Biofuels Potential for Transportation Fuels in Vietnam: A Status Quo and SWOT Analysis

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Abstract. Petroleum consumption for road transportation is well-known as the largest source of CO2 emissions. Worldwide, biofuel is becoming more attractive as substitute for crude oil owing to the increasing demand for environmentally friendly energy and its contribution towards petro dependency reduction and climate change mitigation. This paper reviews the facts and prospects of biofuel production in Vietnam. A SWOT model is adopted to study the strengths, weaknesses, opportunities and threats of biofuels production. The conclusion is drawn that with advantages of weather conditions, soil conditions, the availability of biomass and commitment from government, the country has potential to develop biobuels for domestic consumption. However, threats to production are posed by social acceptance, land use, and technology. Thus, biofuels production still need more supports from government through robust policies, regulations, and institutional framework.

1. Introduction
Air quality problems are mainly caused by vehicle emissions [1]. It has been estimated that the global vehicle fleet will increase from around a billion to 3 billion by 2050. Due to the rapid growth in vehicle ownership, exhaust emissions in developing countries have been growing strongly resulting in an almost three fold increase of CO2 emissions from the global vehicle fleet. This growth adversely affects many populations [2] [3]. Vietnam, located in South East Asia, is highly vulnerable to the effects of climate change. Furthermore, the country is now facing real and urgent challenges in traffic-related air pollution. Vietnam has seen strong population, urban and economic growth in recent decades. In 2015, 30% of the population lived in urban area. The total number of vehicles in the country was approximately 47 million (2015), up by 8.4 million over that of 2012. The rapid population growth, urbanization, and motorization growth are associated with the high acceleration in transport demand and subsequently put immense pressure on energy resources for transportation purposes and the environment as well.

Urban air pollution is largely the consequence of the combustion of petroleum-based fuels for transport. Air pollution from combustion sources has adverse impacts on the structure and function of ecosystems as well as human health [1] [4]. Air pollution is not a distant threat: it is already costing the people in Vietnam. It has been estimated that the annual global mortality attributable to urban air pollution range from approximately 0.8 million to over 4 million [5]. This burden occurs predominantly in developing countries [6]; 360,000 premature deaths per year in Asia alone [7]. A study on the relation
between air pollution and health showed that more than 90% of children under 5 years old living in HCMC (Vietnam) suffer different illnesses. Recently, in order to achieve the goal of air pollution mitigation and reducing the dependence on petroleum fuels, much global attention has been focused on the development of cleaner, greener and environmentally friendly energy sources which have to be technically feasible, domestically available and environmentally acceptable [8] [9]. Energy Policy Act of 1992 defines alternative fuels as ethanol, natural gas, hydrogen, biodiesel, electricity, methanol and so on. Many look to alternative fuels, particularly biofuels as promising complements to petroleum in the near-to-medium term [10]. They are being used to reduce dependence on fossil fuels, petroleum consumption and greenhouse gas emissions (GHG), in the transportation sectors. With potential to alter the transport sectors of decarbonizing societies [11], biofuels are poised to be competitive and there is a role for biofuels in the developing world [12]. In general, biofuels can be in solid form (fuelwood, charcoal, wood pellets or briquettes) or liquid (bioethanol or biodiesel) [13]. The most feasible biofuels for vehicles being considered globally are biodiesel and bioethanol [1].

Many developing countries have successfully produced biofuels [1]. In Southeast Asia, Indonesia, Malaysia, Philippines, and Thailand are the world’s largest biofuels producer. There are currently 8 biodiesel plants in Indonesia and the country accounts for 44.5% of the world’s production and 45.3% of global export of palm oil. The Philippines is well known for production of coconut oil, especially of coconut methyl ester. With an aggregate production capacity of about 4.5 million tons per annum, the Philippines has become the world’s leading producer of coconut oil. In Thailand, palm oil is a biomass resource which has high potential as a renewable energy source for biodiesel production [1]. In 2008, the oil palm harvesting area in Thailand was 0.46 million ha and the fresh fruit bunch output was 8.68 million ton. In order to meet the demand for biodiesel production, the Thai government is planning to expand the oil palm cultivation area to 0.8 million ha by 2009 and to 1.0 million ha by 2012 [1]. There are countries in Asia following the global trend including India and China. Being the largest edible vegetable oil importer, India issued its biofuel policy in which biodiesel would meet 20% of the diesel demand beginning with 2011-2012. In order to achieve this, 11.2 million ha was planted with Jatropha by 2012 to produce sufficient oil seeds for biodiesel requirements [1]. In China, Government proposed the establishment of a biofuel industry in the Tenth Five-Year Planning (2000-2005). As a result, in 2000 fuel ethanol industry was created, and in 2001, a 200,000 ton capacity pilot ethanol production plant was established. By 2008, there were five licensed fuel ethanol plants in operation. In addition, the fuel ethanol production capacity reached 1.94 million tons. Currently, E10 (gasoline mixed with 10% ethanol) is being used in the transport sector in the five provinces and 27 cities [1].

Located in Southeast Asia, Vietnam is an agricultural country with approximately 71% rural population and 48.9% of the labour force working in the agriculture and forestry sector. Vietnam has high potential for crop cultivation, and for biofuels production due to the availability of arable lands and weather conditions. In addition, since 2007, the Vietnamese government has passed legal corridors, institutions, policies, and investment plan for biofuel development [14]. With the aim of meeting the transport demand, minimizing vehicle emissions and increasing sustainability, biomass-based transport fuels are considered an important alternative in the country. The development of alternative fuels, particularly biomass-derived fuels from locally available biomass, needs investigation.

This paper presents a desktop review of the liquid biofuel potentials to produce transportation fuels in Vietnam. SWOT analysis is adopted to assess the strengths, weaknesses, opportunities and threats of the liquid biofuel potentials. In addition, the status quo of country statistics, information on GHG emission from the transport sector and the role of biofuels in policy for climate change mitigation and sustainable transport in Vietnam are also discussed.

2. Status quo

2.1. Country Statistics

Vietnam has a total population of 92.7 million people (2016), 71% of which live in rural area. The total area of Vietnam is 332,000 square km; mountains occupy 75 percent while only 25 percent of the area is arable. Agriculture-forestry-fisheries are an important industries for Vietnam and accounted for 20
percent of the country’s GDP, 54 percent of its employment, and 30 percent of its exports [15]. Since 2000 the sector has grown steadily at 3.4 percent per year. Vietnam has 9.4 million hectares under cultivation; 70 percent of its agricultural products are crops, of which rice is the most important. The forestry sector accounts for 1.2 percent of the GDP. In 2014, forests cover 37% of the land area which has increased from a coverage of 28% since 1995 due to government reforestation programs.

The transport sector in Vietnam much depends greatly on petroleum and, if fossil fuels continues to be used as previously, the country, especially mainly in large urbanized areas, will suffer from severe air pollution. Biofuels are an efficient energy source with no pollution emissions. It is considered that if biofuels are substituted for traditional fuels to meet the needs of travel demand, they can help tackle air pollution and improve urban health. Therefore, since 2007, studies on the feasibility of biofuels production in the country have been carried out [13] [16] [17] [18]. Also, the government has take steps to fight air pollution through policies and long-term strategies which take advantage of abundant agricultural biomass for biofuels production.

2.2. Fuel Consumption and GHG From Transport Sector
In 2011, the energy sector emitted about 33 million tCO2 or 0.37 tonnes per capita [19]. According to the 2014 Biennial Update Report from Ministry of Natural Resources and Environment, the sector produced a total of 141 MtCO2-eq, whereas 31.8 MtCO2-eq (23%) came from the transport sector. The biggest emission source within transport was by far road transport, which accounts for 68.5% (2010), followed by maritime transport (18.9%), aviation (6.8%) and railway (3.7%) (Figure 1) [13]. In terms of emissions by fuel type, diesel oil was the dominant emissions source, which represented 42.7% in 2010, followed by gasoline [19]. From 2000 to 2010, there was an increase in CO2 emission with the rate of, on average, 12.5%. Emissions from two-wheelers/motorcycles constitute the largest share of road transport CO2 emissions (46%) [13] (Figure 2).

20% 7% 2% 4%
67% Roads
4% 7% 2%
68% Inland waterways
2%
4%
Maritime

Figure 1. Emission source within transport - 2010
Figure 2. CO2 Emissions from road transport from 2000 – 2010

The transportation sector is the third largest consumer of petroleum-based fuels and accounted for about 22% of fuel consumption in 2010. Nearly all fossil fuel energy consumption in the transportation sector is from petroleum-based fuels (diesel fuel and gasoline fuel). Importantly, the sector consumed slightly more diesel fuel compared to gasoline fuel in the past two decades [19]. It is estimated that the proportion of diesel consumption will increase from 48% in 2010 to 71% in 2040 [14]. Despite having the petroleum refineries with capacity of 6.5 – 8 million tons of crude oil per year, the country still imports the majority of its refined petroleum. Expected primary energy imports will account for 36% of total primary energy consumption in 2020 and will increase to 57% in 2030 [20]. Gasoline and diesel oil are still the main driver of the country’s petroleum import levels. As a consequence, CO2 emissions are equally expected to rise as fuel use increases steadily each year. Therefore, biofuels that have been considered the major substitution of petroleum-based transportation fuels would bring about more sustainability in the transport sector.

2.3. Biofuels – A Vital Role in Regulatory Framework for Sustainable Transport

The world fleet of motorized vehicles emits millions of tons of pollutants, resulting in poor air quality conditions and causing, among other effects, human health deterioration and climate change [21] [22]. Therefore, emissions reduction targets, low-carbon and sustainable urban mobility objectives play an important role in many climate change programs.

Vietnam has a demonstrated commitment to fighting climate change and air pollution through a series of measures. Vietnam has ratified several international conventions, notably the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol [19]. To achieve the objective of UNFCCC on the “stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system”, a number of environmental protection laws and regulations have been released by National Assembly. In addition, some Action Plans formulated by the Ministries (e.g. National Target Program to Respond to Climate Change, National Green Growth Strategy, National Green Growth Strategy and National Green Growth Action Plan) intend to mitigate emissions and to fight climate change. Apart from focusing on measurement identification, technological development, and infrastructure development, using “fuels of low greenhouse gas emission” or “renewable energy and less GHG emitted fuels” sets out the country’s vision for combating climate change and partly guaranteeing the realization of sustainable transport.
“To introduce fuels of low greenhouse gas emission to means of transport, […] so that 20% of these vehicles will use such energies by 2020 and 80% by 2050” (National Climate Change Strategy, 2011)

“Enhance the application of new technology, usage of renewable energy and less GHG emitted fuels in transportation. Implement a set of management in fuel, emission standards and vehicles maintenance” (In The National Green Growth Action Plan for the period 2014-2020, 2014)

In the transport sector, separate Avoid-Shift-Improve policies have been released ensuring sustainable transport for the future. “Avoid” policies aims to reduce travel demand, while “Shift” encourages people to switch to more efficient modes of transport and importantly, “Improve” promotes the adoption of green fuels and green vehicles (green technology) designed to utilize the fuels in both passenger transport and freight transport [19]. Table A1 (Appendix A) provides a summary of the biofuels policies in passenger and freight transport.

3. A SWOT Analysis for Potential Biofuels Production

SWOT analysis has gained widespread acceptance as a strategic way to analyze the internal and external competitiveness. This section analyzes the biofuel production in Vietnam (Figure 3).

3.1. Strength

3.1.1. Land use

There are 8 major land areas in Vietnam including Red River Delta, Northern midlands and mountain areas, North Central and central coastal areas, Central Highlands, South East and Mekong River Delta [23]. Each region has a characteristic zonal vegetation, soil and climate. Regarding agricultural land, it is divided into 4 types: Agricultural production land, Forestry land, Water surface land for fishing, Land for salt production (Table A2) (Appendix A). Of this, Agricultural production land covers 10231.7 thousand ha in 2014, whereas the figure for Forestry land, Water surface land for fishing and Land for salt production was 15845.2, 707.9, 17.9 thousand ha respectively. Table A2 indicates that from 2000 to 2015, the area of agricultural production land in the country has increased relatively, at an average rate of 114,000 hectares per year. This increase may come from the expansion of unused land, deforestation and forest land. It is expected that by 2020 the area of agricultural land will reach 27,038.09 hectares, an increase of 246.51 hectares compared with that of 2015. Producing biofuel in Vietnam comes from agricultural and forestry feedstock such as cassava, maize, sugarcane, jatropha; therefore, arable land is important in guaranteeing sources for biofuels production.

3.1.2. Biomass resources

Biomass including agricultural resources, agricultural residues, forest resources, waste (e.g. municipal solid waste, industrial waste, and algae) are often used for biofuels production. These materials, based on their sources of biomass, their limitations as a renewable source of energy, and their technological progress, are classified into four generations: first, second, third, and fourth [24]. First generation refers to the biofuels derived from agricultural products: sugar or starch-based crops and oilseeds [24], e.g corn, sugarcane for ethanol production, and soybean, jatropha, palm oil for production of biodiesel. Through well-understood technologies and processes, like fermentation, distillation and transesterification, first generation biomass feedstocks can be processed into bioethanol or biodiesel [24]. The present study focuses on the first generation. In addition, energy crops including: sugarcane, cassava, maize and jatropha are specifically discussed because they are currently the major feedstocks for emerging biofuel projects in Vietnam. Many schemes on development of biofuels in the country also identifies sugarcane, cassava and maize as the main raw materials for bioethanol production. Vietnam General Statistics Office (GSO) estimates in Table A3 (appendix A) show substantial cultivation of energy crops in the country over a ten-year period. There have been continuous changes in the areas of land harvested, yield and production of sugarcane, maize and cassava in Vietnam from 2005 to 2015.
| Strength                                      | Weakness                                                  |
|----------------------------------------------|-----------------------------------------------------------|
| • S1: Land use                               | • W1: Low social acceptance                              |
| • S2: Biomass resources                      | • W2: The shutdown of biofuels plants                    |
| • S3: Policy                                 | • W3: Technology barrier                                 |
| • S4: R&D and Production                     | • W4: Human resource                                     |

| Opportunity                                  | OS                          | OW                          |
|----------------------------------------------|-----------------------------|-----------------------------|
| • O1: Biofuel production and blended fuel combustion | • O1-S4: R&D focusing on production and blended fuel combustion to gain effective social cost | • O1-W1: Using campaigns to raise awareness of citizen about pros of biofuel |
| • O2: Biofuels Production from Residues      | • O2-S2: Using agricultural residues for biofuels production | • O2-W2: Using residues for biofuel plants |

| Threat                                       | TS                          | TW                          |
|----------------------------------------------|-----------------------------|-----------------------------|
| • T1: The shrinking of agricultural land     | • T1,T2,T3-S3: Having policy capturing the issues of land use, biomass resources for production and food security | • T2-W2: Explore policy support in terms of biomass development and production |
| • T2: Biomass Resource Reduction             | • T3-S4: Utilizing wide range of feedstock and appropriate technology for biofuel production | • T3-W2: Having feedstock priority program and releasing policy to avoid food versus fuel |
| • T3: Food Security, Feedstock Priority and Policy |                               |                             |

**Figure 3. SWOT Analysis**

*a) Sugarcane*

Ethanol from sugar cane is well-known as the most attractive alternative to fossil fuel as it provides significant reductions in GHG emissions compared to gasoline and diesel fuel. Sugarcane is grown in the two main parts of Vietnam and its cultivation does not have any negative impacts on the environment. It is harvested once a year in the North and twice per year in the South. Sugarcane can be used by many manufacturers [20].

Sugar, bagasse and molasses can be used for ethanol production. Currently, domestic bioethanol is currently produced from molasses (3-6%). In Vietnam, there is only one factory using molasses in combination with cassava for ethanol production. About 100 million tonnes of ethanol are produced annually (of which the molasses part is really small). It is expected that if the average yield is raised to 800 Quintal/ha by 2020, about 6.5 million tons of sugarcane would be available for ethanol production.

*b) Cassava*

Like sugarcane or maize, the humid tropical weather favours cassava’s growth. Cassava is a tropical root crop, requiring at least 8 months of warm weather to produce a crop, and may be harvested between 10 to 14 months [25]. Thus, it shows high potential as industrial raw material for ethanol production in Vietnam. Cassava is considered as a first generation biofuel feedstock in direct competition with food. In addition, there is competition for the crop from other enterprises which process cassava for starch, produce animal feed, and export of cassava chips.

It is clear from the table 4 that cassava production has developed rapidly in Vietnam; from 6.7 million tons in 2005 to 10.6 million tons in 2015. It is the result of the expanding cultivation from 425.5 thousand hectares to 566.5 thousand hectares and the yield from 83.6 thousand tonne/ha in 2000 to 169.0 thousand tonne/ha in 2009. Furthermore, many kinds of cassava have been grown in different areas in the country (Table 4). They provide high yield, high quality, and high starch content (above 25%) [14]. Production growth at this rate is the result of the investment and application of technology in the selection and breeding of cassava [20].
Table 1. High-yield Cassava in Vietnam (tonne/ha)

| Type     | Cu M'gar (Dak Lak province) | Quang Hiep (Dak Lak province) | Tan Canh (Kon Tum Province) | Average |
|----------|-----------------------------|-------------------------------|-------------------------------|---------|
| KM 140   | 38.7                        | 35.5                          | 32.0                          | 35.0    |
| KM 98-5  | 35.6                        | 34.6                          | 28.7                          | 33.0    |
| KM 98-1  | 24.3                        | 25.5                          | 26.7                          | 25.5    |
| KM94     | 31.5                        | 28.9                          | 26.0                          | 31.0    |

c) Maize
Maize is the dominant feedstock for liquid biofuel production that accounts for about 8.4% of global ethanol production [26]. In Vietnam, maize is grown in the north-east (50%) and the south-east (10%) with the remainder scattered throughout other regions. Maize crops are planted and harvested at 2 major times: Dong Xuan (from December to April) and He Thu (from April to August). Over a 10 year span, agricultural areas harvesting maize increased from 1052.6 thousand ha in 2005 to 1179.3 thousand ha in 2015 with increases in production growing from 3787 thousand tonne in 2005 to 5281 thousand tonne in 2015.

d) Jatropha
Besides palm oil and soybean oil, Jatropha is widely considered as a potential cradle of biodiesel. Jatropha cultivation does not compete with food and other cash crops for arable land as it can be grown in all ecological zones and under harsh climatic conditions [24]. Jatropha’s expected lifetime is about 50 years and the it starts yielding from the second year of plantation, but in limited quantity [26]. However, [27] reported that the plant can produce 4-5kg per tree from the fifth year onwards, if managed properly. In Vietnam, Jatropha has been grown since 2006. The planted area is approximately 3,358.8 in 2010. It was cultivated in many regions such as North West and North East (e.g Lai Chau, Cao Bang, Ha Giang, Yen Bai), North Central Coast (e.g Phu Tho), and South Central Coast (e.g Nghe An, Quang Binh, Quang Tri, Hue).

3.1.3. Policy
Appropriate policies play important roles in guiding and impelling change. Since 2003, the government of Vietnam has enacted a series of policies in energy efficiency and biofuel development.

a) Energy Efficiency and Conservation
As the energy consumption of Vietnam is projected to increase significantly within the next decade, Vietnam considers energy security top priority. The National Assembly and other administrative departments have issued policies and a legal framework for the guarantee of energy efficiency [19] [18]. The policies focus on targets including: (1) conserving resources, economical and efficient use of energy, (2) the application of science and alternate technology to the energy sector, e.g effective mining and utilization of existing energy resources, (3) the development and use of renewable energy sources (Table A5).

b) Biofuels Policy and Incentives
Several government-implemented policies encourage the production of biofuels. In 2007, Decision No. 177/2007/QD-TTg on the “Scheme on Development of Biofuels up to 2015 with the Vision to 2025” issued by Vietnamese government tends to “develop biofuels as a new and renewable energy to partially replace conventional fossil fuels, so that contributing to assuring energy security and environmental protection.” To achieve this policy target, short-, medium-, and long-term strategies have been planned. In addition, the decision set four main missions, and they are (1) enhance scientific research and technology development, (2) firmly establish a thriving biofuel industry utilizing agricultural products as a means of improving the quality of automotive fossil-based fuels, (3) develop an effective framework and policy mechanism capable of attracting domestic and foreign investment in the biofuels industry, (4) promote international cooperation for the growth of the biofuel subsector. Each mission was
accompanied with detailed tasks. The roles of various tiers of government to ensure an orderly development of the biofuels industry were also streamlined.

To guarantee the realization of program’s target, different policies, regulations and incentives have been introduced (Table A6). The Decision No. 177/2007/QD-TTg opens new opportunities for local and international private sector. During 2007–2015, the government provide tax incentives on imported equipment and machinery and zero income tax. Additionally, companies also receive land-use concessions whose period is granted for 20 years. Different funding sources were also introduced to support basic and applied research and development [14].

3.1.4. Research and Development (R&D) and Production

a) R&D
The research on biofuels production in Vietnam started 10 years ago. The projects mainly focused on conventional biofuels, including ethanol from sugar or starch (Lam Son Sugar Co., Binh Tay Alcohol Co., Saigon Petro, Chi Hung Co.), and biodiesel from catfish oil (Agifish An Giang, Minh Tu Co., VAMCO Biochemical Co., Thien An Co.). In the recent two years, R&D activities have been expanded to the second-generation biofuels, with pilot projects on producing biodiesel from non-food crops (jatropha curcas L. tree) [13]. Under the drive of Biofuel Development Scheme, in 2009 a total state budget of 43,376 million VND was approved and granted to organizations and individuals responsible for implementing 22 R&D projects and 5 pilot biofuel production projects during period 2009-2011.

b) Production
Although biofuels production is still in the initial stage, under the drive of biofuels policies, some achievements have been attained. Various development projects are ongoing across the country [18].

From October 2007 to March 2009, with the total investment of over VND5.4 trillion (US$241 million), the Vietnam National Oil and Gas Group (PVN) has invested in three biofuel projects with a capacity of 100,000 m3 of ethanol per year (Table A7). The investment capital of the Dung Quat Bio Ethanol Plant amounted to nearly $92 million while the figure for Binh Phuoc Ethanol plant and Phu Tho plant was 114.2 million and ABC respectively. Construction began in 2009, Dung Quat Bio Ethanol Plant was the largest bio-fuel production plant in central Vietnam, primarily producing ethanol 99.8% from cassava with a capacity of 100 million liters per year. After 18 months of construction the plant opened its first production line of ethanol in February 2012. Binh Phuoc ethanol plant was built in 2010 and finished in December 2012. It produces approximately 300,000 liters of E5 per day. It was estimated that the plant would consume 240,000 tonnes of dried cassava annually. In April 2012, the plant came into effective operation with capacity of 1.4 million liters of bio-ethanol per month. Phu Tho Plant have not been finished due to the increase of capital investment. The Phu Tho bio-ethanol plant located in Phu Tho province was designed to produce 100 million litres of ethanol a year, using first-generation technology with cassava as feedstock.

Annually, Vietnam imported 15-16 million tons of fuels while consumption was growing at an annual rate of 10%. Therefore, biofuels will meet the domestic demand and simultaneously reduce the use of fossil fuels.

3.2. Weakness

3.2.1. Low social acceptance
Since 2009, biofuels (E5 and B5) have been sold in six major cities and provinces in Vietnam including Ho Chi Minh, Hanoi, Can Tho, Da Nang, Vung Tau and Nha Trang. Currently, there are only 13 out of 514 gasoline retailers selling E5 in Ho Chi Minh City, whereas the figure is 63 out of 170 in Can Tho. However, consumers in the cities keep using A92 petrol because the price of E5 petrol is not much cheaper than A92. It seems that end-users pay more attention to the economic benefit rather than the environmental benefit. End-users are reluctant to try a new energy source that has a higher cost. A preliminary survey revealed that not many people and gas station’s owners have high perception of biofuels, e.g what biofuels is, how it can help to protect environment, whether it badly affects vehicle’s
engine and energy-savings. In addition, many biofuels’ sellers frankly said that due to high evaporative losses, high cost of investment and tank cleaning, they were not willing to sell and introduce biofuels to customers.

3.2.2. The Shutdown of Biofuels Plants
The biofuels plants have already racked up millions of losses because of the low demand and the government has moved more slowly than expected to boost biofuel use. Since 2015, three biofuel plants (Table 6) have stopped production due to current difficulties in the market. Thousands of jobs and millions of dollars in investment will be at risk if the government does not have any mandates to speed up the use of green transport fuel.

3.2.3. Technology barrier
Biofuels production technology in Vietnam is far behind the foreign advanced level. Today, biofuels are not cost competitive with conventional fossil fuels in Vietnam because biofuels is still produced in old and obsolete plants resulting in high energy consumption, low productivity. Some biodiesel plants utilize obsolete filtration technology with low oil recovery rate, leading to higher price of immediate products and not economical for blending. Mastering blending technology is also a challenge to biofuels production in the country at present [13].

3.2.4. Human resource
The development of biofuels production requires experts and a skilled labor force. The lack of well-qualified workers restricts the research activities and the production of biofuels in the country. Many projects have been implemented; however, they have appeared on lost. The main reason is low ability (e.g. technical skill and management skill) of biofuels producers. Human resource is one of the main reason that hinder the development of biofuels to a certain degree.

3.3. Opportunity

3.3.1. More attention should be paid to biofuel production and blended fuel combustion
In the research on cost-effectiveness of fuels, [16] stated that “the cost-effectiveness of using biofuel in comparison to fossil fuel depends on the efficiency of biofuel production and blended fuel combustion”. The results of the research, for example, shows that “the biodiesel substitution would be cost-effective if the fuel consumption of B5 and B10, in terms of L km-1 compared to diesel, would decrease by more than 1.4% and 2.8% for B5 and B10 respectively at the discount rate of 4%” [16]. Therefore, the increased attention that has been paid by the government to production and blended fuel combustion provides a good opportunity to develop sustainable biofuels market.

3.3.2. Biofuels Production from Residues
Agricultural residues, organic materials produced as by-product in the course of harvesting and processing agricultural crops [24], can be used for biofuel production [26] [28] [29]. Such biofuels are generally considered sustainable as they use waste materials from food crop production, and do not compete with food crops for land [26] [28]. There are 2 types of agriculture residues: crop residues or field residues (materials left or burnt on farms after the harvest of desired crops, e.g. straw of grain crops) and agricultural industrial by-product or processing residues (materials produced after crop processing, e.g. husks, chaff, cobs or bagasse)

3.4. Threat

3.4.1. The shrinking of agricultural land
The development of biofuels, from 1st or 2nd generation, requires arable land for the production of biomass. However, available land for biomass production is limited in Vietnam due to existing policies on agriculture and forest sector. More importantly, agricultural land continues to decline due to
industrialization and urbanization. According to the report from General Department of Land Management, average annual decrease of agricultural land is approximately 100 thousand hectares, especially in 2007, the figure was 120 thousand hectares, while every year about 400 thousand agriculture workers leave their occupation. Currently the unused land that can continue to exploit in the country is not significant. Meanwhile, climate change is likely to make the available arable land to be at risk of shrinking.

3.4.2. Biomass Resource Reduction
Although sugarcane is one of the main source for biofuels, the production of sugarcane in Vietnam has slightly decreased in the past 10 years. From 2005 to 2012, plantation areas increased from 266.3 to 301.9 thous. ha; however, the figure dropped to 284.5 thous. ha in 2015. As a result, both yield and production were also slightly declined to 644 Quintal/ha and 18320.8 thous. tons respectively in 2015. Despite the annual production of 100 million tome of fuel grade ethanol, it was mainly for export as domestic demand is quite low. The cassava area has expanded in recent years because of high demand from starch factories and for the export of dry chips. Although land suitable for cassava cultivation is available, the government discourages cassava expansion because of the resultant soil degradation and water pollution from cassava processing. Cassava cultivation has been promoted strongly by the government; however, there is not an integrated master plan on land use planning and sustainable cultivation practice. Like sugarcane and cassava, maize has not been favoured as an ethanol feedstock because of concerns about competition with food. Moreover, maize uses large amounts of fertilizers and pesticides, and thus consumes fossil fuel energy.

Jatropha grows on almost any terrain; however, many experts stated that the economic feasibility of jatropha cultivation and biodiesel production from jatropha oil was not investigated enough. In Vietnam, production of biodiesel from jatropha oil might not beneficial because the oil pressed from 3kg of seeds is needed to make 1 litre of biodiesel with price of 10,000VND/litre, and the cost of 1kg of jatropha seeds in Vietnam is 3000VND. With that cost, the production biodiesel from jatropha oil might not be profitable. In addition, cultivation of jatropha alone may not be economically viable, well-management and inter-cropping with other plants & flowers could be a preferred option.

3.4.3. Food Security, Feedstock Priority and Policy
Although biofuels is an important player in the decarbonization of the transport sector and biofuel production helps create opportunities for agricultural development, increasing biofuel production is going to have an impact on world agricultural commodity prices and food security. For the poorest households, food accounts for a major part of their expenditures, and food prices directly affect their food security. Decision No. 177/2007/QD-TTg plays an important role in guiding the development of biofuels production in Vietnam; however, the issues of food security or the selection priority of agricultural feedstocks and residues for biofuels production has not been clarified. Today, as a consequence of the urbanization, population booming, climate change and now the loss of productive agricultural land for biomass, food security in Vietnam might be threatened in the long term. In addition, switching from producing low profitability food crops to producing high profitability biofuel crops may result in price increases for some essential food categories. Take maize and sugarcane for example. Maize is widely used as human food and feedstock for animals. Food insecurity is more urgent than the energy crisis; thus, food security takes priority over biofuel production with regard to maize. Sugarcane becomes a potential feedstock for biofuels as it does not require any specific type of soil as it can be successfully raised on diverse soil types. However, the policies for ethanol production from sugarcane or its by-products are incomplete at the present stage. Sugarcane based ethanol production is just in initial stage and other potentials have not been explored. Thus, it is critical to understand the trade-off of land use, price of feedstock supply, domestic food security when they promote biofuel programs and select feedstock to contribute to agricultural development [10].

4. Discussion and conclusion

4.1. Discussion
Biofuels offer many benefits and is defined as a substitute for conventional fuels. For energy-deficient countries, biofuels help to reduce the dependence on imported fuels and offer improved balance of trade and balance of payments. Fossil fuels produce large amount of greenhouse gases in the atmosphere which causes global warmth and climate change. If people start shifting towards biofuels, emissions could all be significantly reduced. The production of transportation fuels from agricultural resources in Vietnam requires sustainable feedstocks and new technology development. Although biofuels have latent contribution to sustainable development in Vietnam, they face challenges in connecting to food security, land requirements and availability, policies, knowledge, standards, awareness, participation and investment. Therefore, in the short term, petroleum will be still the main fuel used in Vietnam.

According to the SWOT analysis, although there are weaknesses and threats of biofuels in the present stage, the strengths and opportunities impel the development of biofuels. Therefore, the advent of biofuels in Vietnam needs the support of policy, technology, humanity, finance and many other internal and external factors. This paper gives some support measures listed below:

a) Land requirements and availability
Producing biofuels on a large scale could require huge tracts of land that causes potential land use conflict with food crops. Regarding the risk of diverting farmland or crops for biofuels production, much controversy surrounds the future of biofuels. Biomass utilise the same resources required for many forms of food production namely land, water and agrochemicals. Competition between food and fuel is perhaps the most prominent issue; however, competition may be avoided by careful planning for ecological conservation and sustainable production methods. A number of studies on land availability give wide-ranging results [30] [31] [32]; however, there is little research on the land use for biomass and food in Vietnam. Thus, study estimating land requirements to meet specified biofuel is needed.

b) Policy issues
Successful policy development and implementation requires a sound legal, regulatory and institutional framework. Vietnam has not had comprehensive biofuel policies, and the existing ones often driven largely by agricultural or energy considerations. Supportive government policies are essential to the development of biofuels. Policies are urgently required to capture a wide spectrum of activities involving food security transportation, environment, land-use change, forestry, agriculture, biomass priority and residues. In addition, worldwide interest in biofuels is certainly growing, which will hopefully spur investments. Therefore, it is essential to develop a robust investment policy to create a legal corridor to attract and support foreign interest and finance from private sector in the R&D and biofuels production.

At present, the “Scheme on Development of Biofuels up to 2015 with the Vision to 2025” issued by Prime Minister only provides a general orientation on the targets for each period and the prioritized list of activities. It is expected that a road map for biofuel development shall be completed soon in order to provide detailed instructions to achieve the set targets, and a workable implementing plan. Besides, it is also expected that the sources of funding for biofuel projects will be well defined.

d) Awareness and participation
Active government involvement plays a key role in successful biofuel programmes. Valuable lessons can be drawn from Germany and the United States. Germany and US are leaders in high-technology biofuel production, due to strong government commitment, viable policy and solid collaboration from the private sector. It is argued that one of the main reasons behind the shutdown of many biofuels plants in Vietnam is that the government has moved more slowly than expected to boost biofuel use. In fact, biofuel markets depend heavily on government incentives and mandates; therefore, the government should create a positive environment for biofuels production, and providing robust support (e.g. campaigns, PR) to raise biofuel awareness among citizens. Information including environmental impacts of petroleum, benefits of biofuels in terms of health, environment, vehicle engine,… may be used to communicate with community.

e) Investment
Lack of a skilled workforce, R&D and cutting-edge technology keeps Vietnamese biofuels production behind that of the West and other countries in the region such as Thailand, China, and India who have been innovating extensively to improve biofuels production. The government should invest in technology development and fund a broad portfolio of biofuels research programs because fundamental technology improvements and scientific breakthroughs are always necessary in both biomass optimization and the processing of biomass into fuels. The investment normally comes from national budget. Thus, the country should seek to encourage private involvement in biofuels production. In addition, the country could obtain funding from international financial institutions and regional and sub-regional development banks. Other development partners are now ready to participate in viable projects [20].

A qualified workforce is one of the key roles in the development of biofuels program. Currently, better-trained worker in Vietnam is inadequate Thus, the country should place greater emphasis on developing a skilled workforce. High education, professional training programs and other means should be designed to develop a skilled professionals capable of operating biofuels industry.

4.2 Conclusion
This study reviews the biofuels potential for production of biomass transport fuels in Vietnam. Transportation is the third largest single source of air pollution in Vietnam and with the rapid increase of vehicle fleet, air pollution is expected to worsen in the near future. In addition, despite having high crude oil, Vietnam is still a net oil importer of transportation fuel and this makes the country vulnerable to volatility in global fuel prices and dependent on foreign exchange to meet its domestic energy needs. Vietnam is an agricultural country with tropical weather and has a wide variety of sources, such as energy crops, agricultural crop residues, forest resources which are suitable for biofuels development.

By using a SWOT analysis, the internal strengths and external opportunities in terms of land-use, biomass resources, and governmental is currently obvious and significant, but weaknesses and threats such as existing policy gaps, technology barrier, and contractor capability must be tackled in several ways in order to realize biofuels as a major substitution of petroleum-based transportation fuels. Some solutions are suggested in the paper ranging from land requirements and availability, policies to investment. They are derived from the combination of strengths-weaknesses-opportunities-threats of available resources in the country.

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## Appendices

### Table A1. A summary of the biofuels policies in passenger and freight transport

| Policies | Date             | Issuers          | Main content                                                                                           |
|----------|------------------|------------------|--------------------------------------------------------------------------------------------------------|
| Law on Economical and Efficient Use of Energy | June 17, 2010    | The National Assembly | Provides economical and efficient use of energy, policies and measures to promote economical and efficient use of energy, and the rights, obligations and responsibilities of organizations, households and individuals in economical and efficient use of energy. |
| Decision No. 249/2005/QD-TTg | October 10, 2005 | The Prime Minister | Roadmap for application of emission standards for road vehicles                                          |
| Decision No. 909/QD-TTg | June 17, 2010    | The Prime Minister | The roadmap for application of emission standards for road vehicles                                      |
| Decision No. 49/2011/QD-TTg | September 01, 2011 | The Prime Minister | The exhausted gas emission control plan for in-used motorcycles and mopeds in the provinces and cities |
| Decision No. 53/2012/QD-TTg | November 22, 2012 | The Prime Minister | Roadmap for application of ratios for blending biofuels with traditional fuels                         |
| QCVN 05:2009/BGTVT (for emission) | November 19, 2009 | MOT              | National technical regulation on emission of gaseous pollutants from assembly-manufactured automobiles and new imported automobiles |
| QCVN 01:2009/BKHCN (for fuel) | September 30, 2009 | MOST             | National technical regulation on gasoline, diesel fuel oils and biofuels                              |
| QCVN 86:2015/BGTVT (for emission) | July 24, 2015    | MOT              | National technical on the fourth level of gaseous pollutants emission for new assembled, manufactured and imported automobiles |
| QCVN 01:2015/BKHCN (for fuel) | November 11, 2015 | MOST             | National technical regulation on gasoline, diesel fuel oils and biofuels                              |
| QCVN 04:2009/BGTVT | November 19, 2009 | MOST             | National technical regulation on emission of gaseous pollutants from assembly - manufactured motorcycles, mopeds and new imported motorcycles, moped |
| QCVN 01:2009/BKHCN (for fuel) | September 30, 2009 | MOST             | National technical regulation on gasoline, diesel fuel oils and biofuels                              |
| QCVN 77:2014/BGTVT (for emission) | October 3, 2014  | MOT              | National technical regulation on the third level of gaseous pollutant emission for new assembled, manufactured and imported two-wheeled motorcycles |
| QCVN 01:2015/BKHCN (for fuel) | November 11, 2015 | MOST             | National technical regulation on gasoline, diesel fuel oils and biofuels                              |

*Note: MOST (Ministry of Science and Technology), MOT (Ministry of Transport)*
Table A2. Status quo of Agricultural land from 2000-2014

| Type                          | Area (ha)     | Land-use Change (ha) |
|-------------------------------|---------------|----------------------|
|                               | 2000          | 2005                 | 2010 | 2014 | 2000-2005 | 2005-2010 |
| Agricultural land             | 20,939,679    | 24,822,560           | 26,100,160 | 26,822,900 | 3,882,881 | 1,277,600 |
| Agricultural production land  | 8,977,500     | 9,415,568            | 10,117,893 | 10,231,700 | 438,068   | 702,325   |
| Forestry land                 | 11,575,027    | 14,677,409           | 15,249,025 | 15,845,2 | 3,102,382 | 571,616   |
| Water surface land for fishing| 367,846       | 700,961              | 690,218 | 707,9   | 332,215   | -9,343    |
| Land for salt production      | 18,904        | 14,075               | 17,562 | 17,9    | -4,829    | 3,487     |
| Others                        | 402           | 15,447               | 25,462 | 20,2    | 15,045    | 10,015    |

Table A3. Crop cultivation in Vietnam from 2005 – 2015 (GSO Vietnam)

| Crop                          | Cultivable area               | Element         | 2005  | 2006  | 2007  | 2008  | 2009  | 2010  | 2011  | 2012  | 2013  | 2014  | 2015  |
|-------------------------------|-------------------------------|-----------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Sugarcane                     | Mekong River Delta, North     | Planted area    | 266.3 | 288.1 | 293.4 | 270.7 | 265.6 | 269.1 | 282.2 | 301.9 | 310.4 | 305   | 284.5 |
|                               | Middle and Coastal Plain      | Yield           | 561.3 | 580.3 | 592.9 | 596.4 | 587.7 | 600.6 | 621.5 | 629.9 | 648.5 | 649.9 | 644   |
|                               |                               | Production      | 14948.7 | 16719.5 | 17396.7 | 16145.5 | 15608.3 | 16161.7 | 17559.6 | 19015.4 | 20128.5 | 19821.6 | 18320.8 |
|                               |                               | Growth Index    | 102.6 | 103.4 | 102.2 | 100.6 | 98.5  | 102.2 | 103.5 | 101.3 | 103   | 100.2 | 99.1   |
| Cassava                       | Central, North East, Mekong   | Planted area    | 425.5 | 495.5 | 554   | 507.8 | 496.2 | 498   | -     | 551.9 | 543.9 | 552.8 | 566.5 |
|                               |                               | Yield           | 179.4 | 162.5 | 160.7 | -     | 169.0 | -     | -     | -     | -     | -     | -     |
|                               |                               | Production      | 6716.2 | 8192.8 | 9309.9 | 8530.5 | 852.16 | 859.6 | 9735.4 | 9757.3 | 10209.9 | 10673.7 |
|                               |                               | Growth Index    | -     | -     | -     | -     | -     | -     | -     | -     | -     | -     | -     |
| Maize                         | North East, South East        | Planted area    | 1052.6 | 1033.1 | 1096.1 | 1140.2 | 1089.2 | 1125.7 | 1121.3 | 1156.6 | 1170.4 | 1179   | 1179.3 |
|                               |                               | Yield           | 36    | 37.3  | 39.3  | 40.1  | 40.4  | 41    | 43.1  | 43    | 44.4  | 44.1  | 44.8   |
|                               |                               | Production      | 3787.1 | 3854.6 | 4303.2 | 4573.1 | 4371.7 | 4625.7 | 4835.6 | 4973.6 | 5191.2 | 5202.3 | 5281   |
|                               |                               | Growth Index    | 103.9 | 103.7 | 105.2 | 102.2 | 100   | 102.5 | 104.9 | 99.7  | 103.1 | 99.3  | 101.6  |

Planted area (Thous. ha), Yield (Quintal/ha), Production (Thous. tons), Growth Index (%)

### Table A4. Policy support for Energy Efficiency and Conservation

| Policy | Date | Issuer | Main content |
|--------|------|--------|--------------|
| Decree No. 102/2003/ND-CP | September 03, 2003 | Prime Minister | • Specifies roles and responsibilities for the various government agencies regarding energy efficiency;  
• Focuses on mitigating energy use by production establishments, buildings, and equipment through technological modification and choice of investment, energy-efficient design, and operations management;  
• Promote thrifty energy consumption of citizens’ lifestyles. |
| Vietnam National Energy Efficiency Program | April, 2006 | Prime Minister | • In line with EE&C decree, the Ministry developed specific strategies to promote energy efficiency  
• A targeted national program and the first-ever comprehensive plan to institute measures for improving energy efficiency and conservation across all sectors of the Vietnamese economy;  
• The overall aim is to make initial savings of 3–5% during the period 2006–2010 and a further 5–8% during the period 2011-2015 (Chau 2015) |
| Decision No. 1427/2012/QD-TTg | October 2, 2012 | Prime Minister | • National Targeted Programme on Energy Efficiency and Conservation - Phase 2012-2015  
• Specifies six objectives to promote and achieve energy efficiency |
| Decision No. 1885/QD-TTg | December 27, 2007 | Prime Minister | • Strategy on National Energy Development up to 2020, with vision to 2050:  
• Develop refineries to meet the domestic demand for oil products, bringing the total refinery capacity to around 25-30 million tons of crude oil by 2020;  
• Increase the proportion of renewable energy to about 3% out of total primary commercial energy by 2010; about 5% by 2020 and about 11% by 2050 |
| The Law on Energy Efficiency and Conservation | June 18, 2010 | National Assembly | • Highlights energy labelling as an effective method to increase the use of vehicles and appliances with high efficiency, gradually removing vehicles and appliances with outdated technology, reducing energy consumption in production.  
• Encourages citizens to be involved in the development of mass transit networks, to manufacture and use energy-saving vehicles |
|          |      |        | exploit and expand the application of liquefied gas, natural gas, electricity, mixed fuels and biofuels in replacement of petrol |

### Table A5. Biofuels Policy and Incentives

| Policy | Date       | Issuer | Main content |
|--------|------------|--------|--------------|
| Decision No. 177/2007/QD-TTg | November 20, 2007 | Prime Minister | • Develop biofuels as a new and renewable energy to partially replace conventional fossil fuels, so that contribute to ensuring energy security and environmental protection |
| Decision No. 3638/QD – BCT | July 17, 2009 | MOIT | • Establish a task force to develop standards and technical regulations on the production, storage, distribution and certification of biofuels |
| Circular No. 20/2009/TT-BKHVN | September 30, 2009 | MOST | • The national technical regulation on gasoline, diesel fuel oils and biofuels following QCVN 1:2009/BKHVN |
| Decision No. 400/ QD-TDC | March 25, 2010 | MOST | • The guidelines for standard-compliance certification of gasoline, diesel and biofuels following QCVN 1:2009/BKHVN |
| Decree 24/2007/ND-CP | February 14, 2007 | Government | • The guidelines for the implementation of The Law On Enterprise Income Tax |
### Table A6. Three major Biofuels plants in Vietnam

| Plant                      | Location                     | Investor                                                                 | Investment  | Capacity                  | Construction          | Remarks                                                                                       |
|----------------------------|------------------------------|--------------------------------------------------------------------------|-------------|---------------------------|-----------------------|-----------------------------------------------------------------------------------------------|
| The Dung Quat Bio          | North Central and            | PetroVietnam (PV Oil, BSR, PVFC, Petrosetco)                            | $92 million | 100 million liters per    | 2009-2012             | Products: ethanol 99.7%, feedstock, purified CO2 for food industry, biogas Central market     |
| Ethanol Plant              | central coastal areas        |                                                                          |             | year                      |                       |                                                                                               |
| Binh Phuoc Ethanol Plant   | North Central and            | Vietnam Oil Company (PV Oil), LICOGI 16 and ITOCHU Corporation (Japan)  | -           | - 100 million liters per  | 2010-2012             | Products: ethanol 99.7%, bio-fertilizer, purified CO2 for food industry, biogas Southern market |
|                            | central coastal areas        |                                                                          |             | year                      |                       |                                                                                               |
| Phu Tho Biofuel plants     | Northern midlands and        | Vietnam Oil Company (PV Oil, a company under Vietnam National Oil and     | $114.2      | - 100 million liters per  | On-going              | Products: ethanol 99.7%, bio-fertilizer, purified CO2, for food industry, and biogas for      |
|                            | mountain areas               | and Gas Group – PetroVietnam) and SEA bank                              | million     | year                      | (under construction) | Northern market.                                                                               |
|                            |                              |                                                                          |             | - Using 260,000 tons of  |                       |                                                                                               |
|                            |                              |                                                                          |             | cassava slices             |                       |                                                                                               |
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