during the 20th of March until the 15th of May 2017 to conduct a site visits and perform interviews with stakeholders. The literature review was mainly used in the background study and as a complement in the result part of the MLP analysis as well as general data inputs of the LEAP model.

3.2 Theoretical and Conceptual Framework

3.2.1 Framework for Determine Factors Hampering the Biofuel Development: The Multi-Level Perspective

Today's environmental problems, such as biodiversity or climate change, are what we call socio-technical problems. To be able to solve these problems, major changes must be done in regard to user practice, cultural behaviors and the market, but it also entails a transition towards new technologies (Geels, 2010). Existing systems as for example the transport sector, is a system that needs to be changed in all the aforementioned categories in order to generate a socio-technical transition towards sustainability (Geels, 2004).

The multi-level perspective (Geels, 2002, 2012; Geels and Schot, 2007) is a concept aiming to describe how system transitions happens with the help of an examination of the linkages in between technology and society (Geels, 2004). It's also widely used to describe sustainability transitions, which makes it especially suited for the transport sector as it refers to changed transport behavior as well as a change in both the market and the use of technology (Whitmarsh, 2012). In Figure 14, Geels (2004) shows an example of land based road transportation viewed from a sociotechnical system perspective.

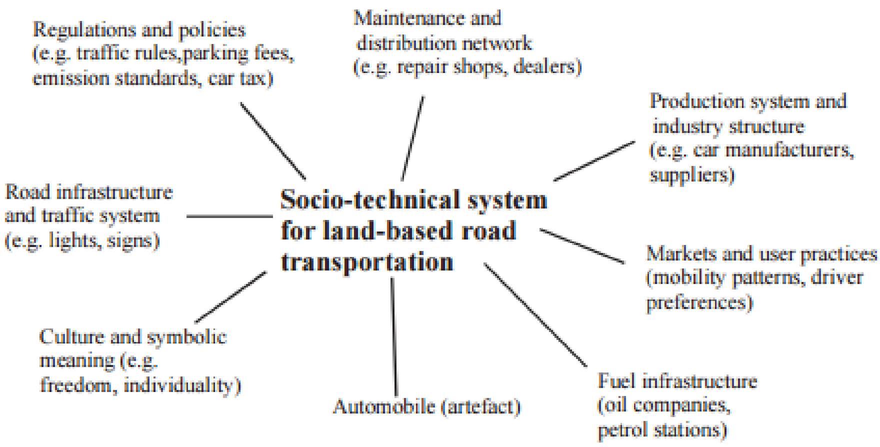


Figure 14. A socio-technical system perspective of land based road transportation (Geels, 2004).

The multi-level perspective was first mentioned in 1998 by Rip and Kemp and were later on further developed in a number of different articles (e.g. Geels, 2010; Verbong and Geels, 2007; Whitmarsh, 2012). The MLP, as its name entitles, builds on three different analytical levels within socio-technical systems; niches, socio-technical regime and socio-technical landscape as can be seen in Figure 15 below (Geels, 2012). These three levels provide different kinds of coordination and structuration of activities in the everyday life.

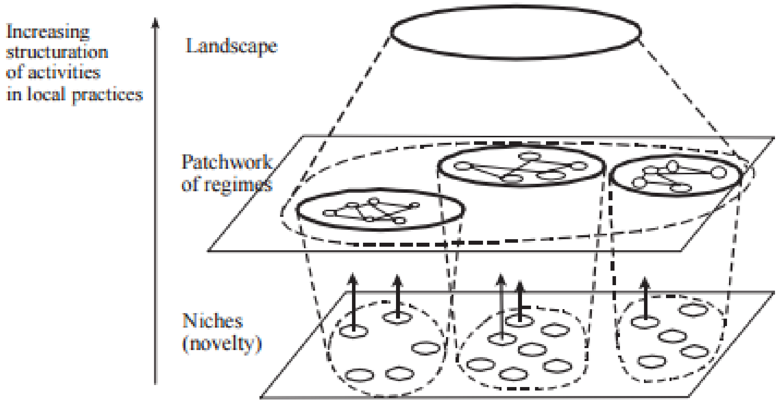


Figure 15. The three different levels in MLP (Geels 2002, p. 1261).

Niches; the Micro-Level

The first level, the niche level is the place which paws the way for new practices and discoveries by containing the radical innovations which later on can be enforced in the above levels as new learning material. It is also here where new social networks are built to support the new innovations which later on makes them part of a regime. (Geels, 2012)

Niche actors is those who works with the development of new technologies that doesn't exist in the existing regime, in hopes of one day implement their "niche technology" in the regime (Geels 2012, p. 473). This is also why the niches is so important; if a new innovation succeeds, it lays the foundation to a system change (Geels, 2004).

Socio-Technical Regime; the Meso-Level

Socio-technical systems are either maintained or changed by various social groups and actors, which behavior comes from already existing socio-technical regimes, rules that guide the actor's behavior and how they see the world (Giddens, 1984). Socio-technical regimes has several actors that affect the regime, as a socio-technical system is built upon several actors that interact with each other (see Figure 16) and are also often aligned with each other as they are in the same socio-technical regime and thus are affected by the same rules (Geels, 2004).

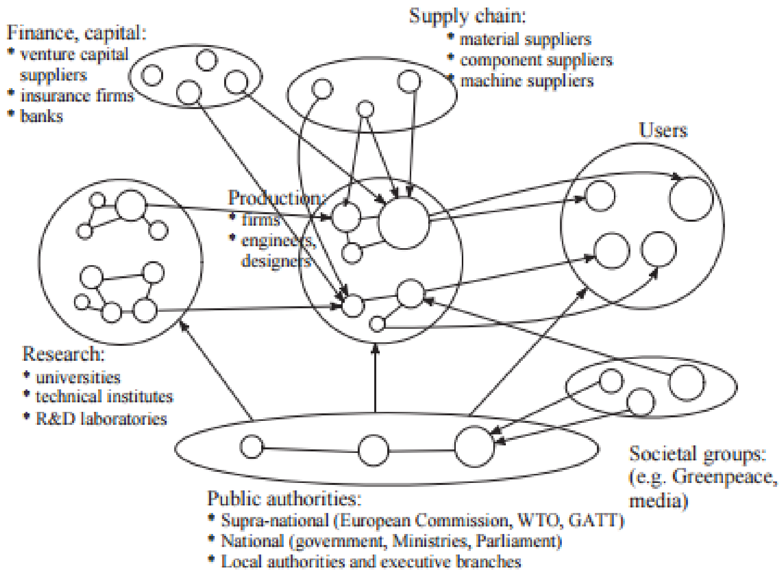


Figure 16. Socio-technical systems includes a number of different groups (Geels 2002, p. 1260).

The different regimes coexist with each other at the regime level, and one regime can entail several regimes under it. For example can the automobile regime be seen as the dominant regime over the subaltern transport regime, as the transport regime is made up by several different regimes e.g. the bus, cycling, motorcycle or train regime, which all goes under the concept of automobiles (Geels, 2012). Together these regimes all make up to one regime as they cannot be called niches due to the fact that they already have a fully developed net of laws, regulations, believes and associated feelings due to their long history, they are not new or emerging. Though, in the sense of their small regime occupation, they could in a sense be called "*small market niches*" (Geels 2012, p. 473).

A change of the regime can be hard due to certain lock-in mechanisms, such as economic barriers, laws and regulations, social shared beliefs and existing infrastructure (Geels, 2012).

Socio-Technical Landscape; the Macro-Level

The socio-technical landscape is an abstract concept describing the environment in which socio technical development occur (e.g. globalization or economic and political changes) and can be viewed as something that maintain our surroundings (Geels, 2012; Rip and Kemp, 1998, p. 334). This include the material aspects of the society, such as transportation, housing and how a city is built in terms of infrastructure but also ideologies, morals and political development (Geels, 2004; Geels 2012). A landscape is hard to change and cannot be directly influenced by individuals direct will, which can put pressure on the regime as the landscape 'controls' their behavior, which makes development at this level relatively slow (Geels, 2004).

A Transition Change Towards Sustainability According to the Multi-Level Perspective

A transition is only happening if linked developments occur at all three different levels (Geels, 2002). According to Geels and Schot (2007, p. 400), for a transition to happen, the niche regime can put pressure on the other levels by price changes, learning processes or lobbying with the help of powerful actors, landscape changes can put pressure on the regime and the regime can be unstable due to inner pressure which is opening up opportunities for the niche actors. It is important that the landscape is with on the transition, as it is the landscape who puts pressure on the regime to change, for example by forcing the regime to consider new technologies.

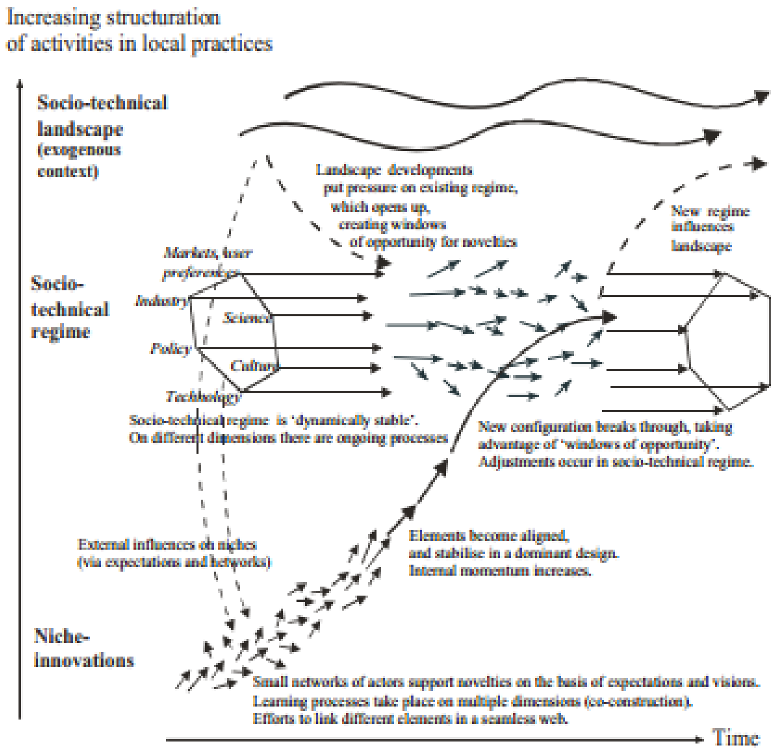


Figure 17. Transition shown by the MLP (Geels 2002, p.1263).

Geels (2004) and Geels and Schot (2007) also talks about four phases when a system breakthrough takes place (see Figure 17). The first phase, shows the new technology emerging and take its spot under the regime and landscape. It's an early design of the innovation, often without a finished design and many similar products to compete with. The second phase is when the innovation has gained ground in form of user practices, a steady development with engineers and scientists and thus, its own place in the niche regime. The third phase focus on the breakthrough of the new technology. According to Geels and Schot (2007), there is either internal drivers that push for a breakthrough, such as price changes or actors interest clashing, or external pressures such as landscape pressures at the regime level. There may also be negative externalities from the usage of the technology, that changes the thoughts of the technology.

The third phase, the transition pathways when a niche technology gets a breakthrough, can be of four different categories according to Geels and Schot (2007), which can happen either alone or in combination;

1. The first way, **Transformation**, is where landscape changes pushes the regime to change. Here, the niche technologies cannot take fully advantage of the landscape changes but nevertheless, regime actors are able to take on some important new niche features.
2. The second way, **De-Alignment** or **Re-Alignment**, happens when landscape pressures comes sudden and hard, causing the different niche technologies to compete for a spot as a regime technology, which eventually causes one to win.
3. **Technological substitution**, is when a sudden destabilization of a regime happens due to hard landscape pressures, causing a fully developed niche technology to break through to the regime level after having been repressed by the regime.
4. The fourth way, **Reconfiguration**, occurs like the first way by mediate pressure from the landscape but in comparison to Transformation, these changes lead to changes in the framework of the system, such as user practice or rules.

To note here is that these categories is the ideal, it is not often this happens as smoothly as stated. Often infrequent changes happen in the landscape, forcing first one pathway to act as a solution and then moving on to another when another change hits.

In the fourth phase, in time, the niche technology replaces the old technology and gain its own dimension in the socio-technical regime. It may also influence the landscape regime to a larger extent. (Geels and Schot, 2007)

Application of MLP in This Study

The MLP parts in this study is mainly be built upon the MLP concept developed by Geels (2002, 2004, 2010, 2012) and interviews with key stakeholders, as "*MLP can be used for making comprehensive analyses of the possibilities, barriers and drivers of transitions towards sustainable transport*" (Geels 2012, p. 481). To support the MLP analysis and put forward thoughts and considerations from stakeholders from the biofuel sector, interviews were used to investigate the different MLP levels, interactions in between and to make barriers more distinctive.

The MLP was a fitting tool to use in this study regarding identification of barriers due to mainly three reasons:

1. MLP has a "*system-wide focus and consideration of 'outsider' and radical perspectives*" (Whitmarsh 2012, p.5), MLP has also been described as a good framework when handling socio-technical problems related to unsustainability. Due to current mobility systems and sustainability related problems being such a broad problem ranging over economy, social and technical perspectives, a solemnly technical examination of new sustainable technology such as biofuels is not possible as it will only address a small range of problems, e.g. noise problems from vehicles also influence problems such as biodiversity and quality of life. MLP research helps determine also these unexpected outcomes and highlight the actor's involvement in bringing about the social change.
2. Due to biofuels being an emerging technology aiming to replace the fossil fuels, MLP is also seen as a fitting perspective due to its examination of transitions change of sustainable technology "*fruitful*

middle-range framework for analyzing socio-technical transitions to sustainability" (Geels 2011, p.24) and helps to describe the development of biofuels within each MLP level.

3. Geels (2012) used the MLP for the transport sector, by describing different emerging niche developments, how the landscape develops, how stable the regime is and by looking at cracks in the regime, possible for letting a niche innovation through. This gave him a good perspective of possible barriers regarding the niche transition, something that this thesis seeks to accomplish.

MLP has been used as a guide and framework in this study to capture the factors that influence the implementation of biofuels, allowing this framework to explore key barriers to biofuel implementation. A socio-technical system perspective of land based road transportation from Geels (2004) was used as a basis to understand how the MLP perspective worked in the transportation sector, which this thesis examines. It sets the ground for MLP in a transport sector.

The multi-level facilitated the examination of the implementation of biofuels in Indonesia's transport sector as it allowed a view of multiple level factors together and their interactions and contrast against each other, which made the identification of barriers clearer. By looking at biofuels in Indonesia's transport sector, factors and processes is examined across the three MLP levels; niche-level, regime-level and landscape-level. This will also lead to an identification of the underlying structures in the biofuel sector in Indonesia.

This thesis further used the MLP to examine the barriers for a development and a possible transition of biofuels as a niche technology in the transport sector in Indonesia. The concept of landscape was used to show the external pressures the regime was under and in which context the landscape changes the regime, the regime concept was used to show dominant key actors and elements and the niche describes biofuel as the new innovation trying to break through or transcend into the regime. The MLP builds up a system for how biofuels interact in Indonesia and how the different levels work in between themselves. The barriers are those barriers that prevent the biofuel niche to enter the regime in Indonesia.

A Transition Change Towards Sustainability According to the Multi-Level Perspective (see the paragraph above) brings forward theory on how this transition is supposed to work from a multi-level perspective, further highlight what needs to happen for a development of the biofuel sector and thereof, possible barriers. This theory was also used to highlight where in the transition path biofuels in Indonesia's transport sector are today, with the help of identifying transition pathways that has occurred or is occurring in Indonesia, e.g. outer pressures that has influenced the regime to take it to where it is today. From this, some barriers could also be identified as the pressures against the transition or development of the biofuel sector.

As socio-technical systems includes several different groups, it was important to get each of the groups view on how the development of biofuels in Indonesia's transport sector were transpiring, to get 'voices from within' the biofuel sector. This was done through a number of interviews with different stakeholders, where Geels (2002) theory were used as a ground for identifying these groups to get a full cover of groups for the MLP analysis. These stakeholders shape the direction of the development, therefore making it important for them to counteract the identified barriers. For more information on how the interviews were made and built up, see chapter 4.

3.2.2 Projections and Scenario Analysis with LEAP: Indonesia's Transport Sector by 2030

LEAP is a software tool created by the Stockholm Environment Institute that has a wide range of applicability and have been used globally for energy policies, environmental planning and development strategies (Emodi et al., 2017; Heaps, 2016; Nojedehi et al., 2016). Some of the features included are both supply and demand side projections of energy demand, GHG emission and resource consumption for different scenarios (Heaps, 2016). Therefore, LEAP is well suited for this research as it has been used in similar studies such as in the analysis of the energy demand of the transport sector and energy policies in Korea, Pakistan and India (Bose and Srinivasachary, 1997; Hong et al, 2016; Shabbir and Sheikh, 2010). LEAP have also been used to evaluate the impacts of different policy actions through scenario analysis in

Nigeria and previously in Indonesia (Deendarlianto et al., 2017; Emodi et al., 2017). LEAP was also used for INDC:s reports by more than 30 countries (Heaps, 2016; Kemausuor et al, 2015; Mengistu, 2013).

Model Framework for LEAP in this study

To answer the questions of *What is the projection of the Indonesian transport sector by 2030 in terms of fuel consumption and GWP and what role could biofuels play in reducing those?* the LEAP model in this study is designed to produce the necessary results through estimating the energy consumption and GWP emissions in the study area, Indonesia's transport sector (for limitations, see chapter 3.4). In the LEAP model, scenarios was used for examining different policy actions as well as a business-as-usual scenario. The model consists of six data input components which are divided into four major modules that is presented in the conceptual framework as depicted in Figure 18 and compute outputs for each of the scenarios. The input data will be collected from literature as well as from the interviews and will then be processed by the LEAP tool to form new inputs for the next part of the model. The new input is then combined with further input to continue until the model is finished. The different components will be explained in detail below in the LEAP calculations.

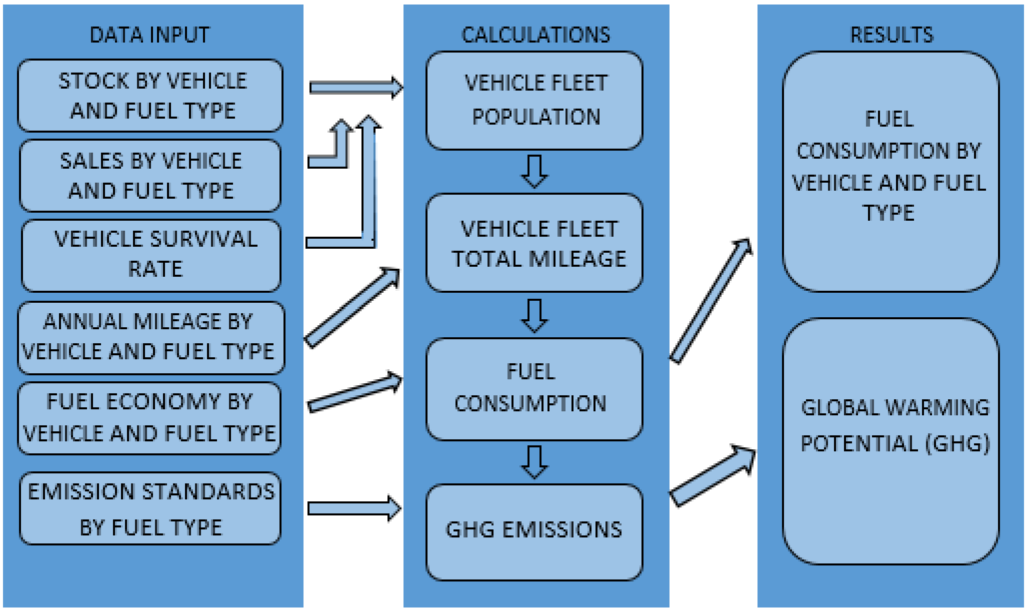


Figure 18. The conceptual framework of the LEAP modeling work process. Compilation by authors.

LEAP Calculations

The first module were built up by a number of factors. Firstly, the current stock of vehicles in the fleet was determined by using official statistics in conjunction with the sale trend in order to create the required input to form a projection of the vehicle population. In this part, there was a division between each type of vehicle and engine size as well as by fuel to reflect the real situation and to gain more detailed results (see chapter 4). This was useful for identifying the effects of changes on a more specific level.

For module two, the different annual mileages were added for each type of vehicle the LEAP model used together with the fleet population output (of module one) to produce the total activity of the vehicle fleet in terms of distance travelled. The annual mileage of vehicles will decrease as the vehicle ages to account for real conditions (National Center for Statistics and Analysis [NCSA], 2006). As there is no specific data on Indonesia for the rate of decrease, it was assumed that the decline would follow the same trend as for USA, based on data from NCSA shown in Figure 19.

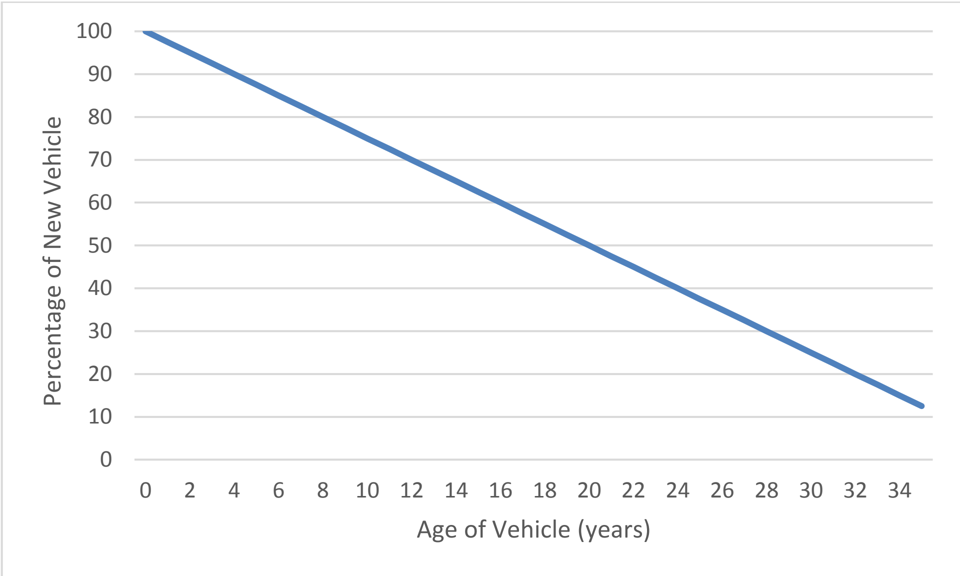


Figure 19. The vehicle mileage by vintage. Compilation by authors based on trends from NCSA (2006).

The vehicle specific fuel economy was then added to module three where LEAP calculated the total fuel consumption with the use of the previous output of module one and two. This was done by multiplying the fuel economy with the mileage for all of the vehicles in the fleet. This was summed up in the final module, where the GWP of the vehicle fleet was computed by multiplying the total fuel consumption with the specific emission factors for each fuel.

The LEAP model is based on two core concepts; the stock turnover and the survival rate of devices which both directly influence the stock component. The LEAP model uses the following equations [1] and [2] to calculate the current vehicle population.

Eq [1] $$Stock_{c,y,v} = Sales_{c,v} * Survival_{c,y-v}$$

Eq [2] $$Stock_{c,y} = \sum_{0}^{v} Stock_{c,y,v}$$

c=category of vehicle
y= year in the LEAP model
v=vintage of the category
Stock= number of vehicles in a specific year
Sales= number of vehicles added in specific year
Survival= portion of vehicles that have survived after a period of time

In equation [1] the stock of a specific category and vintage in a certain year is the number of sales for that year and the portion of vehicles surviving until that year. For equation [2] the total stock of a particular category is the sum of stock of that category over all of the vintages.

The survival rate is based on a lifecycle profile that estimates how many vehicles survives for each passing year based on the age of the vehicle. The lifecycles used in this model follows the exponential features in equation [3].

Eq [3] $$S_y = S_{y-1} * EXP^{(y*\alpha)}$$

S= survival rate
y= year in the LEAP model
α= a constant value

For the model, there will be two different lifecycle profiles used, one for cars and one for motorcycles, the constant exponent is found based on average lifetime for the vehicles in literature. For cars, the median age is estimated to be 13.5 years from studies in the UK and USA, due to lack of studies on this subject in Indonesia (NCSA, 2006). According to Interviewee E[4] (see chapter 4), the average lifetime of motorcycles in Indonesia is five years therefore the survival rate was adjusted to account for it. In this model, there is no forced retirement for any vehicle at a certain age as Indonesia have not implemented such legislations. For the lifecycle profile of cars and motorcycle see Figure 20.

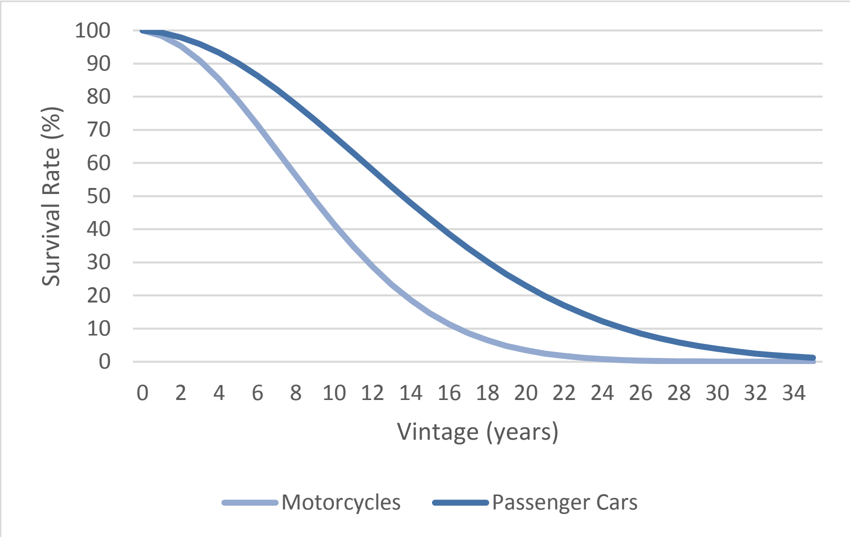


Figure 20. Lifecycle profile for passenger cars and motorcycles. Compilation by authors based on trends in NCSA (2006) for passenger cars and estimations of Interviewee E[5] (see chapter 4) for motorcycles.

LEAP Scenarios

Scenarios are in this study used as a tool to examine the outcomes of different policy actions and their impacts in the future projections. For modeling purposes, the Business as Usual scenario was based on the premises that current trends would continue without any changes. There are three alternative scenarios which are based on the Business as Usual scenario and the results are compared to the Business as Usual scenario and the base year when applicable. The scenarios are: Improved Standards, Biofuel mandate and Low Carbon. A brief summary of the scenarios is presented in Table 5, while a more detailed description is presented below.

[4] Interviewee E, Personal communication, 12 April, 2017.
[5] Interviewee E, Personal communication, 12 April, 2017.

Table 5. Summary of the different scenarios. Compiled by the authors.

Scenarios	Description	Assumptions	Actions
Business as Usual	The continuation of the current situation.	Sales continues as current trend and the biofuels remain at current blending shares.	None
Improved Standards	Raising the emission standards to a higher Euroclass and fuel economy improvements.	The fuel economy improves by 2% annually. Emissions standards are reached at a linear rate.	Implementing Euro4/5/6 in 2019/2025/2030 for cars Implementing Euro4 in 2025 for motorcycles
Biofuel Mandate	The effect of achieving the biofuel mandate for biodiesel and bioethanol.	Biodiesel the rate of success is 80/100% in 2017/2025 Bioethanol the rates are 50/70/100% in 2017/2020/2030	Biodiesel at 20/30% in 2016/2020 Bioethanol at 5/10/20% in 2016/2020/2025.
Low Carbon	Alternative scenario for further actions to reducing GWP and fossil fuels with vehicle paradigm shift and introduction of electric vehicles.	Diesel sales will increase to 15% until 2030, with a three times higher rate for affordable energy saving cars and multi personal vehicles 1500. The sales share for multi personal vehicles 2500 and SEDAN 3000 will decrease by 50% at 2030, for multi personal vehicles 1500 60%.	50% biodiesel and 40% bioethanol in 2030. Electric vehicle sales share 5/25/45% in 2019/2025/2030 for motorcycles and affordable energy saving cars.

Scenario – Business as Usual

In the Business as Usual scenario, it is assumed that current growth patterns continue as described above and that the relative sale shares for car by models and fuels remains unchanged. Moreover the fuel economy will be considered to be constant. The biodiesel share in diesel will remain at 5.7% throughout the period and the bioethanol mix is predicted to remain unenforced and continue at 0%.

Scenario – Improved Standards

The scenario is examining the impact of a stricter emission policy and fuel economy improvement would have on the GWP and fuel consumption of the transport sector. The fuel economy is expected to increase due to more efficient vehicle models and new driving patterns on an annual basis of 2% which is on par with global average (Global Fuel Economy Initiative, 2014). The emission standards are based on the standards used in EU, where the first restriction on emissions were referred to as Euro1 and each following standard have increased the restriction. By the time existing models had to comply with the Euro2 in Indonesia, China had reached Euro3 while India had Euro3 in cities (CAA, 2016b). Additionally, many countries have had plans to implement higher Euro class before 2017 (CAA, 2016b). However in 2017, it was declared that Indonesia will increase their emission standard to Euro4 and be in effect immediately (Gaikindo, 2017).

It is presumed that Indonesia follows through with their implementation of fuel standard Euro4 as announced and will be finalized in 2019 for cars and in 2025 for motorcycles. Moreover is it assumed that for cars Euro5 is reached in 2025 and Euro6 by 2030 for Indonesia. The standards are expected to be implemented at a linearly rate. For the different standards, see Table 6.

Table 6. Emission standards for the different vehicles. Compilation by authors based on data from The Automobile Association (2015) and EU (2013).

Emissions (g/km)	Car (Gasoline) Eu4/Eu5/Eu6	Car (Diesel) Eu4/Eu5/Eu6	Motorcycle (Gasoline) Eu4
CO	1.0/1.0/1.0	0.5/0.5/0.5	1.0
NO_x	0.08/0.06/0.06	0.25/0.18/0.08	0.17
HC	0.1/0.1/0.1	0.05/0.05/0.05	0.63

Scenario – Biofuel Mandate

For the Biofuel Mandate scenario, the possibility of fully achieving the biofuel blending mandate and reaching the biodiesel target by 2030 as well as implementing the bioethanol target will be investigated. For the realization of the biofuel mandate, it will be assumed that the rate of fulfillment is increased linearly from 80% of 2017s target in 2017, 90% of 2020s target in 2020 and 100% of 2030s target in 2030, all based on the interviewees. The bioethanol target will be fulfilled in a similar fashion as the biodiesel target but linearly reach 50% achieved in 2017 to then increase to 70% in 2020 and 100% in 2030. This scenario was created to determine the effectiveness of the biofuel mandate if fully realized.

Scenario – Low Carbon

The Low Carbon scenario is used to estimate how much of a reduction can be achieved if more actions were taken on both a governmental level with policies as well as on a public level through consumption patterns changes. On the governmental level the biofuel mandate is fulfilled as in the Biofuel Mandate scenario but additionally the share for biodiesel will reach 50% and bioethanol will reach 40% in 2030 to further reduce fossil fuel consumption. Moreover electric vehicles will be implemented in the scenario in order to replace gasoline vehicles at a market sale share of 5/25/45% in 2019/2025/2030 for motorcycles and AESC. The fuel economy of electric AESC is 15 kWh/100km and 4.5 kWh/100km for motorcycles (Weiss et al., 2015). Gasoline will also be replaced with diesel as the diesel penetration will increase to 15% by 2030. For the two gasoline cars with the highest sales share, AESC and MPV 1500, the diesel penetration will be tripled. There is also assumed to be a paradigm shift to smaller vehicles as the preferences of the public will be towards more fuel efficient vehicles. Therefore the sales shares are projected to gradually decrease to 50% for MPV 2500 and SEDAN 3000 and to 40% for MPV 1500, these sales are added to the sales of the alternative AESC.

3.3 Identification of Relevant Renewable Energy Penetration Barriers

From the empirical data collection emerged several analytical articles concerning the barriers for a successful penetration of renewable energy. Two articles were used in regard to this subject to create a list of possible barriers regarding the Indonesian biofuel sector; *Barriers to renewable energy penetration; a framework for analysis* (Painuly, 2001) and *Diffusion of renewable energy technologies— barriers and stakeholders' perspectives* (Reddy and Painuly, 2004). Both these articles were picked due to a high research significance and credibility.

With the first main question, one of the main aims was to present a number of key barriers for the Indonesian biofuel sector. With the help of the two above articles, six barrier categories were identified, which later on will help answering main question one: financial and economic barriers, market barriers, technical barriers, institutional and regulatory barriers, social, cultural and behavioral barriers and other barriers (Table 7). These barriers can then be linked to the scenarios for the LEAP analysis as seen in the discussion and conclusion of the report.

Table 7. Barriers and their description. Compilation by authors based on Painuly (2001) and Reddy and Painuly (2004).

Barrier Category	Description of Barriers
Financial and Economic	Mainly concerns lack of or a too high cost of capital in regard to investments, rates or credit. Also includes lack of financial institutions.
Market	Includes market failure/ imperfection and distortions. This include trade barriers, investments creating barriers for other technologies and missing market infrastructure.
Technical	Lack of standard codes, technical reliability and actors such as entrepreneurs and specialists. Lack of facilities specializing in the technology.
Institutional and Regulatory	Lack of institutions, framework, rules, R&D culture and specialized institutions. Lack of transparent information.
Social, cultural and Behavioral	No social or consumer acceptance. Constraints on time or interest can lead to less engagement. Lack of or no access to relevant information. Awareness is not as high as it should be.
Other Barriers	Environmental, political or infrastructural barriers.

These key barriers will later help to analyze the interviews with the thought of bringing forward barriers perceived to hinder the development of the biofuel sector. Most of these barriers are according to Painuly (2001) either fitting for all renewable energy technologies or just one certain technology or area, but in this case, they are all chosen from the aspect of biofuel technology in the transport sector in Indonesia.

3.4 Research Scope and Limitation

The scope of the research questions is different from each other as the scope of the energy model (answering question two) is limited to the passenger transportation of passenger cars and motorcycles while the MLP analysis (answering question one) covers the biofuel sector and it's connection to relevant sectors as seen in Figure 21. Moreover, due to only looking at biofuels in the transport sector, this generally only concern liquid biofuels, whereas biogas or biomass are not discussed in this research.

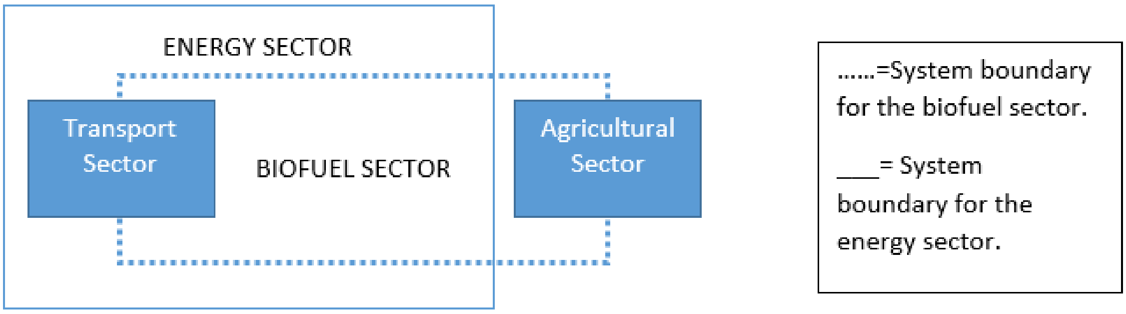


Figure 21. System boundaries for the MLP analysis. The system boundary for the biofuel sector represents the system boundary for the MLP analysis. Compilation by authors.

Biofuel technology can be of three different categories; biodiesel, bioethanol and bio-oil. The bio-oil production is almost non-existent in Indonesia, currently only 5% of all the utilizing biofuels according to MEMR (2015). For 2025, this number is supposed to decrease to 4%. Due to the small amount of bio-oil produced in Indonesia, bio-oil will be excluded in this report. Because of this, bioethanol and biodiesel are going to be the only biofuels of interests in this report. The scope is therefore bioethanol and biodiesel in Indonesia's transport sector.

Several limitations have influenced this research in different ways, where the limitations for the MLP analysis is presented first.

The levels for the MLP analysis will be examined as a whole (as biofuels) and not divided into bioethanol and biodiesel specifically, even though different aspects will be presented individually when exemplified in the interviews.

Not all generations of biofuels are discussed in the MLP analysis. The limit is drawn by only looking at the existing biofuels currently functioning in Indonesia; the first generation biodiesel and bioethanol are used as fuel whereas the second generation biodiesel is still in the research stage, and they will therefore be the only biofuels discussed in this report (Wright and Rahmanulloh, 2016). The third generation bioethanol, biofuels mainly from algae, only has a very limited utilization in Indonesia, and is therefore not discussed in this report (Wright and Rahmanulloh, 2016). The second generation of bioethanol doesn't exist in Indonesia[6,7].

In the interview stage of the report, all of the asked stakeholders were not able to participate in the study. Important stakeholders from for example NGOs related to biofuels, important Indonesian ministries and fuel distribution companies such as for example the ministry of energy and mineral resources, Pertamina or Greenpeace, were not included into the interviewed stakeholders, which needs to be taken in consideration when reading this study.

Another limit were the barriers brought forward in this study. All the barriers were in relation to renewable energy, which affected the shape of the barriers presented in this study.

For the LEAP model there are certain limitations and assumptions, the general of those will be presented here while specific ones will be in the data chapter where they are used. The time period investigated is 2014-2030 with 2015 being the first calculated year. Geographical boundary is the same as the nation's border, however sea and air transportations are excluded as the report will only focus on the land transportation and more specifically road transportation for passenger as rail and freight is excluded as well. The primary focus of the investigation is on the impacts on the personal vehicle fleet explicit on cars and motorcycles, therefore buses and registered taxis are not accounted for.

The fuels used for the LEAP modelling are diesel, gasoline, biodiesel, bioethanol and electric. Diesel and gasoline were chosen as they are the main basis for the current vehicle fleet. Biodiesel have been introduced into the fuel mix and will also be used as a base in order to evaluate the impacts of biofuels. Bioethanol have so far not been implemented but will be used for comparison purposes. It is assumed that diesel is mixed with biodiesel and gasoline is mixed with bioethanol when applicable. For emissions only the tank to wheel parts are considered therefore biodiesel, bioethanol and electricity are considered carbon neutral and have zero GWP.

The changes in the scenarios are assumed to happen continuously and with total compliance with the specific conditions added. Additionally, it is presumed that all the vehicles are on par with the current emission regulations and that there is no difference amongst the vehicle stock in terms of vehicle efficiency and emission outputs even though the vintage differ. For simplicity, it is assumed that the demand for fuels are always met in the LEAP model.

[6] Interviewee C, Personal communication, 11 April, 2017.
[7] Interviewee B, Personal communication, 10 April, 2017.

4. Data

4.1 Methods for Data Collection and Analysis

4.1.1 Data Collection

This study focused on a socio-technical transition in the making, building upon an integrating document analysis with empirical field work. Material from secondary sources such as scientific articles, case studies and relevant scientific books is mixed with semi-structured interviews that lays ground for the result, mainly for the barrier analysis but also for specific key input data for the projection of the transport sector, which could not be found in literature, such as the fuel division between gasoline and diesel cars.

The scientific articles were located by using the two databases; Google Scholar and Scientific direct, as these databases both is known to give clear and objective research. The sources used were also peer-reviewed (evaluated by two or more experts), which increased the source's credibility (Creswell and Miller, 2000).

For the projection of the transport sector, data were collected from relevant sources of that category. Emissions standards were for example collected from governmental sites while vehicle sales were found from the official Indonesian industry associations, whereas the fuel emissions literature came from reputable scientific sources such as the Intergovernmental Panel on Climate Change and the European Commission (European Commission, 2017; IPCC, 2007). As much of the specific data regarding Indonesia is limited, estimations were made from more well documented international regions such as Europe and USA (Hirota, 2010; Widyaparaga et al., 2017). The specific conditions for Indonesia's transport sector were found in technical reports from credible institutions such as the Asian Development Bank and official policy document from the Indonesian government.

The literature review had several aims, to find detailed information about the biofuel technology and possible barriers in its development, to collect information about Indonesia, actors and sectors related to biofuels in Indonesia and find important numbers and features with the biofuel technology in general, even already existing problems with the sector which possibly could give insight into possible barriers. It was also used to look at possible barriers for already existing renewable technologies.

This thesis is also built upon semi-structured interviews to complement the document analysis. The semi-structured interview form was chosen due to its ability to "*provide reliable, comparable qualitative data*" (Cohen and Grabtree, 2006). It is also an interview form that allows the interviewee to participate in an active way in the interview due to a certain freedom in answering the questions as pleased (Cohen and Grabtree, 2006). The interview is following a beforehand conducted "*interview guide*" with prepared questions and topics, but the interviewer is allowed to ask follow-up questions as well as straining a bit from the format of the interview, allowing for more in-depth interviews, more adapted to the different interviewees (Bernard, 1988; Jacobsen, 2002).

The participants in the interview were chosen with the help of purposive sampling; where the interviewees were chosen due to their particular characteristics and suitability to enable the research question of the study to be fulfilled (Teddlie and Yu, 2007).

The selection of interviewees was discussed with researchers at the Division of Energy and Climate Study at the Royal Institute of Technology, Sweden. From there, several interviewees were chosen due to their suitability for the study by the authors of this thesis. When choosing the interviewees, two criteria's were utilized;

1. They had to have a close relation with the biofuel sector in Indonesia, either by working directly with biofuels in some way or by working with a topic closely related to the biofuel technology. Due to this, the interviewees in the study were all chosen to be different stakeholders, here defined by Freeman as "*any group or individual who can affect or is affected by the achievement of the organization's objectives*" (Freeman 1984, p. 46) in the biofuel sector of Indonesia.

2. They should come from a large variety of stakeholder categories to do an accurate and elaborative MLP analysis. Together these stakeholders can give a diverse perspective of the development of the biofuel sector in Indonesia. The diverse perspective is particularly important since a MLP analysis requires a diverse perspective from key stakeholders to produce an accurate MLP analysis and complement the literature review (see chapter 3.2.1).

Table 8 shows interviewees described as letters due to protection of anonymity and confidentiality.

Table 8. Stakeholders' occupation, organization type and assigned letter. Compilation by authors.

Interviewee	Occupation	Organization type
A	Researchers	Academic
B	Consultant/Researchers	Company/Private
C	Energy Planning modeler	Governmental*
D	Senior engineer/Lab	Governmental*
E	Manager/Division head for promotion and marketing	Producer/Private

*Agency under the coordination of governmental ministry.

Interview Design

In order to conduct the interviews, methods used by Ziniel (2015) and Valenzuela and Shrivastava (2008) were used and due to a ranking exercise taking place, complementary methods were used by Case (1990). All interviews were conducted in person and in English. Due to maintaining a full capture of the interviewees answer, one author was assigned to be the interviewer and the other took notes.

Five semi-structured interviews were conducted in five different locations, all quiet and non-disruptive to get as accurate answers as possible. In some of the interviews, more than one participant was present but due to their similarity in occupation and background, their responds were all recorded due to their stakeholders' category.

Prior to the study, an extensive pre-study of interview techniques and the study area were conducted as to reduce possible biases and increase the reliability of the data collected. This was especially important as the interview were done in English, which were not the native language of either of the interviewer or the interviewee. Before conducting the interviews, an interview guide was also made, which were divided into two parts; the start of the interview and the actual questions and consisted of 21 questions and one ranking exercise (see Appendix A).

It was conducted in English. A digital recording were also on the entire interviews after permission from the interviewees. For more information regarding the interviews and interviewees, see Appendix A and Appendix B.

The first part included a presentation of the study as well as the interviewers, presenting of support letter from The Royal Institute of Technology and as well a small reminder of the importance of answering elaborate and to stick to the question. The next part entailed the questions for the interview, divided into seven parts; 1. General information about the interviewee, 2. General about biofuels in the transport sector of Indonesia, 3. Indonesia, Biofuels and sustainability issues, 4. Factors of influence, 5. Ranking exercise, 6. Policies, subsidies and targets of biofuels in Indonesia and 7. Biofuel development in Indonesia.

The first two topics aims at giving an overview of biofuel in Indonesia, possible known problems and opportunities with them in general whereas the third topic aims at describing what and who brings the biofuel sector forward and why or why not. The fourth topic aims at looking how governmental incentives develop and are applied in Indonesia, but also how significant part they have in the development of the biofuel sector. This also gives a notion of how transparent these regulations are outside governmental sectors. The last topic entails how the stakeholders look at the development of the biofuel sector but also challenges in the development.

The ranking exercise brings forward who aids the development of the biofuel sector and more importantly, why or why not they bring forward it. Furthermore, was it used to identify the most influential stakeholders and why or why not they had the most influence. Depending on how influential the actors were deemed to be, the greater their potential were to influence the further development of the biofuel sector. The ranking also gives a good insight into their interaction in between them and whether if the interaction was good or bad, therefore also helping to identify several barriers.

The Ranking Exercise

1. The interviewees were presented with the equipment as the ranking exercise were explained to the interviewees. The interviewees were also reminded of the importance to be as complete and accurate as possible.
2. The equipment was:

-The first tool were four paper cards with the categories:

- The government
- The public
- The private companies
- The researchers

Each card had a different description on them to represent their category.

-The second tool were a paper with the number one to four on it, in a column starting with one from the top to four at the bottom.

3. The interviewees were then asked to rank in order from one to four the most influential group in the development of the biofuel sector of the cards and explain why they chose as they did. They were to do this with the help of the tools, as they were then to put the cards (tool one) on responding number on the paper (tool two). Number one had the highest influence. A maximum of two names could be put on the same number of influence to ensure that all views were being presented without interference of the interviewer.

To conclude the result, the ones with the highest influence got number one, next highest influence got number two and so on. These numbers were then summarized and put in order of lowest number- highest influence depending on summarized number for the result part.

All ranking exercises were done in compliance with the work by Case (1990).

4.1.2 Data Analysis

For the data analysis, first of all, the interviews were gathered together and transcribed into notes as soon as possible after the interviews had ended. This were to avoid any misinterpretation of the interviewees answer and as well verifying answers when the information was fresh. An emphasis was made to try to do the transcription as accurate as possible with exact wording and expressions. The data were then analyzed to try to answer the research questions and looking for similarities and links in between them.

In combination with the complementary data collection of the literature review, patterns and phenomenon of interest occurs, leading to answers to the research questions as perceived in the result section of the thesis. This part of the thesis is therefore in overall based on a transcription of the interviews, with a combination of the literature studies of Indonesia and the biofuel technology, creates a revealing and expressive approach.

Ethical Approval

Potential interview participants were contacted by email and all stakeholders who agreed to take part in the study gave their consent at the interview in person. The stakeholders were also showed a support letter from The Royal Institute of Technology. To increase truthfully answers and openness from the participants, they were informed of their confidentiality of their answers and that they would be anonymous in this thesis. Moreover, the participants in the interview were informed that their responses would be used solely in the study and not published somewhere else.

4.2 Data for Projections and Scenario Analysis with LEAP

Vehicle Population

For Indonesia, there are currently no data available on the composition of the vehicle population other than the classification used for the BPS statistics which divides vehicles into either motorcycles, passenger cars, trucks or buses. Motorcycles has no further division and will therefore be considered uniform for the sake of modelling, while trucks and buses will not be investigated in this report.

However, as the Association of Indonesian Automotive Industries (hereafter Gaikindo) offers a more detailed classification of passenger cars sales, those will be used to add accuracy in the LEAP model since it will better reflect real conditions. In Gaikindo's sale statistics, passenger cars are divided into either multi personal vehicle, SEDAN, sport utility vehicle or Affordable Energy Saving Cars (AESC), each with different subclasses for the engine size in terms of cubic centimeters (cc). There are however no division between fuels used for the vehicle sales. The AESC is a program started in 2013 to promote low cost fuel efficient cars by exempting it from taxes (Government Regulation No. 41/2013). The sales between 2004 and 2014 are shown in Figure 22 and Figure 23.

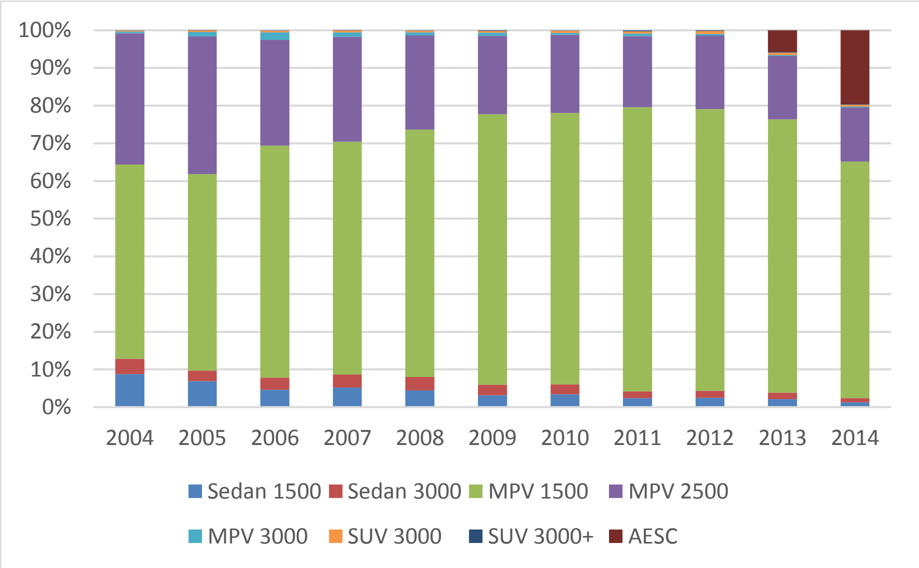


Figure 22. New cars sales share by car class and engine size. Compiled by authors based on data by Gaikindo (2015a, 2015b, 2015c, … 2015k).

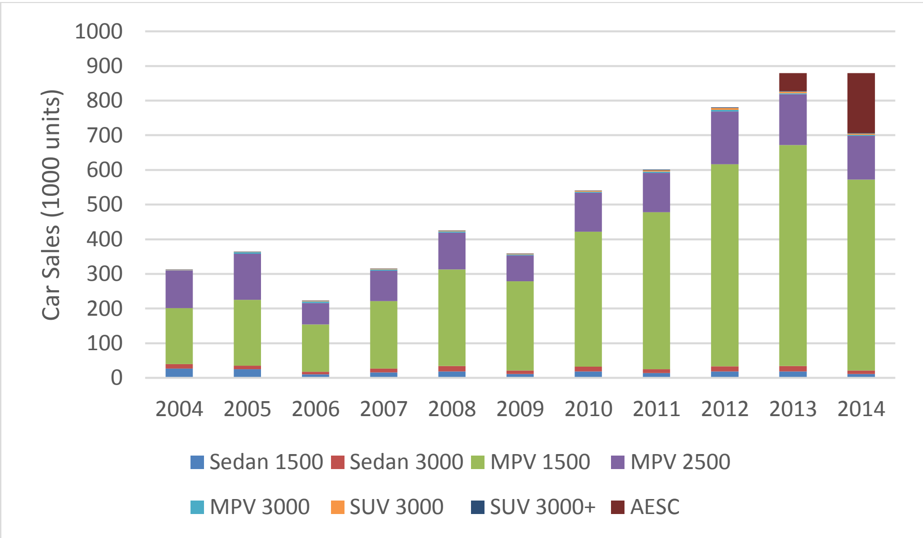


Figure 23. New cars sales in absolute numbers by car class and engine size. Compiled by authors based on data by Gaikindo (2015a, 2015b, 2015c, … 2015k).

As can be seen in Figure 22 the combined share of multi personal vehicle above 2500 and sport utility vehicle for all engine sizes have been less than 1.5% during the time period. They have therefore been excluded from this report as it will focus on the dominant private passenger vehicles. As seen from Figure 23, it is also clear that multi personal vehicle is the preferred car type in Indonesia as 2014 were the only year when it didn't account for more than 80% of the sales. Multi personal vehicles are favored as they can carry more people, suiting Indonesian preferences (Wijeratne and Lau, 2015). The AESC have also been a favorite, with a significant market penetration and market shares of almost 20% during 2014.

The sales have been increasing by an annual average of 10.9% which is higher than the growth rate indicated by BPS. The total growth is however significantly higher for BPS by almost 25% for the years 2011-2014. This difference can come from the different classifications of vehicles, however BPS values are higher still than Gaikindo even if the sales of pick-up, trucks and double cabins are added to the new car sales. It would be illogical that the number of cars grows faster than the pace of which they are sold, but a possible reason for this could be that the source for the BPS data which is the Indonesian National Police tracks the sales differently. For example could that allow for multiple registrations or that a second hand car is counted as a new one and is therefore overestimating the true numbers.

In the model, the cumulative sales and sale shares of 2014 will provide the first year sales and the growth rate of passenger cars will be based on Gaikindo's statistics. The base stock of passenger cars in the model that represents 2013 values is 20% lower than BPS estimations of 11.5 million to account for the overestimations. The division of stocks between the categories were done by using the cumulative sales in the 2004-2014 period for each vehicle type and engine size and then determine its associated share of the total stock.

For motorcycles the sales are based on data from Indonesian Motorcycles Industry Association (hereafter AISI) compiled in Figure 24 below. During the time period, the sales increased at an annual rate of 7.3% and 7.87 million units were sold in 2014. The stock were based on BPS data as the official sales from AISI seemed to correlate to those of BPS.

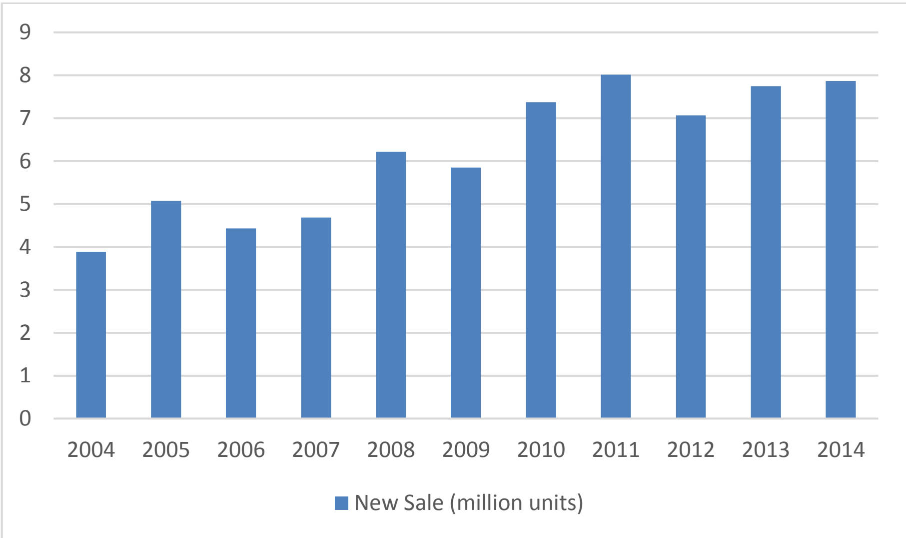


Figure 24. Motorcycle sales in absolute numbers. Compiled by authors based on data by AISI (2017).

In order to estimate the age distribution of the different passenger vehicles, their respective sales numbers for each year were used to determine the share of the population for that year.

Vehicle specifications

There is no available data on the fuel division for Indonesia's vehicle fleet and Gaikindo does not differentiate the sales of diesel and gasoline vehicles in the statistics, with the AESC as the only exception due to being exclusively gasoline fueled since 2014 (Gaikindo 2015a, 2015b). In this report, the estimate from Interviewee E[8] of 5% diesel and 95% gasoline will be used for all the passenger cars sales and stock with the exception of 100% gasoline driven AESC stock with 5% diesel sale share.[9] Furthermore are all motorcycles assumed to be gasoline driven as there are no diesel driven motorcycles in Indonesia according to the interviewee E.[10]

[8] Interviewee E, Personal communication, 12 April, 2017.

[9] Ibid.

[10] Ibid.

The fuel economy was based on the bestselling models in their respective category when the data were available, or from real consumptions data from online sources. For the cases of data gathered by online sources, the data were weighted against the technical specifications of those models. As most fuel consumptions were found for either gasoline or diesel an assumption of gasoline having 15% higher fuel consumption were used to estimate the fuel consumptions that lacked data sources, the assumption is based on the energy content being 15% higher for diesel (Alternative Fuels Data Center, 2014). Additional similar assumptions are made for biodiesel and bioethanol with 13.9% and 67.5% higher than the corresponding diesel and gasoline consumptions (Hofstrand, 2008). For the fuel blending used in this report, it is assumed that gasoline is mixed with bioethanol while diesel is mixed with biodiesel and unless otherwise specified the values for the fossil fuels and their respective biofuel is assumed to be the same. The fuel share of bioethanol in the mix is currently 0% according to all of the interviewees[11]. For biodiesel, it was estimated that it accounted for 5.7% of the diesel mix in 2014 which have been implemented in the model using a 5.7% of the diesel driven devices to be biodiesel fueled (Wright and Rahmanulloh, 2016).

All of the data for distance traveled annually are based on correspondence with interviewee E[12] as there are no official statistics. The data is divided into diesel and gasoline fueled passenger cars and motorcycles and can be seen in Table 9. For the emission of the vehicles they are assumed to be in compliance with current emission standards. In Indonesia, the emission standards are on par with Euro 2 as of 2007 for both cars and motorcycles and are summarized in Table 9 (Clean Air Asia (CAA), 2016a; Ministry of Environment, 2009). Other emissions are based on the technology and environmental database (TED) that in integrated into the LEAP program from reputable sources such as IPCC and IEA (LEAP). Biodiesel and bioethanol being the exceptions as they are not yet implemented into LEAPs database.

Table 9. The annual vehicle kilometer and specific emission standard for cars and motorcycles. Compiled by the authors based on data from Ministry of Environment (2009) and interviewee E.[13]

Vehicle Type	Annual Vehicle Kilometer	CO Emission (g/km)	NO_x Emission (g/km)	HC Emission (g/km)
Car (gasoline)	9629.2	2.2	0.2	0.3
Car (diesel)	9629.2	1	0.6	0.1
Motorcycle	7 918.3	5.5	0.3	1

Emissions are evaluated according to the global warming potential metric as used in the fourth IPCC report (2007) over a time scale of 100 years. The investigated pollutants impact as greenhouse gases are calculated using CO_2 as a reference, the values can be seen in Table 10.

Table 10. The GWP potential for each of the investigated pollutants. Compiled by the authors based on data from IPCC (2007), Heaps (2016) and European Commission (2017).

Name	Carbon Dioxide	Methane	Carbon Monoxide	Nitrogen Oxides	Nitrous Oxide	Total Hydrocarbons
Chemical Formula	CO_2	CH_4	CO	NO_x	N_2O	HC
GWP tonnes CO_2-eq/tonnes at 100 years	1	25	1.9	27	298	4

[11] Interviewee A-E, Personal communication, 10-12 April, 2017.
[12] Interviewee E, Personal communication, 12 April, 2017.
[13] Interviewee E, Personal communication, 12 April, 2017.

For the LEAP model inputs had to be estimated based on different sources in order to be applied. When values differed across sources an average was used. If the value range were higher than 15% of the value itself then more sources were used to adjust for outliers. The stock, sales and fuel economy data is compiled in Table 11.

Table 11. Summary of stock and sales data presented in Figure 22, 23 and 24 as well as the fuel economy data input. Compiled by authors based on data from [a] to [d].

Passenger Car by Type and Engine Size (Gasoline)	Stock in Thousands	Share of Total Stock in %	Sales in Thousands	Share of Total Sales in %	Fuel Economy (km/L)
Affordable Energy Saving Cars	19	0.21	164	18.8	21[a]
SEDAN 1500	280	3.1	11	1.2	10[b]
Multi Personal Vehicle 1500	6311	68.7	524	60.1	9.3[c]
SEDAN 3000	204	2.2	10	1.1	8.5[b]
Multi Personal Vehicle 2500	1915	20.8	120	13.8	7.7[d]
Passenger Car by Type and Engine Size (Diesel)	**Stock in Thousands**	**Share of Total Stock in %**	**Sales in Thousands**	**Share of Total Sales in %**	**Fuel Economy (km/L)**
Affordable Energy Saving Cars	0	0	9	1	24.7[a]
SEDAN 1500	15	0.16	1	0.07	11.8[b]
Multi Personal Vehicle 1500	332	3.6	28	3.2	10.9[c]
SEDAN 3000	11	0.12	1	0.06	10[b]
Multi Personal Vehicle 2500	101	1.1	6	0.73	9,1[d]
Motorcycles (Gasoline)	**Stock in Million**	**Share of Stock in %**	**Sales in Million**	**Share of Sales in %**	**Fuel Economy (km / L)**
Motorcycles	84.7	100	7.87	100	42.5[e]

[a] = Lim (2013), [b]= U.S. Environmental Protection Agency and U.S. Department of Energy (2016), [c]= Fuelly (2017a), [d]= Car Guide (2014), [e]= Fuelly (2017b).

5. Result

Chapter five is divided in two parts, the first part 5.1 focuses on identifying factors hampering the development of the biofuel sector and the second part 5.2 focus on biofuel demand projections in the transport sector.

5.1 Identified Factors Hampering the Development of the Biofuel Sector

In chapter 5.1, the main objective is to identify factors hampering the development of the biofuel sector. The chapter is divided into three parts in order to provide clearness. 5.1.1 provides the multi-levels for related to biofuels in Indonesia and 5.1.2 describes the main barriers for biofuels in Indonesia's transport sector perceived by stakeholders. 5.1.3 examines the development of biofuels in Indonesian transport sector from a stakeholder perspective and give a notion of the barriers affecting the status of the biofuel technology in Indonesia's transport sector. What to note in this text is the word '*Biofuel sector*', which from now on is regarded as the biofuels sector oriented towards biofuels in the transport regime.

5.1.1 The Multi-Levels Related to Biofuels in Indonesia

a. The Different Levels

The three different levels in a MLP analysis; the landscape, the regime and the niche levels have all been constructed with the help of the interviewees answers from the interviews as well as literature studies. The literature studies gave the ground for the different levels, how they looked like and were built up, whereas the interviews answered questions on important actors and features for the different levels. The levels are all built upon the analyze of the work of Geels (2002, 2004, 2010, 2012) and Geels and Schot (2007).

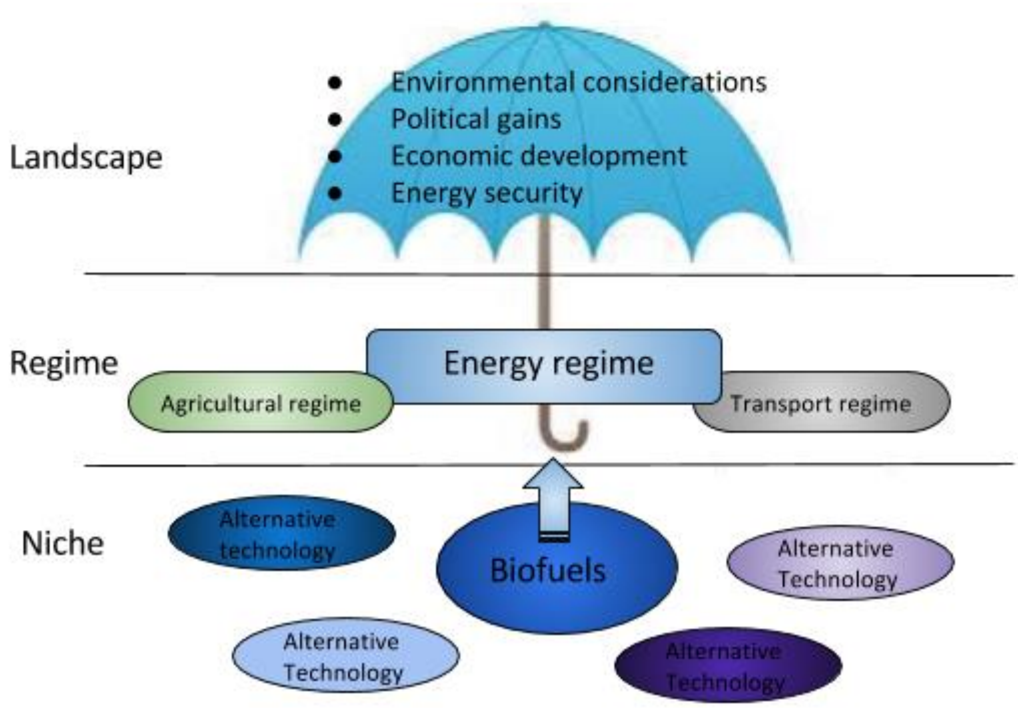


Figure 25. The biofuels in Indonesia's transport sector in a multi-level perspective. Research findings by authors based on Geels (2002, 2004, 2010, 2012), Geels and Schot (2007), literature studies from chapter 2 and the interviews. Alternative technology= alternative fuels or vehicle technology that could compete with biofuels for a spot in the energy regime, such as electric vehicles, fuel-cell engines or the second generation of biodiesel.

The socio-technical landscape consists of the general social, political, economic, cultural and infrastructure background facing the biofuel sector. This includes general facts concerning Indonesia such as population, political and economic features, religion and energy reliability but also overall international ideologies, morals and political development. In the case of the biofuel sector in Indonesia, five things stood out and was mentioned the most by the interviewees, and therefore deemed as the most important to notice in the case of the socio-technical landscape; environmental considerations (mostly international), political gains, local culture, economic development (both international as it affects the oil price and thus overall demand, but also national as it affects the supply and local demand) and energy security as seen in Figure 25. There were also other factors mentioned, but as they were not deemed as significant, they are not mentioned in this text.

Regarding the energy considerations in the global settings, environmental issues got its first awareness as the oil crisis hit in the 1970s, giving the Indonesian government a shock according to Interviewee C: "*Renewable energy came from the start of the oil crisis, when Indonesia's government had to find other solutions.*"[14] Pushes from outside of Indonesia came in the form of environmental considerations and awareness, and Indonesia was forced to oblige. Geels and Verbond (2007) describes this occurrence as a "landscape shock", a shock that deemed a fast solution to the problem of the oil crisis. In this case, Indonesia needed to start looking for energy and fuel elsewhere, which stirred more environmental awareness in its way, as fossil energy was deemed more unreliable than before. The next landscape shock happened in 2004, when "*Indonesia imported more oil than exported*".[15] This also got the attention of the public, as rising fuel and electricity prices concerned them, making the environmental pressures in the landscape regime spread the awareness of other energy sources, energy security and protection of the nature.[16]

The regime includes all rules that the regimes actors apply to, all gathered around the biofuel sector, working together in one group. The biofuel regime is made up by several regimes coexisting together, all concerning biofuels; the agricultural regime, the energy regime and the transport regime (Figure 25). All these three together forms the regime for the biofuels in the transport sector. The Indonesian biofuel sector aims to be embedded into the energy regime of Indonesia, making it interact with energy actors as well as the technologies in the regime, as it strives to replace the fossil fuel technology that's used in the transportation sector.

The energy regime in Indonesia is currently characterized by a shift towards more renewable sources, as seen in the National Energy Policy from 2006. What to note here is that biofuel only contributed with 0.42% of the energy mix in Indonesia in 2014 (MEMR, 2016a). Nearly all of the interviewees (all except one) stated that they think Indonesia will increase this percent in the future. The energy sector is heavily dependent on oil, as nearly half of the energy sector is made up by oil and is still increasing (Novianto, 2008). Since the 1960s, the fossil based fuel has played a large part in the energy regime but also taken a toll on the governmental budget, as the government has subsidized the fossil fuel for a long time. Attempts to decrease the subsidize has led to large demonstrations and protests, making it nearly impossible to decrease the subsidizing (Beaton and Lontoh, 2010). The subsidizes has since then been decreased several times in both 2008, 2009, 2010 and 2013 but is still a debated issue for both the government and the public, as demand rises and put a tool on the relations between politicians and their electors, making it as well be a problem heavily influenced by political notions (JG, 2013). Interviewee E also confirm that the government doesn't want to stop the subsidies; "*The idea is* [to] *never stop with subsidies.*"[17]

The agricultural regime is the one feeding the biofuel regime with biofuels, as the production process of biofuels starts in the agricultural regime, making it possible to sell biofuels and later on be a part of the energy regime. This highlights the interactions the biofuel technology will have to have with the agricultural regime and in turn, be influenced by its mobility. The agricultural regime is heavily influenced by economic

[14] Interviewee C, Personal communication, 11 April, 2017.
[15] Interviewee B, Personal communication, 10 April, 2017.
[16] Ibid.
[17] Interviewee E, Personal communication, 12 April, 2017.

considerations, as it is one of the most profitable sectors in Indonesia, and employs 38% of the population and as well has a very fertile ground, suitable for a variation of crops (Oxford Business Group, 2013). Interviewee C stated that the production site of the biofuel sector had a; "*very big benefit. Already many people depend on this business.*"[18] Despite these positive notions, Indonesia still import food crops such as wheat, rice, corn and sugar, making it compete with the agricultural land of biofuels and thus, the future development of biofuels (IEA, 2015a; Wright and Rahmanulloh, 2016).

Regarding the transport regime, biofuels are influenced strongly by the fossil fuels as a competitor to the market and also by the key actors of the transport regime, such as car producers or scientist working with fuels. Interviewee E stated that the future development of the biofuel sector is heavily dependent on how the car manufacturers collaborates with the biofuel producers; "*Misubitsu says they do 100% rapeseed on an engine for 72 hours and that the engine is ok. The engine manufacturers need to talk with us. The engine manufacturers are doing their own research ... we need to consult them.* "[19] The interviewee continued; "*The engine coming to Indonesia should be able to take the blending, there is where the research should be.*"[20].

The niche includes today several different biofuel technologies, all with different advanced development in Indonesia. These niche technologies are first generation biodiesel from palm oil, biodiesel from jatropha and bioethanol made by sugarcane molasses. The second generation biodiesel is still in the research and development stages (Figure 25). According to interviewee C, "*In order to use … second generation biofuel, it needs more research but it may not be enough money to do that*."[21] and interviewee B confirmed "*The second generation is yet not effective in terms of cost and production.*"[22]

Biodiesel from palm oil is the most advanced biofuel in Indonesia and is today a big income source for the government, especially in the export sector. Biodiesel from palm oil has during a long time been produced in Indonesia and already had its established network of actors and institutions in Indonesia, something that come in handy when Indonesia's government agreed to go in for the biofuel technology in 2006. This and thanks to its economic lucrativeness, has made it even more developed. According to Kharina et al. (2016), Indonesia is currently the largest producer and exporter of palm oil worldwide. The production (19.2 to 32 million tonnes) and export (15.1 to 27 million tonnes) of biofuels from palm oil has steadily increased since 2008 and are planning to continue increasing (Indonesia-Investments, 2016). Biofuel from palm oil has as a niche technology gathered a few actors and institutions from the agricultural and energy regime to form a small network.

However, biodiesel from palm oil is still embedded in the niche level and not the energy regime. This is deeply connected to the fact that the fossil fuel dependency is so great in Indonesia and therefore very embedded in the energy regime. The subsidies for fossil fuel is a big factor of influence for the continuing fossil dependence and is working like a block for the biofuels and makes it harder for it to be embedded into the energy regime. Interviewee B stated; "*The cost and the political condition in Indonesia, somehow it makes bioenergy not that attractive in comparison with fossil fuel for example.*"[23]

Biodiesel from jatropha was once very popular in Indonesia, but has the last couple of years, decreased in popularity as it has been hard to farm it; "*Jatropha was very popular but it* [starts to] *dye as the yield is very low and many things is not easy as jatropha tends to hold mosquitos so if you want to harvest it, they say you have to use something like a mosquito suit to cover yourself to even get near it.*"[24] Biodiesel production from jatropha is still in the early stages in Indonesia, reasons mainly due to unsuccessful attempts of farming jatropha in Indonesia and less demand of biofuels from jatropha than expected (Caroko et al., 2011).

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[18] Interviewee C, Personal communication, 11 April, 2017.
[19] Interviewee E, Personal communication, 12 April, 2017.
[20] Ibid.
[21] Interviewee C, Personal communication, 11 April, 2017.
[22] Interviewee B, Personal communication, 10 April, 2017.
[23] Interviewee B, Personal communication, 10 April, 2017.
[24] Interviewee E, Personal communication, 12 April, 2017.

The bioethanol industry was a commercially produced industry of first generation bioethanol before in Indonesia but has since then ceased to exist. Nowadays, the bioethanol industry is according to interviewee C nonexistent as "*Bioethanol will not happen as it's not enough source. It will probably always stay zero as its also to expensive.*"[25], and gets coherence from interviewee B: "*Pertamina claims that bioethanol is not yet developed* ... [palm oil] *already have a founding mechanism to support this system but for bioethanol, not so. ... The truth is that it's nothing, so zero percent of mixture of bioethanol in the field nowadays.*"[26] As bioethanol is mainly made of sugarcane in Indonesia, "*Bioethanol already has the advantage of becoming food, it's the feedstock for alcohol so it's not working for the transportation, for the fuel. ... The sugarcane industry is a competitive industry, maybe in more than 50 years there is good.*"[27]

According to interviewee C[28], biofuels are competing with other alternative technologies in the niche. Alternative technology is other less developed niche-innovation technologies than the conventional biofuels, that could compete with biofuels for a spot in the regime in the future, such as electric vehicles, fuel-cell engines or less developed biofuels, such as the second generation of biodiesel.

b. Key Actors and Factors of Influence

In the following step of the multi-level analysis, the key actors are divided depending on the different levels in the MLP perspective to make it more apprehensive but also to show the interactions among them in a clearer manner (Figure 26). This is also closely viewed in how they influence the development of biofuels in Indonesia.

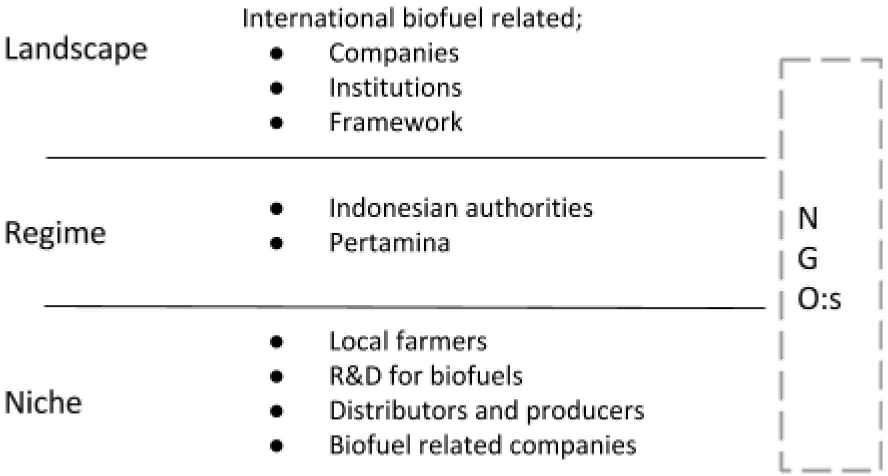


Figure 26. Key actors for biofuels in the Indonesian transport sector. Research findings by authors based on Geels (2002, 2004, 2010, 2012), Geels and Schot (2007), literature studies from chapter 2 and the interviews. NGO:s = Non-governmental organizations, such as for example Greenpeace.

The landscape's main influence is the sustainability concept, as the increased demand of biofuels is mainly due to the increased environmental concern throughout the world, but it's also heavily driven by the economic winnings that lay in biofuels.

When asked to mention the most important factors of influence of the biofuel sector, the Interviewee gave several reasons. The most frequently mentioned reason were exemplified by interviewee E as "*The palm oil industry is just there to give what the government needs."*[29] and by interviewee D as "*The Indonesian economy depends on the price of commodity, and the biggest commodity is crude-palm oil - we are addicted to use biodiesel.*"[30] This statements were confirmed a number of times by all interviewees as it was clear that the biofuel sector was economically

[25] Interviewee C, Personal communication, 11 April, 2017.
[26] Interviewee B, Personal communication, 10 April, 2017.
[27] Interviewee C, Personal communication, 11 April, 2017.
[28] Ibid.
[29] Interviewee E, Personal communication, 12 April, 2017.
[30] Interviewee D, Personal communication, 11 April, 2017.

driven and clearly very important for the Indonesian economy, both in terms of export and domestic usage. The other frequently mentioned reason, were the energy security aspect of developing the biofuel sector. As Indonesia currently is a net importer of oil and rely on it for both fuel and energy usages, an improvement of energy security is also politically favorable "[Biofuels] *is a lot about energy security. It's more like a business opportunity actually.*"[31] Other reasons mentioned was sustainability related, such as a decrease of GHG emissions in comparison to fossil fuels, or a reduced extraction of crude oil.

The above mentioned answers highlight how heavily the biofuel industry in Indonesia is affected by international regulations and morals, especially as the Indonesian biofuel sector is exporting more than they are using domestically. This bounds the biofuel sector to be closely viewed by international NGO:s as well as international institutions, causing the Indonesian biofuel landscape to be heavily shaped by outer pressures around biofuel, the sustainability concept and market changes.

At **the regime level**, the Indonesian government and other public authorities were mentioned several times as the most influencing actor of the biofuel sector in Indonesia. The key actors who were most mentioned were Ministry of Energy and Mineral Resources, Ministry of Agriculture, Ministry of Transportation and Ministry of Research and Technology. It was though clear that it was several different ministries working together, each one issuing their own regulations that affected the biofuel sector and caused trouble as they not always cohered, "*There is a lot of ministries and there is no coordination in between them ... that's a problem in Indonesia, when there is a policy, every ministry will give another policy and it is not coordinated* [enough]."[32]

Pertamina, Indonesia's national energy company, is mentioned several times as a strong lobbyist for the biofuel sector. This is partly since they are the ones to fully implement the biofuel mandate, something that's making them a key actor in enforcing the governmental goals and regulations when it comes to biofuels. As stated by interviewee B; "[Pertamina] *are really trying to follow the mandate but the price is so unattractive in comparison with the fossil fuels so that is why it's not yet developed. Pertamina is hesitant to go to bioethanol because of the price. Even if they have the mandate, if the price is not attractive, it won't be fully implemented. That's a good view on how strong Pertamina really is.*"[33]

Regarding the interactions in between the landscape and the regime level, it is acknowledged the key actors in the regime heavily depend on the market and its demands, interviewee E mentioned several times during the interview the government's willingness to bow for the international sustainability demands placed upon the biofuel sector, in an attempt to continue with the development of the biofuel sector; "*No one really wants to support crude-palm oil, it's not possible. Its political based, NGO:s puts a lot of pressure on it, it doesn't look good politically. Palm oil is associated with many bad things, including environmental issues like deforestation.*"[34] and "*We do a lot of sustainability work since it was introduced and demanded from the market.*"[35]

The niche level consists of local and regional actors surrounding the development of biofuels, from researchers to producers of both the feedstock and biofuels to local consumers, even NGO:s and distributors.

More specifically, one lobbyist mentioned was Association of Indonesian Biofuel producers (APROBI), as they represented most of the biofuel producers in Indonesia and were often consulted by the government or Pertamina in biofuel related issues. A frequently mentioned environmentalist was Greenpeace, as they closely monitored the production of CPO due to its environmental issues according to interviewee E.[36]

Concerning the collaboration in between the public authorities and the researchers, the lack of R&D (Research and development) institutions were stressed several times, as for example interviewee A stated

[31] Interviewee B, Personal communication, 10 April, 2017.
[32] Interviewee C, Personal communication, 11 April, 2017.
[33] Interviewee B, Personal communication, 10 April, 2017.
[34] Interviewee E, Personal communication, 12 April, 2017.
[35] Interviewee E, Personal communication, 12 April, 2017.
[36] Interviewee E, Personal communication, 12 April, 2017.

"*The government doesn't give substantial allocation for the development of the biofuel in Indonesia. The research should be an investment but somehow the government have not given good investment, so there is not much research as there is no money*"[37] and interviewee C mentioned; "[There is] *no budget from government, the researcher budget less than 0.1% from the total budget so that's why there is not many researchers as it's no money.*"[38] According to interviewee E, the research is instead acknowledged to be done by producers of biofuels or companies related to the transport sector, in an attempt to increase the usage of biofuels.[39] Interviewee D also stressed that there is enough research done right now concerning biofuels; "*The development needs to stop, we can't make any more efficiency or any better biodiesel. The technology has already reached its top.*"[40]

In regard to the interactions in between the landscape level and the niche level, interviewee E acknowledge a strong bond "*The way Indonesia do the oil palm industry is getting very much considering on the sustainability, previously maybe not but again this is market driven, not governmental driven of sustainability, that's why the government in 2011 put regulation on sustainability with ISPO.*"[41]

Ranking exercise

Table 12. Results of ranking exercise, presented in decreasing order of preference with explanation. Research findings by authors based of interviews.

Ranking Place[a]	Actors	Causes for Place of Ranking with Comments from Actors
1	The Government	"*The central government is actually the ones who allocate the land in Indonesia from the forest land to be agricultural land and actually the only authority for this*"[42], "*The authorities issue the license for production of biofuels e.g. production area or the land allocation- everything- without government these companies can't move- even if they want to change land they have to get approvement by the governmental.*"[43]
2	The Private Companies	"*In Indonesia, the power here is investors in Indonesia that is needed to develop the oil pump for biofuels.* "[44], "[The private companies] *make money that the government will use and make subsidy to the fuel. They take money through taxation or regulation, there is the ministry of finance regulation to correct the money and then use it to increase the money for Indonesia. If the* [fuel] *price increase, [the government] takes the subsidy from the private companies.*"[45]
3	The Public	"*The civil society actually have a voice of deliver opinion about biofuels but somehow, because the oil pump is economically important in Indonesia, so somehow their voice is not heard.*"[46], "[The public] *because their main concern is the price so the authorities that gives the policies etc., all depends on how the public react, eg if the price is too high, the project itself will not develop.*"[47], "*The public don't really care* [about biofuels]."[48]
4	The Researchers	"*They work on the background and the investment and how the technology evolves but is not directly involved in how the biofuel will improve in Indonesia itself.*"[49], "*They also got*

[37] Interviewee A, Personal communication, 10 April, 2017.
[38] Interviewee C, Personal communication, 11 April, 2017.
[39] Interviewee E, Personal communication, 12 April, 2017.
[40] Interviewee D, Personal communication, 11 April, 2017.
[41] Interviewee E, Personal communication, 12 April, 2017.
[42] Interviewee A, Personal communication, 10 April, 2017.
[43] Ibid.
[44] Ibid.
[45] Interviewee C, Personal communication, 11 April, 2017.
[46] Interviewee B, Personal communication, 10 April, 2017.
[47] Interviewee C, Personal communication, 11 April, 2017.
[48] Interviewee E, Personal communication, 12 April, 2017.
[49] Interviewee C, Personal communication, 11 April, 2017.

		something to say but the most important driver is the investments."[50], "*No budget from government, the researcher budget less than 0.1% from the total budget so that's why not many researchers as it's no money.* "[51]

[a] The ranking is based on all the participants ranking summarized together.

Ranking of influencing actors for Indonesia's biofuel sector again shows that the key actor in the Indonesian biofuel sector is the government, clearly since they are the one renting the land to the producers of biofuels (Table 12). They have also issued laws and regulations so that they can take subsidies from the private companies, using their profit to subsidy the biofuel and thus increase the demand of it in Indonesia. The public seems to have some power as they give the government political power and as interviewee C stated; "*it all depends on how the public react*"[52], clearly showing that if the government wants to increase the biofuel development in Indonesia, they must have the public on their side. The researchers were acknowledged to have some power by interviewee A[53] and E[54], but usually the government and the private companies seemed to only listen to them to an extent as "*the most important driver is the investments.'*[55] The interactions at the niche-regime level therefore seems to be small, as both public and the researchers at the niche level has a hard time making their opinion heard to the government or other lobbyists.

5.1.2 Main Barriers Regarding the Development of the Biofuel Sector in Indonesia as Perceived by Stakeholders

a. Main Barriers to Renewable Energy Penetration

The barrier categories as observed from Painuly (2001) and Reddy and Painuly (2004), were perceived in relation to the interviewees answer. All the barrier categories in chapter 3.3 from Painuly (2001) and Reddy and Painuly (2004) were mentioned during the interviews. The main barriers perceived by stakeholders from the interviews can be seen in Table 13, where the most mentioned barrier were institutional and regulatory barriers, as it was mentioned by all interviewees in the study once and sometimes more.

Table 13. Results of barriers perceived by stakeholders based on interviews. Research findings by authors based on the interviews.

Barrier Category	Barriers Perceived by Actors
Financial and Economic	-Small profit margins due to biofuels being expensive to produce. -Biofuels need substantial subsidies or a founding mechanism to be competitive in the domestic market. Otherwise, a reduced market will occur. -Economic considerations deem bioethanol to be more suitable for food and beverage usage. -No funding for the R&D culture for biofuels.
Market	-Most of the biofuels are favored to go to the international market and not the domestic market due to economic considerations, causing a reduced domestic market for biofuels. -High taxes to export biofuels causes a trade barrier. -Missing market infrastructure for biofuels. -Bioethanol has little to no production resulting in a 'missing market'. -Unstable fuel subsidies and founding from the Indonesian government affects the domestic biofuel market. -No financial or regulatory support for smallholders to produce or sell biofuels.

[50] Interviewee A, Personal communication, 10 April, 2017.
[51] Interviewee D, Personal communication, 11 April, 2017.
[52] Interviewee C, Personal communication, 11 April, 2017.
[53] Interviewee A, Personal communication, 10 April, 2017.
[54] Interviewee E, Personal communication, 12 April, 2017.
[55] Interviewee A, Personal communication, 10 April, 2017.

	-Subsidized conventional energy makes it harder for biofuels to gain a market and affects competitiveness.
Technical	-The car engine is today not enough developed to run on higher amounts of biofuel. A newer car fleet may be needed in order to implement future Indonesian biofuel mandate. -The second generation of biofuels is yet not enough technical developed in terms of cost and production. -Biofuels in general are not as energy intensive as fossil fuels. -Lack of entrepreneurs causes the technical development to be slow and reduces the technological competitiveness. -Lack of technical standard codes and regulation except for the CPO sector increases the financial risk.
Institutional and Regulatory	-Lack of involvement of stakeholders in laws and regulation from the government, results in lost decision making. -Food vs. biofuel production is creating a clash of interest among the biofuel stakeholders. -Lack of R&D culture. -Lack of framework for the biofuel technology. -Political awareness decreases transparency of the biofuel industry. -Market monopoly is created as the government owns all of Indonesia's land, creating issues with land ownership. -Not enough cooperation among the governmental institutes about biofuels. -Lack of entrepreneurial institutions. -Biofuel related laws and regulation regarding biofuels is not enforced enough, there is not enough penalty when laws and regulation concerning biofuels is not implemented. -Hard to realizing biofuel goals and national plans. -Lack of environmental law and regulation.
Social, Cultural and Behavioural	-Fossil fuels are sometimes still preferable over biofuels. -Lack of public interest for biofuels. -The public lacks knowledge of biofuels. -Lack of awareness of biofuel related laws and regulation.
Other Barriers	-Environmental impacts in the form of ● land changes, ● forest degradation and deforestation, ● a high water usage. -More economic interest than environmental, causes landscape pressure of environmental awareness to not fully penetrate to the regime from the landscape. -Lack of infrastructure in Indonesia, such as roads and grid, doesn't allow the biofuel technology to come to all of Indonesia.

b. Indonesia, Biofuels and Sustainability Issues

One of the most discussed barriers for biofuels is the sustainability issues concerning biofuels, which was seen under the barrier category "other barriers". How proponent these issues is and what kind of issues that concerns the Indonesian biofuel sector in regard to sustainability was discussed throughout the interviews.

In regard to the sustainability concept, there were an agreement amongst the actors that sustainability had not been the main concern regarding biofuels, but as international pressures (e.g. Greenpeace's concern about CPO) pushed the Indonesian government to take a greater interest in it, an awareness about sustainability has begun to spread. Interviewee A described that "*Indonesia is heading towards the right direction; ISPO has many standards about zero carbon, many organizations are committed, impacts on groundwater is decreasing ... generally speaking the government and public are more aware of sustainability these days. I am hoping they are heading in the* *right direction in the future.*"[56] The increasing land use caused by the expansion of plantation area for biofuel crops has also been discussed frequently in Indonesia, especially as it is seen as a threat to natural forest growth and reduces the carbon sinks area. According to Interviewee E[57], NGO:s has many times criticized the palm oil industry in Indonesia for their unsustainable biofuel agriculture and expansion practices, something that has affected the regime and made it a focal point for international criticism.

The biggest environmental concerns with the biofuel were mentioned to be land usage issues, deforestation, a decreased carbon sink due to less forest and as well the issue of food vs. fuel. The feedstock for bioethanol has been deemed more economic preferable as food or other uses instead of fuel production, clearly affecting the bioethanol market and is closely related to the the financial and economic barrier. There is also not enough land to both satisfy the fuel industry and the food industry, creating a food-water-land issue as the agricultural industry is closely related to intense water usage.

In spite of these mentioned issues, the interviewees were in an agreement that biofuels were more or less sustainable. Interviewee A and B[58] both highlighted that biofuel as a sustainable fuel are much due to how it is treated: "*All depends on how you plan and manage the source to bioenergy, for example what was the previous land use and how do you engage to local communities. Sometimes it's neutral, sometimes both positive and negative.*"[59] Interviewee C and D couldn't even see any current negative impacts with biofuels as they both viewed the negative externalities to be regulated to nonexistent by government laws and regulation[60] [61]. Interviewee D state that "*Right now there is no negative impact* [with biofuels] *as we have free CPO plantation in Indonesia and then we have the regulation mandatory for the plantations and then we have the producer for the CPO to increase the production of biodiesel.*"[62]. This lack of issues can though be doubted, as several interviewees witnessed about a lack of interest in and education about biofuels in general and sustainability aspects, as they were not talked enough about in Indonesia. Interviewee B expressed this as "*Not at all* [talked about] ... *maybe about the price*"[63], and interviewee E answered that "*Not really ... the awareness of the people is not really there. If we ask anybody; do you know why it says Biosolar? I don't think they know. Most probably they don't know. They just use it.*"[64] There were also expressed a concern about lack of sustainability criteria and law and regulation. Outcomes like more job opportunities when producing biofuels and polluted land and water and eutrophication were mentioned briefly, but not elaborated in detail by the interviewees.

5.1.3 Biofuel Sector Development According to the Actors

In order to fully understand the development of the biofuel sector, it is important to understand how the actors in the biofuel sector view the future for the biofuel sector as well. The interviewees will be discussed below, and later on incorporated in the conclusion of how the Indonesian biofuel sector will look like in the future.

In the short turn, most of the interviewees answered that they saw a positive development of the biofuel sector in Indonesia. Interviewee A answered; "*Policy is there, interest is there, it's heading in right direction. Biofuels got a clear trend up, usage of fossil fuels going down. Fossil fuels more complementing than competing.*"[65] but the interviewee also saw a hinder in the low price of fossil fuel, as it made the government to continue to subsidize the Indonesian biofuel sector for the demand to not decrease; "*As the fossil fuel price is still low, the biofuel development will still be low, that's the key. The government still gives subsidy for the fossil fuels. If government starts to reduce subsidy and*

56 Interviewee A, Personal communication, 10 April, 2017.
57 Interviewee E, Personal communication, 12 April, 2017.
58 Interviewee B, Personal communication, 10 April, 2017.
59 Interviewee A, Personal communication, 10 April, 2017.
60 Interviewee C, Personal communication, 11 April, 2017.
61 Interviewee D, Personal Communication, 11 April, 2017.
62 Ibid.
63 Interviewee B, Personal communication, 10 April, 2017.
64 Interviewee E, Personal communication, 12 April, 2017.
65 Interviewee A, Personal communication, 10 April, 2017.

try to allocate the subsidy for the investment for the biofuel development maybe the prospect is good in Indonesia."[66] This concern was also voiced by interviewee D who also thought the future "*It depends on the price of the crude oil*."[67] Another concern was the technology in the cars "*Mix will increase but it has to be met by the technology. If they increase the mixture, it can be problem with old cars technology. If government wants to increase more, then the government needs to confound the vehicle industry*."[68]

In the long run, no interviewee really knew how the biofuel sector would develop. Many stated again that it all dependent on the fossil fuel price and how the demand for biofuels will look like in the future, both nationally and internationally.

The continued challenges to get the biofuel market to grow had many answers among the interviewees, but interviewee B gave a good concluding interpretation "[The] *first challenge is how we collect, distribute and process it. The second one is the policy, it needs to be really carefully processed on how to be implemented domestically ... there will be challenges as we still rely on fossil fuel ... there is lack of market and spurt, the true challenge is for companies to be kept alive and work together until it one day is a shift that allowed this sector to grow*."[69]

5.2 Projections and Scenario Analysis with LEAP: Indonesia's Transport Sector by 2030

In this chapter, the LEAP model's results will be presented as fuel consumption and GWP for the different scenarios mentioned in chapter 3.2.2.

5.2.1 Projections of Fuel Consumption

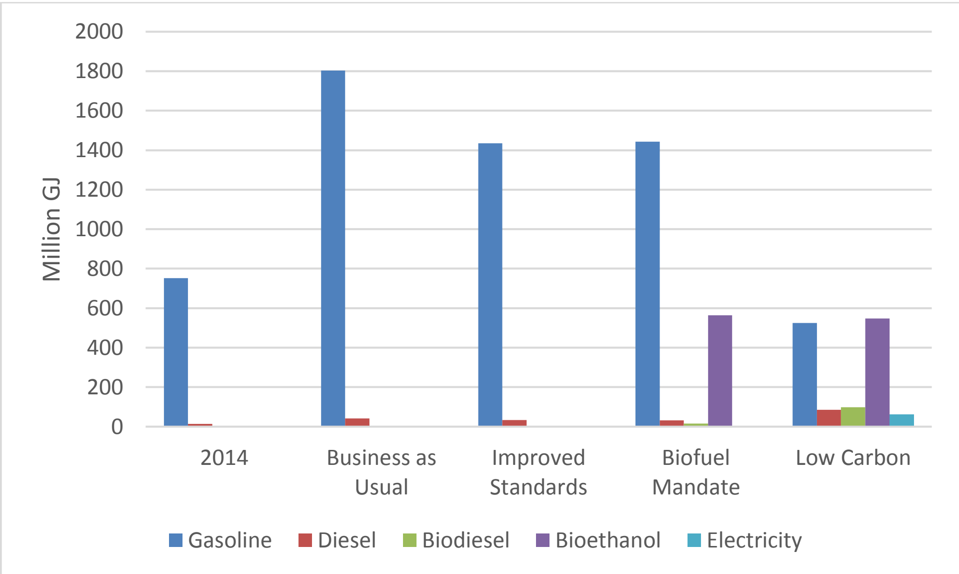


Figure 27. Annual fuel consumption in 2030. Research findings by authors based on the LEAP model result.

Indonesia's passenger transport vehicle fleet is estimated to grow to 203 million units in 2030 from 102 million units in 2014. The passenger car share increases from 10% to 20% during the period.

The total fuel consumption is projected in Figure 27 to increase to 1850 GJ in 2030 from 770 GJ in 2014 which is a 140% in the Business as Usual scenario. In the Improved Standards scenario the consumption is 20% lower in 2030 than for Business as Usual as it reaches 1470 GJ. Biofuel mandate scenario has a slight

[66] Ibid.

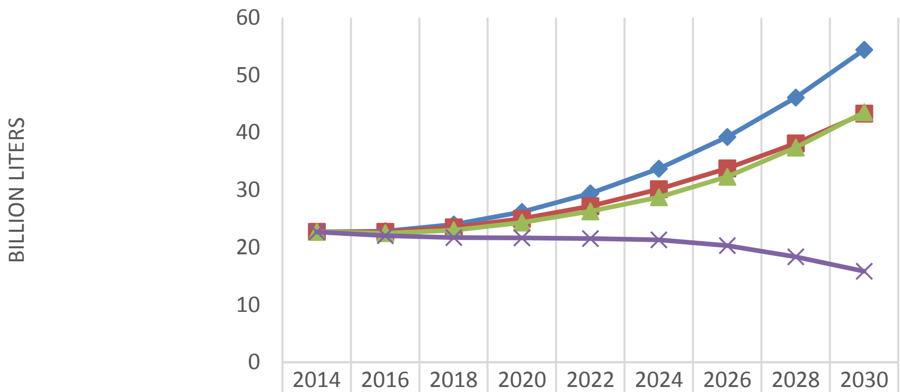
[67] Interviewee D, Personal communication, 11 April, 2017.

[68] Ibid.

[69] Interviewee B, Personal communication, 10 April, 2017.

higher fuel consumption than Business as Usual as the total is 2050 GJ. The lowest fuel consumption for the scenarios in 2030 is 1320 GJ in the Low Carbon scenario which is a 72% increase from 2014.

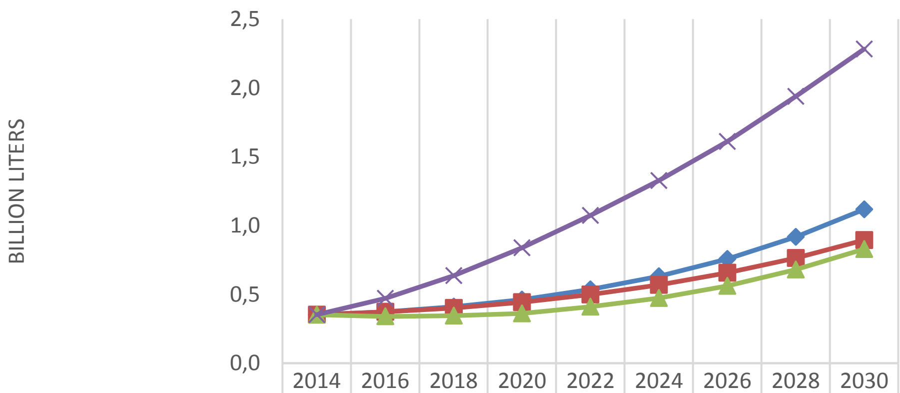
In Figure 28, the gasoline consumption of the Low Carbon scenario is less than a third of the Business as Usual in 2030 and 30% less than base year. Both the scenarios of Improved Standards and Biofuel Mandate reduced the gasoline consumption with roughly 20% from Business as Usual but increased with 92% from 2014. The gasoline consumption reaches 54 billion liters in 2030 in the Business as Usual scenario.



	2014	2016	2018	2020	2022	2024	2026	2028	2030
Business as Usual	23	23	24	26	29	34	39	46	54
Improved Standards	23	23	23	25	27	30	34	38	43
Biofuel Mandate	23	22	23	24	26	29	32	37	44
Low Carbon	23	22	22	22	22	21	20	18	16

Figure 28. Annual gasoline consumption. Research findings by authors based on the LEAP model result.

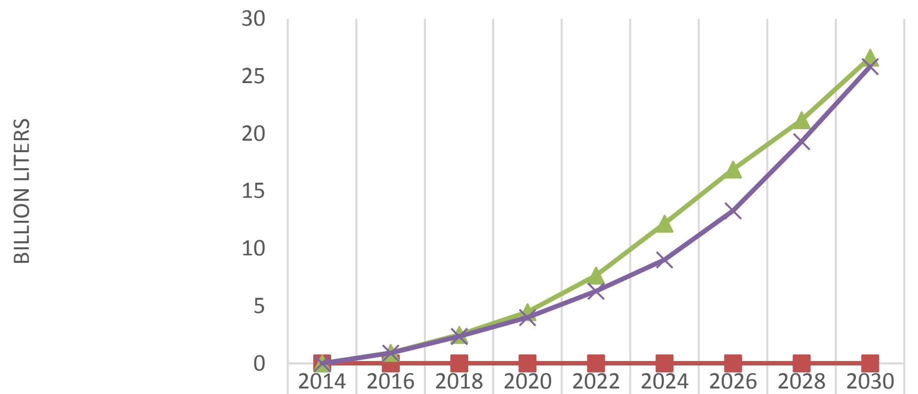
Diesel is projected to increase in Figure 29 from 0.4 billion liters to 1.1 in the Business as Usual scenario. The Improved Standards scenario reduced the diesel consumption to 0.9 while the Biofuel Mandate reduce it further to 0.8 billion liters. For the Low Carbon scenario the diesel demand is more than twice as high as Business as Usual and almost six times higher than in 2014.



	2014	2016	2018	2020	2022	2024	2026	2028	2030
Business as Usual	0,4	0,4	0,4	0,5	0,5	0,6	0,8	0,9	1,1
Improved Standards	0,4	0,4	0,4	0,4	0,5	0,6	0,7	0,8	0,9
Biofuel Mandate	0,4	0,3	0,3	0,4	0,4	0,5	0,6	0,7	0,8
Low Carbon	0,4	0,5	0,6	0,8	1,1	1,3	1,6	1,9	2,3

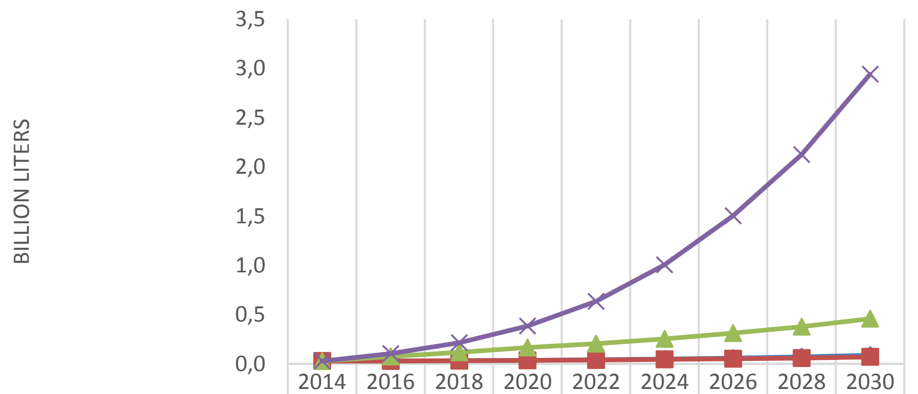
Figure 29. Annual diesel consumption. Research findings by authors based on the LEAP model result.

In Figure 30 the bioethanol demand is highest for the Biofuel Mandate scenario at 27 billion liters while the Low Carbon reaches 26 billion liters. There is no bioethanol fuel in the other scenarios.



	2014	2016	2018	2020	2022	2024	2026	2028	2030
Business as Usual	0	0	0	0	0	0	0	0	0
Improved Standards	0	0	0	0	0	0	0	0	0
Biofuel Mandate	0	1	2	4	8	12	17	21	27
Low Carbon	0	1	2	4	6	9	13	19	26

Figure 30. Annual bioethanol consumption. Research findings by authors based on the LEAP model result.

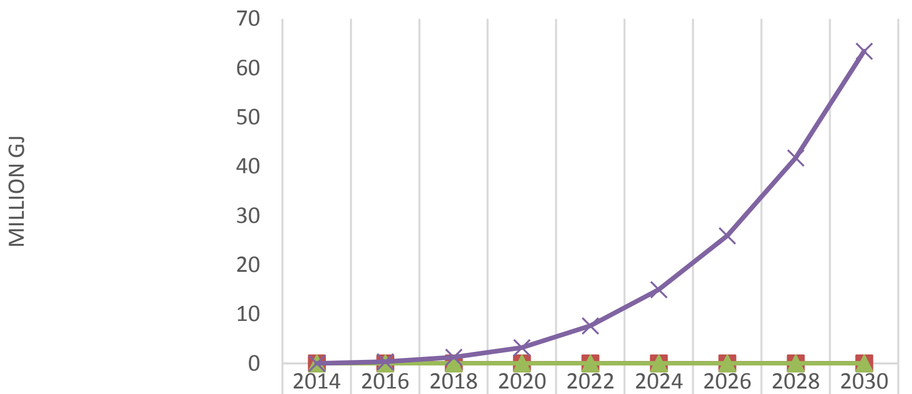


	2014	2016	2018	2020	2022	2024	2026	2028	2030
Business as Usual	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,1	0,1
Improved Standards	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,1	0,1
Biofuel Mandate	0,0	0,1	0,1	0,2	0,2	0,3	0,3	0,4	0,5
Low Carbon	0,0	0,1	0,2	0,4	0,6	1,0	1,5	2,1	2,9

Figure 31. Annual biodiesel consumption. Research findings by authors based on the LEAP model result.

The biodiesel demand increases three times from 2014 to 2030 in Figure 31 for Business as Usual, with a 20% lower demand in 2030 for Improved Standards. In the Biofuel Mandate scenario the biodiesel reaches levels five times higher than in Business as Usual. Over 2.9 billion liters of biodiesel is used in the Low Carbon scenario which is more than 33 times the reference case.

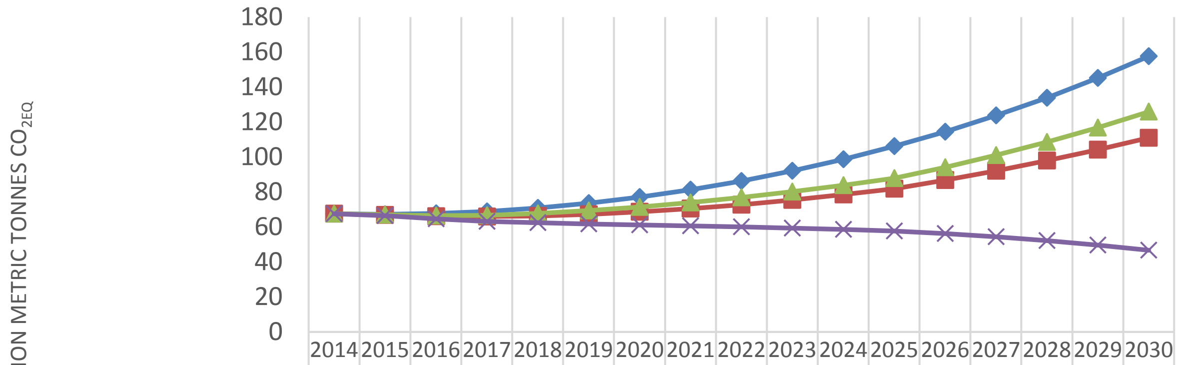
Electricity used as fuel reaches 63 GJ annually in the Low Carbon scenario in 2030, see Figure 32. In the Low Carbon scenario electricity amounts for almost 5% of the total fuel demand by 2030.



	2014	2016	2018	2020	2022	2024	2026	2028	2030
Business as Usual	0	0	0	0	0	0	0	0	0
Improved Standards	0	0	0	0	0	0	0	0	0
Biofuel Mandate	0	0	0	0	0	0	0	0	0
Low Carbon	0	0	1	3	8	15	26	42	63

Figure 32. Annual electricity consumption. Research findings by authors based on the LEAP model result.

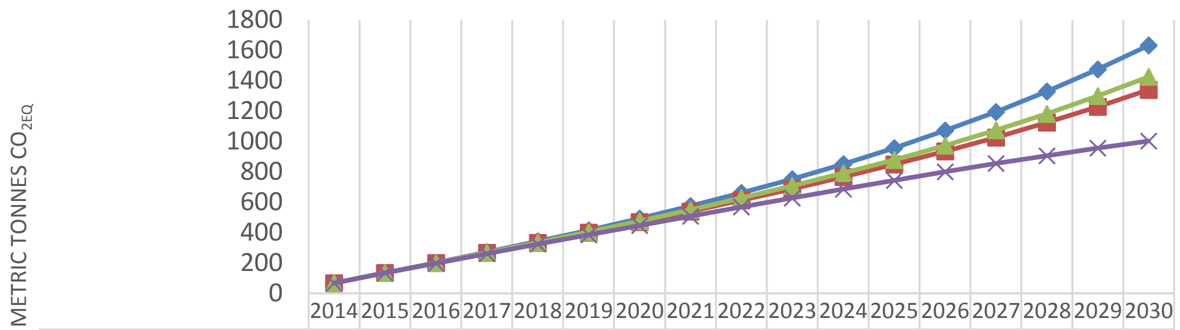
5.2.2 Projections of Global Warming Potential



	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Business as Usual	68	67	68	69	71	74	77	81	86	92	99	106	114	124	134	145	158
Improved Standards	68	67	66	66	66	67	69	70	73	75	78	82	87	92	98	104	111
Biofuel Mandate	68	67	66	67	68	69	71	74	77	80	84	88	94	101	109	117	126
Low Carbon	68	67	65	63	62	62	61	61	60	59	59	58	56	54	52	50	47

Figure 33. Annual emissions. Research findings by authors based on the LEAP model result.

The annual emission shown in Figure 33 indicates that the annual GWP is projected to increase from 68 million metric tonnes of CO_{2eq} to 158 in the Business as Usual scenario, an increase of 133%. Fulfilling the biofuel mandate leads to a decrease of 20% from Business as Usual scenario which can be seen in the Biofuel Mandate scenario. For the Improved Standards scenario a reduction of 29% compared to Business as Usual is attained. In the Low Carbon scenario the emissions will decrease to 69% of the base year level, and is the only scenario which has a lower GWP in 2030 than 2014. Low Carbon scenario emits 30% of the Business as Usual scenarios emission in 2030.



	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Business as Usual	68	135	202	271	342	416	493	574	660	752	851	957	1072	1195	1329	1474	1632
Improved Standards	68	134	201	267	333	400	469	539	612	688	766	848	935	1027	1125	1229	1340
Biofuel Mandate	68	134	201	268	335	405	476	550	627	707	791	879	973	1074	1183	1299	1425
Low Carbon	68	134	199	262	324	386	447	508	568	627	686	744	800	854	906	956	1003

Figure 34. Cumulative emissions. Research findings by authors based on the LEAP model result.

In Figure 34 the cumulative GWP reaches 1632 million metric tonnes of CO_{2eq} over the period in the Business as Usual scenario. Reduction in GWP is achieved for all of the scenarios, 18% in Improved Standards, 13% in Biofuel Mandate and 39% in Low Carbon.

6. Discussion

The discussion part of this thesis will start by looking at the development in Indonesia's transport sector, what already have happened and what could happen in the future. Key barriers will be discussed and the resulting projections and their significance for the transport sector will be examined. The discussion ends with a discussion of the accuracy of the report findings.

6.1 The Biofuel Development in Indonesia's Transport Sector

Since the start of the 21th Century in Indonesia, both the economy and the population has grown exponentially, causing a larger demand of a higher living standard. The transportation sector was heating up in the late 20th century in Indonesia due to this, as the number of cars increased profoundly. This, with the increasing demand of energy, caused the Indonesian government to look for new energy sources and as well, new fuel sources, especially as Indonesia's net import of oil increased in line with the increased consumption of energy and fuel, leaving Indonesia vulnerable in the case of energy security. When the financial crisis of Asia hit in 1997, the Indonesian economy were no exception, causing worry in the government. The destabilization of the regime actor created a window of opportunity for new innovations to emerge, one of these were the biofuel technology, which Indonesia's government also saw as an opportunity to increase the economic profits due to its increased demand and price. Global climate change also put pressure on regime actors of the energy, agricultural and transport regime to increase their environmental security.

Moving forward, the transport regime suffered from several problems; lack of energy security, high cost (increasing demand threatens to increase the fuel price) and environmental pollution. These problems were made worse by landscape developments, for example was the environmental awareness increasing, causing a pressure on the regime to further change from fossil fuels to biofuels.

When Indonesia became a net importer of oil because of higher demands on the domestic market due to rising living standards and a higher population, energy security became a hot topic, especially as variating oil prices put a pressure on Indonesia's economy. These changes forced the Indonesian government to react, firstly by subsidizing fossil fuels, and later, when the environmental concern demanded an increase in biofuels, the government started to subsidize biofuels as well. Today, many interviewees believed the biofuel sector would not survive without these subsidies. One has to wonder though if these subsidies is good for making biofuels more competitive on the market, especially as Indonesia has a lack of R&D for biofuels. Many interviewees on the contrary described there were no need for more R&D and suggested that the technical advancement would instead come outside of the country.

Sustainability Problems in the Biofuel Sector

It was also clear that the interviewees saw a lot of benefits with biofuels and were positive to its development, even though many interviewees agreed that biofuels had sustainability problems. The interviewees mainly talked about GHG emissions, deforestation, and water scarcity, all which were closely related to the farming of the biofuels, especially the palm oil industry. It was mentioned many times that biofuels could be fully sustainable, if you farmed it in a sustainable practice. The GHG emissions were believed to be less than with fossil fuels, but it seemed to be an overall consent among the interviewees that all depended on how much land were devastated in relation to the farming and what kind of crop that was used, especially as the amount of water used depended on which crop you farmed. Due to Indonesia having made several GHG commitments, this may be closely monitored in the future.

Tukker (2015) urged for a carefulness with new innovations in relation to sustainable development to not repeat the developed economies mistakes, something that here doesn't seem to be fully followed. The clearing of forests in Indonesia, especially rainforest, and the not fully sustainable farming seems to be occurring problems with biofuels, also in Indonesia. As stated in 2.2.2, Indonesia has implemented certifications in the palm oil industry such as ISPO or RISPO, but as Elliot (2015) stated, there is a lack of sustainability perspective in regulations regarding biofuels. One interviewee even indicated it was only sustainable regulations in the palm oil industry, but not anywhere else. The interviewee closely related this with the fact that this were where outer pressure regarding sustainability were laying as heaviest, not on any other industry, causing the Indonesian government to only implement a sustainability perspective on the palm oil industry, and nowhere else. As the biofuel industry not yet have a sustainability perspective in relation to all of its industry, this may be a problem in the future and cause a barrier to emerge as this sustainability aspects will need to be addressed in the future. If the overall fuel consumption in the world will go towards more usage of biofuels and less fossil fuels, the industry will be more closely examined in relation to the sustainability concept by both environmental oriented NGO:s and the buyers of biodiesel. As in all markets, if not the producers oblige with the buyer's interest and demand, the buyers may not want to buy the products and look elsewhere instead, causing problems to sell the products.

Even though these sustainability problems were mentioned in relation to biofuels in Indonesia, in the short future, biofuels in the Indonesian transport sector seemed to have an overall positive future according to the interviewees.

The Road to Transition

From this, the first and second phase of the transition theory by Geels and Schot (2007) can be seen as already happened. The new technology (biofuels) is used in the regime and had its own design and usages in combination with producers, scientists and people who only work with biofuels. The third phase through, has just started. As landscape changes pushes the regime to change and open up for biofuels, the first of Geels and Schot's (2007) transition pathways: Transformation, seem to be starting to take place due to landscape changes pushing the regime but in the same time, the technology don't seem to fully take advantage of the landscape changes.

How close is then biofuels in the Indonesian transport sector for a breakthrough through? Geels and Schot's (2007) transition theory (see 2.4.2), states that changes need to happen in all three levels in order for a breakthrough to take place. The landscape level has forced changes on the regime and niche level (e.g. environmental concern and unstable energy security) so that a need for biofuels came along in the beginning of the 21th century. In the regime level, the competition between fossil fuel and biofuels has been strongly influenced by political choices, especially after Indonesia becoming a net importer of oil and the need for biofuels increased the Indonesian biofuel export, increasing Indonesia's export profit. Today, Indonesia has a heavy bureaucracy surrounding the biofuel sector, with many laws and regulations. These laws and regulations has changed many times, especially the amount of subsidizes for biodiesel, causing an uncertainty among interviewees what these laws and regulations really entail. These policies and economic incentives heavily regulates the Indonesian biofuel market, creating in itself a number of barriers for the continued development of biofuels in Indonesia's transport sector. Not least, due to the big bureaucracy creating laws and regulations in many cases without enough of the stakeholder's views and without cooperation with all governmental agencies. As subsidies has been a topic for debate many times in Indonesian government and as well been meet with recurrent demonstrations from the public, this shows an unstable regime due to inner pressures, which is opening up for regime changes.

In the niche level, as discussed above, the pubic or with another name, the consumers have put pressure on the regime by mass demonstrations when the prices for the fuels changed. Price performance has in this case been a powerful economic driver for the public. This involvement through seems to stop here, and several interviewees express that as with the government, the major driver is economic change for the public to react. Otherwise, the public does not have knowledge about biofuels, except general facts, and especially not governmental laws and regulations concerning biofuels. Environmental issues don't seem to be any problem as well for the public according to the interviewees. It clearly isn't any pressure on the regime to change anything with the usage of biofuels today, putting a stop for further change towards biofuels taking over for fossil fuels in the regime. This also shows another barrier except the lack of knowledge or interest from the public; a lack of transparency of biofuel framework in Indonesia. Thus, acceptance of biofuel in

Indonesia by the general public and the government is clearly influenced by the price of biofuels and other advantages such as environmental advantages and it being a renewable fuel is often forgotten.

Further Barriers Hampering the Transition

Further barriers lie in the infrastructure of Indonesia. Many interviewees argued that the biofuel mandatory mixing was only happening in urban areas in the three most populated areas of Indonesia; Jawa, Sumatra and the southeast parts of Sulawesi. As it is only Pertamina that seems to almost follow the mandatory mixing of biofuels today, and they have their bases in urban areas, which could indicate a connection. Something that's strengthen this theory is how the other fuel companies act. According to both interviewees and literature, other fuel companies (which usually operate at more rural areas) does not follow the mandate fully. If the infrastructure were to advance in rest of Indonesia, Pertamina may have a larger spread and thus, the mandatory fuel mixes may be more implemented. Another thing the government could do to ensure this would be to increase the monitoring of fuel blending and implement the penalty for not following the mandate, something that clearly isn't done today. If the biofuel mandate isn't followed, the biofuels in Indonesia will not be as in high demand that a breakthrough will happen for the technology.

In the longer future though, biofuels development is more uncertain. Technical barriers, such as an expensive production of biofuels and not enough developed second generation of biofuels for the market and especially a not enough developed engine for a higher biofuel percentage, causes a threat for the future in the long run. Especially as biodiesel today cannot be used in older engines with more than a 20% mixture with diesel. In order to increase the biofuel market, Institutional and regulatory barriers need to be rectified, especially if the market for biofuel is to increase. A transition towards sustainability only seems to be one of the reasons to implement biofuels in the long run, but with a stronger environmental awareness amongst the people, this could lobby for a larger pressure on the regime. By having pressure on both niche and landscape level, can clearly foster sustainability transitions for sustainable energy technology. The future for the development of biofuels seems to depend on a great variety of things to consider; taxes or subsidies, technical improvement (both of cars and biofuels related technologies), investments in infrastructure and tougher environmental regulations such as tougher CO_2 regulations. Right now, the full market and thus demand, is missing for biofuels in Indonesia and affects its future. Something that clearly affects also the blending mandates fulfillment. If petroleum become more expensive in Indonesia (either by less subsidies of petroleum from the government or higher oil prices), this will also open up for a larger market for biofuels.

The Future Projections for Biofuels in the Indonesian Transport Sector

Bioethanol has a much more unclear future than biodiesel. Bioethanol has a larger advantage as other products than fuel according to many interviewees, something probably fueled by the type of crops bioethanol is made of; crops containing sugar, such as corn or sugarcane. These crops are in high demand in Indonesia, and known as some of the food crops Indonesia imports, clearly making a problem between food vs. fuel usage for bioethanol, which may put pressure on the food-water-energy nexus. The biodiesel is also clearly more favored by the government than bioethanol due to bioethanol not being subsidized, causing the bioethanol to be too expensive to produce and sell. In the long run, many interviewees didn't see any future for the bioethanol if it weren't more supported from the governmental side, something the authors agree with. Today, none of the national goals regarding biodiesel has been fulfilled but due to biofuels being in a transition state in between niche and regime, fulfilling of the goals in the future does look possible even through it is facing many barriers.

The potential and possibility of biofuels also depends greatly on the transport conditions and structure. The massive surge of the vehicle population will cause momentous changes for the transport sector as the vehicle ownership per capita rises from 45% up to 66% during the timeframe. Consequently, this could lead to new preferences in vehicles, it is possible that people will opt for less of the dominant multi personal vehicle in favor of smaller cars as the availability of vehicles increases. This could potentially open up the market more for alternatives as the AESC and thereby change the vehicle paradigm as is investigated in the Low Carbon scenario. However, a current identified barrier is the lack of interest among the public which might prevent this change from occurring. On the other hand, could financial incentives such as more subsidizes from the government towards biofuels, a carbon tax or a removal of subsidized fossil fuels, facilitate the change as smaller cars are also cheaper to operate. Due to most of the vehicles on the road in 2030 are yet not sold, it is a huge opportunity for vehicle fleet improvement and the next years will be impactful for the course of the future transport structure. Introduction of actions now on emission standards and fuel blending compliance would therefore be easier implemented before the fleet is much larger and harder to adapt.

For cumulative GWP the Low Carbon scenario leads to a reduction of 38.6% of the GWP compared to the Business as Usual scenario projections. This will be in line of the determined reduction of 29% stated in Indonesia's INDC. However neither of Improved Standards nor Biofuel Mandate scenario reaches a sufficient reduction. This indicate that further actions are needed as those in the Low Carbon scenario for the transport sector to fulfill its GWP emission reduction target.

Another current issue that could grow in intensity is Indonesia's dependence on fossil fuel importations, as the gasoline usage is projected to grow by almost 140% while diesel will rise by over three times in the Business as Usual scenario. Biofuels has the potential to play a major role in securing domestic energy supply as can be seen in the Biofuel Mandate scenario as it leads to 25% reduction in diesel and 20% in gasoline demand. However the total demand will increase in the Biofuel Mandate scenario which might put pressure elsewhere. On the other hand, there are research that suggests that the necessary biofuel to fulfill the target for both biodiesel and bioethanol is possible to produce in Indonesia. The 27 billion liters of bioethanol from the most bioethanol intense scenario is within the potential of Indonesia's production capacity (Khatiwada and Silveira, 2017). In the Low Carbon scenario, 2.9 billion liters of biodiesel is projected to be used which is below the production in 2014, indicating that a much higher penetration of biodiesel expansion is possible in the future. This means a higher share of biodiesel than in the scenarios could be used for the transport sector. There is therefore no need for any additional farm land if some of the exported biodiesel is redirected domestically. If the produced biodiesel is used domestically instead of being exported then the funding mechanics coming from the taxation on exporting biofuels, which also keeps the biodiesel prices down, will lead to a reduction in subsidization and ultimately leading to a less competitive price for biodiesel. However, if the freight transport would be considered as well in the transport projections, this might no longer be the case due to the fact that heavy duty trucks and buses often are diesel driven. Moreover might the available land required for bioethanol expansion not be sufficient if freight transport is considered depending on the shares of gasoline fueled vehicles.

Due to the fact that one of the barriers Indonesia is facing is that there is not enough R&D culture in Indonesia surrounding biofuels, the Improved Standard scenario will have to be fulfilled with inventions from outside Indonesia. As many interviewees stated that this is the case already today, it might indicate that the lack of R&D surrounding biofuels in Indonesia is not as a big of a barrier as one might think. As can be seen, the Improved Standard scenario is closely connected with the technical barriers.

There could also be variance in the GWP reductions due to which conditions the biofuels are created under in the well-to-tank, the same is true for the electricity vehicles in Low Carbon Scenario. If Presidential Regulation No.79/2014 is followed then at least 75% of the energy will be fossil fueled in 2025 which means that the electricity is likely to be produced by mostly fossil fuels which reduces its emission reduction.

As the Indonesian transport sector is projected to have gasoline as the predominant fuel in all but one scenario the energy security is relatively low and makes the country vulnerable to price and supply changes. This indicates that there could be more advantages with the Low Carbon scenario aside from fuel consumption reductions and GWP savings such as energy security.

Barriers Related to the Scenarios

For the Improved Standards scenario, two barriers can be related: technical barriers and institutional and regulatory barriers. The scenario demands a two percent annually increase in fuel economy and that the emission levels complies with higher euro standards, highly linked with a developed car engine and technical standard codes and regulations for emissions, all technical developments. For the institutional and regulatory barriers, the government and regulatory institutions needs to ensure that the biofuel goals and mandates are meet by both enforcing them but also realized and further developed.

In the Biofuel Mandate scenario there are multiple barriers associated with the actions taken. The first one is the technical barrier of adapting higher blends of biofuels in the vehicles, something that will also require regulatory monitoring to ensure compliance and thereby invoking the institutional and regulatory barrier. Moreover will the institutional and regulatory barrier also be related to the production and distribution of biofuels so that the quotas are met. The distribution will also fall under the other barrier criteria as the infrastructure network is not fully developed and is unable to reach all parts of Indonesia. The production and funding of the biofuels will cause issues related to the market and financial and economic barriers as bioethanol is deemed to be better used for other purposes than fuel and therefore has no established market for biofuel usage.

As the Low Carbon scenario incorporates both the Improved Standards scenario and the Biofuel Mandate scenario as well as further actions, it will face the same barriers as those scenarios and specific new ones as stated here. The car preference shift towards AESC from larger less energy efficient cars can be hindered by the social, cultural and behavioral barrier as it's a preference shift affected by already existing norms and behaviors. The higher biofuel blends in the vehicles will amplify the barriers from the Biofuel Mandate scenario and the introduction of electric vehicles will have to overcome the market barrier to penetrate the market. If the cars need to improve, additionally possible technical and financial and economic barriers may be needed to address.

These barriers are though only identifying the proponent problem categories the problems exist in and not how severe these issues are, further increasing the importance of investigating the barriers to a larger extent.

6.2 Accuracy of Report Findings

The single greatest source of inaccuracy is likely the lack of reliable and specific data for Indonesia. This factor alone influences almost every part of the model but most particularly on the annually vehicle travelled and the fleet composition. The distance travelled is the used measurement for activity and therefore have a noticeable impact on the results. The values used for the model were from a single year 2009 which meant a trend could not be identified. However the Increased Motorization scenario dealt with a heightened activity which was useful for determining the outcome of the possibility of an increasing activity trend.

For the interviews, the language barrier could be an influence in inaccuracy of interview findings. Some of the interviewees expressed a concern of not be able to express themselves accurately and to their fully desire. Furthermore, not enough variation of interviewees was able to participate in the interviews in order to do a full examination of MLP actors, something that were of significance when looking at the interview result. All of the interviews were also made within the borders of Indonesia's capital Jakarta, something that affected the interviewees background to mainly have an urban background. Around one third of the interviewees were though from more rural areas originally and had moved to Jakarta, which balanced the urban backgrounds out and gave a more variation of the whole of Indonesia. Another notable thing is that the interviewees working with promoting biofuels could be overly optimistic with the future of the biofuels in the transport sector in an attempt to reflect their own wishes for the future. They could be biased due to their research.

For the fleet composition further data on the vehicle division and vintage would be beneficial to better estimate the current stock. However as the car population will grow in such a pace that even if the current stock avoided retirement it would still be a minority of the on road fleet. For motorcycles their relative shorter lifespan makes the turnover rate much faster which means that the initial conditions will soon have been completely replaced. On the other side will the accuracy on average lifespan of the vehicles be important as it indicated how long the vehicles stay on the road, i.e. a higher lifespan could mean that the fleet average changes slower.

The MLP analysis were looking at bioethanol and biodiesel simply as biofuels instead of individually, to facilitating the study, even though they have different niches, regimes and landscapes in reality. This have affected the Geels and Schot's (2007) transition pathways to be more accurate for biodiesel, as it is used and has a larger socio-technical system than bioethanol which has none or a very small production and usage in Indonesia. As biodiesel is the dominant biofuel in Indonesia, the MLP is more similar to the path of biodiesel.

The estimation of using the Euro2 as a basis for the vehicle emissions have two potential simplifications that could have an effect, firstly there is the fact that some vehicles surpasses that standard for emission while it is possible that some does not reach it. However as the standard was to be complied with in 2007 it is likely that most at least comply with it and thereby would such an assumption only find the worst case scenario. Secondly due to the design of the standard with a roof on NO_x particles it does not consider the division between the different types of NO_x particles, as N_2O have a GWP of 298 kg CO_{2eq}/kg N_2O while NO_x is estimated at 27 which mean there is a great range of emissions.

7. Conclusion

This section summarizes the key findings of the study, identifying the factors hampering the biofuels development and policy options for reducing fossil fuels and GHG emissions in the transport sector in Indonesia. The conclusion is derived in three parts in order to bring clarity and answer the research questions. A summary of the research findings gives the reader an overview of the report, whereas the recommendations is presented as an alternative how to overcome barriers and develop biofuels in the transport sector of Indonesia. Further research orientation highlights future possibilities to develop this reports area of interest.

7.1 Summary of Research Findings

The initial surge of biofuels in Indonesia were driven by energy security and economic benefits, grounded by an increased population, new energy demands and a quick increase in the economy. Due to existing market forces not being enough to drive the biofuel demand forward, the Indonesian government imposed a number of regulations, policies and laws regarding biofuels in Indonesia, something that functioned both as a cause for barriers and a driving force for the continued consumption of biofuels.

The subsidies the government imposed for biofuels helped impose a market for biofuels, where supply and demand for biofuels is depending on the continuation of subsidies and financial support from the government. Biofuels needs a funding mechanism in order to be competitive with conventional fuels, especially as the government also subsidies gasoline, something that's holding back the domestic demand for biofuels. This affects the domestic market for biofuels.

Climate change and an increased sustainability awareness was once what helped introduce biofuels on the Indonesian market according to the interviewees, but recently has rising concern about sustainability issues made the use of biofuel being questioned, especially biodiesel from palm oil, to some extent hindering the development of biofuels. Due to Indonesia being one of the largest exports of palm oil, this has affected Indonesia's biodiesel regime. Still, the domestic demand for biodiesel continues to increase overall and the export of biodiesel increases steadily. This may be due to the economic interest in biodiesel is greater than environmental concerns, which causes landscape pressures of environmental awareness to not fully penetrate the regime.

The future prospects for biofuels in Indonesia depends on a number of factors, e.g. the Indonesian infrastructure, technical development and how the regulating institutions collaborate and implement biofuel law and regulations. The car engine needs to be more developed to function with higher biodiesel rates in the fuel, the governmental institutes needs to cooperate more in between and with stakeholders in general in order to fulfill national goals and regulations regarding biofuels, a more developed R&D culture will push for a technical biofuel development and Indonesia's infrastructure needs to develop so that biofuels can be used in the overall Indonesia. In the long run though, of biofuels in the transport sector, biodiesel seems to have the brightest future and will able to be fully implemented from a policy, mandate and goal aspect given the compliance of the car manufactures. Bioethanol doesn't seem to be able to follow the mandate regulations though, mainly due to the lack of governmental support and the low production rates, especially as bioethanol is seemed to be unprofitable. However, bioethanol was found to have a higher reduction of fossil fuel consumption and GWP as it replaces gasoline which the majority of the vehicle fleet consists of. To note here though, is that the availability of biofuels in Indonesia were not considered in the model. Although in the discussion, it was stated that the biofuel demand was within the potential production capacity of Indonesia. For biodiesel even higher levels of penetration than those projected could be met if either more area was dedicated to domestic biodiesel production or if biodiesel for export purpose were used domestically.

From this thesis, it is still clear that biofuels in the Indonesian transport sector is in the transition pathway to get a breakthrough, due to the innovation gaining ground in the niche level and has its own steady actors.

It stands on the brink of breakthrough through both internal and external pressures but mainly technical, market and institutional and regulatory barriers and negative externalities such as sustainability issues stands in its way for a breakthrough. The sustainability aspects need to be further addressed in Indonesia's biofuel sector, not only in the palm oil industry, and the public awareness and interest for biofuels needs to increase. The public needs to also want a development for the biofuel sector.

Biofuels has the potential to take fossil fuels place to a larger extent in the future than it has today, if a high demand pushes technological developments both for the cars and agricultural production, something that will not come through if the Indonesian government and the population keeps relying on fossil fuels as a fuel in the Indonesian transport sector. The technological transition can only happen if changes also occur in the social dimensions.

The vehicle fleet is projected to double by 2030 following current trends which will place significant stress on the fuel supply as in the Business as Usual scenario it will more than double to 1850 from 770 GJ. Fossil fuels accounts for more than 99% of the consumption, where gasoline is the dominant fuel type at 97% of total fuel consumption. Due to the increased fossil fuel usage the annual GWP is expected to grow from 68 to 158 million metric tonnes of CO_{2eq}.

The continuing of the biodiesel and bioethanol implementation can lead to significant reduction of fossil fuel consumption. The energy model findings suggested that in achieving the biofuel mandate in the Biofuel Mandate scenario there would be reductions in the cumulative GWP of 13% which would amount to a reduction of over 200 million metric tonnes of CO_{2eq}. Moreover it would reduce the gasoline fuel consumption with 20% and 25% for diesel, in terms of total consumption the reduction is of 10 and 0.3 billion liters for gasoline and diesel respectively. In light of this, biofuels could potentially play an important role in the transport sector. However, if following the current trends with solely biodiesel implemented, biofuels will not play a big role as the transport sector is majorly powered by gasoline, which only mixes with bioethanol, something that currently is currently not produced in Indonesia. For the passenger transport the biofuel production potential in Indonesia is sufficient.

The actions in Improved Standards, which shows an improvement of fuel economy and higher emission standards, has a higher reduction of GWP at 18% and gasoline consumption at 21% while the diesel consumption is lower at 20% than the implementation of the Biofuel Mandate scenario. However the Low Carbon scenario, with higher bioethanol/biodiesel shares and an increased electric vehicle fleet, has the most significant reductions of all the scenarios and is the only scenario that has a lower yearly emission level in 2030 than in 2014 with a reduction of 31%.

Regarding barriers and scenarios, the Low Carbon scenario was seen to having the most barriers and were identified in every barrier category but it is also giving the largest reduction of fossil fuel consumption as well as global warming potential. The Biofuel Mandate scenario had the second most barriers and the largest consumption of biofuels, thus promoting biofuels to a larger extent than the other scenarios. The last scenario, Improved Standard scenario, had just a few barriers in comparison to the other scenarios. However, as seen in the barrier analysis, the most dominant barrier was the institutional and regulatory barriers in all of the policy scenario options.

7.2 Recommendations

The recommendations are;

- Avoid conflict and inconsistencies by collaborate the biofuel policy, regulations and laws among and in between the government institutions and authorities as there is a great variation in performance and coherence. Make the framework clearer and structured by reducing unnecessary framework and conflict in between national and local levels.
- Include all stakeholders in the regulatory process, so that all views are taken in consideration. This will increase the possibility for policy framework to be implemented and followed, especially

increase the transparency of policy making. This will also increase the knowledge of biofuel framework, both in the niche and regime levels.

- Go in for more R&D of biofuels, especially for the car industry but also the agricultural industry. More private and government investments is needed.
- Develop the Indonesian infrastructure in regard to biofuels. Poor interconnection and a widespread country does not promote renewable technology developments due to inconsistency to get them forward and little knowledge about them. A better developed grid increases all this.
- Increase awareness of biofuel technology by increasing the public debate through capacity building in schools and workshops. Open up for more debates regarding sustainability to ensure that landscape pressures reach down even to the niche level.
- Raise the emissions standards and set compliance requirements for newer cars and motorcycles in order to reduce GWP emissions and other local emissions (pollutants).
- Investigate the possibility for bioethanol introduction or schemes of reducing the gasoline consumption as it is the most significant part of the fuel usage and GWP of the transport sector in Indonesia.
- Depending on the penetration and availability of bioethanol in the future, an option could be to replace the gasoline cars with diesel cars in order to take advantage of the already established biodiesel market. Regardless, an increase of biodiesel in the fuel shares in diesel cars is better from a GWP and fossil fuel reduction point of view.
- Tackle the development of the biofuel technology in Indonesia's transport sector from a more sustainable perspective. Include sustainable thinking in decision making through R&D and stakeholders' perspective, and strive to develop more sustainable future solutions.

7.3 Further Research Orientation

A further and deeper research of barriers and the complex problems related to them could be advised to research. This thesis only serves as an introduction to further research and a deeper understanding of the biofuels in the Indonesian transport sector could come of a deeper analysis. Furthermore, this could also bring forward more concrete recommendations for the overall development of biofuels in Indonesia and as well point out further interactions in between barriers, actors and structures for the biofuels.

It would be beneficial if further data on current vehicle stock in terms of composition and vintage as well as annual mileages were accumulated to promote more accurate studies in the future. There could be significant gain in adapting future projections and actions for key regions due to Indonesia's island geography making an overall projection simplified. Lastly would the inclusion of freight transport make for a more accurate model, and determine the potential for biofuels in heavy duty vehicles.

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Appendences

Appendix A. Interview Guide

Feedback to consider during the interview:
–Active listening techniques/ Positive response: "Thank you, that was a good answer, nod your head encouragingly.
–Neutral response: "ok, I see", maintain eye contact.
–Negative response: "Can you please elaborate on your answer?".

For vague or unsatisfactory answers, it can be helpful to be prepared with some probing:
– For undetailed answers ask "Give me more details please", "give me an example please".
– For clarifying what they said "So you are saying …?".
– For open-ended listings ask "Would you like to add anything else?".
– To steer back after a deflection/wandering away from the topic: "How does this relate to the initial question?".

The interview starts with:
1. *Introduction of the project collaborators*: "My name in Sophia and this is Henrik, my project partner. I will be your interviewer today, and Henrik will help by taking notes. With your permission, we will use a recording device to record this interview, as this will help us get full answers from you. To note here is that the recorder can be turned off any time you want during the interview whenever you wish. I would further like to thank you for taking your time to do this interview and if there is any questions about the project or uncertainties, please ask."
2. Support letter from KTH. *Take out the support letter and hand it over.*
3. *Introduction of the project*: "To give you a notion about this interview, I would also like to state that this is a master thesis project about the development of the transport sector in Indonesia where my part, where this interview will fit in, is about biofuels in the transport sector. We will soon start with a brief questioning about personal information, followed by questions about biofuels and the transport sector divided under six different headings. The interview is expected to last approximately 60 minutes."
4. *Data validation and a reminder what to think about*. "To ensure the validity of the data, please attempt to provide precise and refined answers throughout the interview. Please also try to stay within the area of the question in order to ensure a good quality of the interview. When regarding the 'biofuel sector' in this interview, this indicates the part of the biofuel sector that is used for transportation only."
5. *The digital recording device is started with the permission from the interviewee.*

6. **Interview questions**

General information about the interviewee:
Name:
Occupation/work title:
Organization/Company:

General about biofuels in the transport sector of Indonesia
Could you please describe briefly the current development of biofuels in Indonesia?

Do you see any negative and positive impacts with biofuels?

In your opinion, what is the most important features with biofuels in Indonesia today (e.g. energy security or a sustainable development)?

How reliant is Indonesia on biofuels as an energy source?

Are biofuels debated/talked about enough in Indonesia today among the general population?

Indonesia, biofuels and sustainability issues
How do Indonesia view the sustainability concept?

Are there any measures/approaches taken towards sustainability issues in the Indonesian biofuel sector and if so, by whom?

In your opinion, are biofuels sustainable?

Factors of influence
What kind of interests are involved when it comes to the development of the biofuel sector (e.g. economic or environmental interests)?

Which are the main actors influencing the biofuel sector?

From where is the most investments coming to the biofuel sector, nationally or foreign investments? Please also give examples of investors.

How would you say the division is between large and small companies working with biofuels in Indonesia's biofuel sector (e.g. mostly large companies have monopoly on the market or are there many new startup companies)?

Ranking exercise
Present the equipment (one paper with the numbers one to four on it in a row and four small bits of paper in squares with group name on them.

Before you lay a paper with four different squares. To this, you have four different cards with different names representing different groups on it. Could you please rank in order from one to four the most influential group in the development of the biofuel sector of the following cards and explain why you chose as you did;

1. the guvernement
2. the researchers
3. the general population
4. the private companies

In this exercise, one will represent very important and four is representing the least important. Please pick the one that best matches your personal opinion. If you feel that you are missing any influential group, feel free to enlighten me and take that group into consideration when you rank the alternatives. For this exercise, you can have more than one group on the different level of importance.

Policies, subsidies and targets of biofuels in Indonesia
How do you think the national energy policy to have 22% new and renewable energy by 2025 will influence the biofuel sector and how important will biofuel be in achieving the target?

What do you think about today's biofuel blending mandate (15% biofuels must exist in transport fuels by 2015 and 30% blending in the transport sector by 2025)? Is it achievable, why/why not? Also, how do you think it will influence the biofuel sector?

What do you think about the biofuel subsidy financed by a levy on palm oil and palm oil production export from 2015? How important is it for the development of the biofuel sector and could it be replaced with something else?

What do you think about the 5% biofuel in national energy consumption mandate that is supposed to be achieved by 2025? Is it achievable, why/why not? Also, how do you think it will influence the biofuel sector?

Are there any other important policies and targets in the development of biofuels that you would like to mention?

Biofuel development in Indonesia
How do you see the Indonesian biofuel industry in the future in the short and long term? (e.g. 5 and 30 years)

Which are the most important factors influencing the growing of the biofuel sector?

Which are the challenges when talking about the growing of the biofuel sector?

Do you see much research generally about biofuels and emerging new technologies in Indonesia and if so, which one's and how much of an influence could they have in the future?

Conclusion
Is there anything more you would like to add about the topic? I would then like to thank you for your time.

Appendix B. List of interviewees and details related to the interviews

Date	Interviewee	Occupation	Organization Type	Duration (h)
10/04/17	A	Researchers	Academic	0:55
10/04/17	B	Consultant/Researchers	Company/Private	0:48
11/04/17	C	Energy Planning modeler	Governmental[a]	1:23
11/04/17	D	Senior engineer/Lab	Governmental[a]	0:40
12/04/17	E	Manager/Division head for promotion and marketing	Producer/Private	0:57

[a]Agency under the coordination of governmental ministry.