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Progress Report on:

BIOETHANOL SUPPLY CHAIN DYNAMICS

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1-Introduction

1.1-Background of the Project

Biofuels are non-fossil fuel energy carriers that store the energy derived from organic materials (biomass) directly from plants or indirectly from industrial, commercial or domestic wastes. They may be solid, such as fuel wood, charcoal and wood pellets; liquid, such as ethanol, biodiesel and pyrolysis oils; or gaseous, such as biogas **[16, 24]**.

Often the term biofuel is used in a narrow sense to refer to liquid biofuels for transport these are often separated into biodiesel and biogasoline and further qualified as first or second generation. First generation biofuels generally refers to biofuels produced from edible crops that are either high in sugar (sugar cane, sugar beet, corn, wheat) and used to produce bioethanol, or high in oil (rapeseeds, oil palm, and soybean) and used to produce biodiesel using conventional technology. Second generation biofuels generally refers to biofuels produced from non food components of plants (stems, leaves and husks), non food crops (switch grass, jatropha), or industry and agricultural waste (wood chips, skins, pulp). It can also include biomass-to-liquids (BTS), such as biodiesel created using the Fischer Tropsch process that corresponds to advanced processing of natural materials **[24]**.

Biofuels have many advantages that have fuelled their rapid development. Basically Biofuels may be referred to as renewable energy because they are a form of transformed solar energy in which the technologies use renewable biomass resources available anywhere in the world to produce an array of energy related products. Moreover the technology is simple; and uniquely for renewable energy sources with a variety of storage and transport options **[3]**.

However, there are some serious challenges that biofuels globally must overcome before they become truly useful as a renewable alternative to fossil fuels. Large quantities of crops

are used to produce commercial biofuels, and these are currently all food or crops (sugarcane, maize, cereals, soy etc.), because the technology is not yet fully developed that can utilise cellulose rather than starch or sugar. Thus, it still shows clearly that using current conversion technique with food crops as a base is not feasible in large quantities. When accounting for emissions released from fertilisers, harvesting operations, transport and processing, some biofuels have an end balance of greenhouse gas emissions that is equivalent to or sometimes worse than the fossil fuels they are replacing **[2, 9]**.

Concern for negative biodiversity arises from the risk expanding agricultural land into natural forest or grassland, so as not to come into conflict with food production. Of greater concern are the potential indirect impacts, where it is not the biofuel production itself that causes deforestation, but that at some point biofuel displaces crop production perhaps to natural ecosystems. Not only are biofuels in competition with arable land for food crops, or high biodiversity, but also for other energy uses. Another disadvantage of using biomass to produce liquid biofuels for transport is that the energy conversion efficiency is very low for example, corn ethanol may only provide 1.2 times as much energy as was used to produce the ethanol. Hence, there is concern about bad labour conditions on plantations, and uncertainty surrounding the impacts of large-scale purchases of land in tropical countries for biofuel production on resident landowners **[2, 17]**.

Bioethanol is ethanol produced from biomass *(Directive 2009-28-CE). Ethanol or ethyl alcohol (C_2H_5OH) is a clear colorless liquid; it is biodegradable, low in toxicity and causes little environmental pollution if spilt.*

To use bioethanol as final product there are stages along the supply chain. The processes are mainly feedstock production, feedstock preparation, feedstock logistics, ethanol production and ethanol distribution.

Supply chain is a system of suppliers, manufacturers, distributors, retailers, and customers where materials flow downstream from suppliers to customers, and information flows in both directions **[13]**.

Coming to the global issue, The Kyoto Protocol places an obligation on all countries to reduce national carbon emissions to below 1990 levels. To achieve this goal the use of renewable energy specially the use of bio-fuels in transport sector has great contribution.

In Europe, one of the major applications of ethanol is using it as a fuel with the main goals behind the promotion of biofuels: environment protection, sustainable development, energy security and job opportunity **[20]**.

The EU has set the target to minimize the carbon emissions at 20% by 2020 (European Parliament 2009b). The transport sector is responsible for 28% of the EU's carbon emissions **[1]** and is the sector where the least progress has been made in replacing fossil fuels. Renewable transport fuels only account for 3.29% of the EU's fuel consumption in transport **[7]**. The transport sector is also highly dependent on oil imports, giving rise to both economic insecurity and long-term supply insecurity **[1, 6]**. Therefore, the transport sector has a separate target, requiring that 10% of the energy in transport must come from renewable energy sources by 2020.

The liquid biofuels, ethanol and biodiesel are currently the most important renewable fuel, accounting for around 80% of the EU total renewable transport fuel production in 2008 **[7]**, and have shown rapid increase in production globally in the past 15 years **[2]**. However, recent heavy criticism challenges their sustainability. Increasing the use of bio-ethanol has great role in minimizing GHG emissions. Even though, energy conversion technologies running using ethanol emit CO_2 which is the primary source of GHG emissions, the released CO_2 is absorbed by feedstock which are used as a raw material for production of ethanol often described as carbon neutral on its own cycle **[21]** but bio-fuels' environmental sustainability has been questioned due to their potential life-cycle emissions of greenhouse gases that rival fossil fuel emissions **[8, 9]** and negative impacts on biodiversity if badly managed **[11]**. Social sustainability questions revolve particularly around the competition for land and water with food, and bad labor conditions **[5]**.

Of the European member states, Sweden has the highest share of renewable energy in terms of total energy consumption, with 44.4% in 2008 **[7]**, and one of the highest shares of renewable energy in transport with 5.4% in 2009 **[4]**. Sweden also has a long history of

governance mechanisms targeting increased renewable energy, and is one of the few EU countries to have already implemented renewable energy directives in national law.

Sweden has a target to have fossil fuel energy independent fleet by 2030. To support and promote the use of biofuels, Sweden has policy called tax exemption for biobased motor fuels. This policy leads to tax exemption for up to 6.5% blending in petrol and 5% in diesel and vehicle tax exemption up to five year; and Sewden has a policy that states public authorities are required to ensure that passenger cars, purchased or leased, are clean vehicles that have emission levels less than 230 gram of CO_2 per km **[15]**. These policies which are implemeted to promote the use of biofuels in transport sector and hence they are the motivation factor to work on this project.

In Sweden, three types of bioethanol are using in transportation sector namely, E5, E85 and E95. E5 is 5% ethanol and 95% petrol. E85 is 85% ethanol and 15% petrol mainly used in passenger cars. And E95 is 95% ethanol and 5% petrol mainly used as bus fuels **[15]**. The following figure shows production and consumtion of ethanol in Sweden in million liters **[19, 23]**.

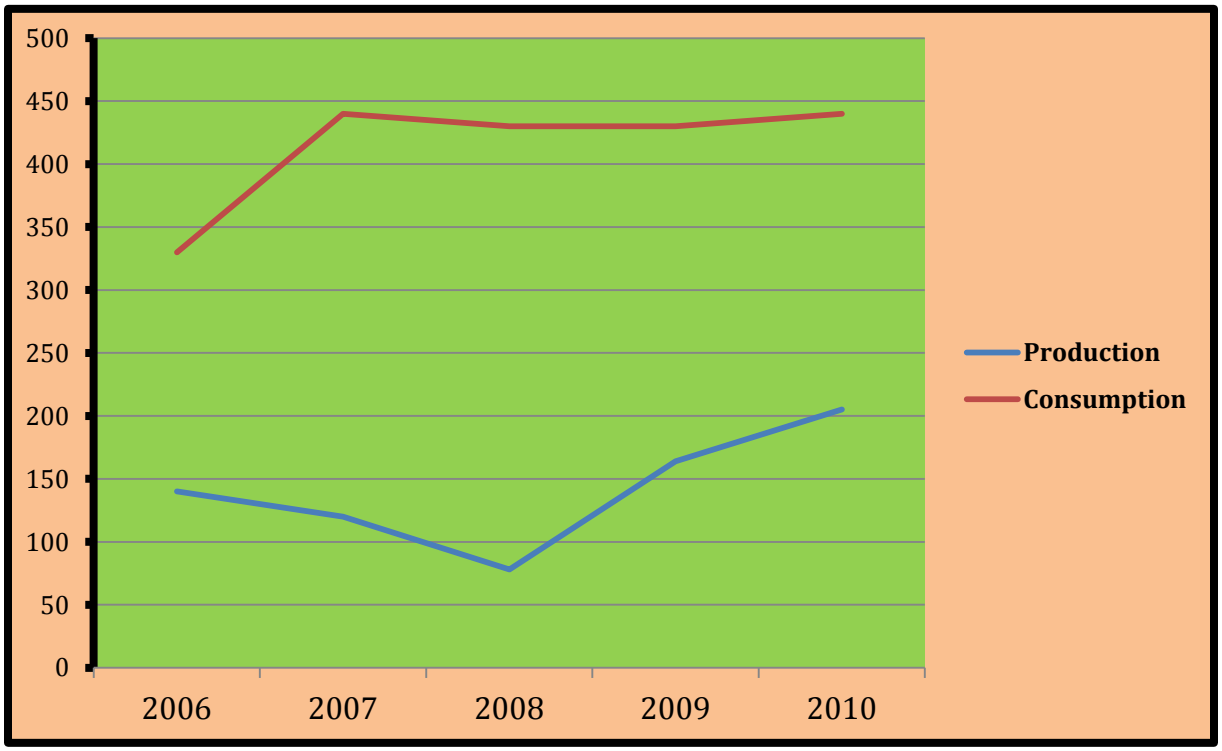

Figure 1.1: Production and consumption of ethanol in Sweden

As it can be seen from figure 1.1, the consumption ethanol show increased trend up from 2006 to 2007 then shown slightly decreasing up to 2009 then increased. Whereas the production of ethanol shown decreasing from 2006 to 2008 and then increased up to 2009. These two trend lines show the dependence of Sweden on imported bioethanol which is one of the central problem areas on which this project deals with.

In addition to the above factors that drive the team to work on this project, some of the team members have prior knowledge on biomass and supply chain management; and all the group members has basic knowledge on entrepreneurship. Therefore, this project work is considered as an opportunity for the group member to reinforce their prior knowledge in to practical and then, in the future, to create a consultant company that provides **green transport solutions**.

1.2-Statement of the Problem

As it was stated in the background part of the project, Sweden has a fossil fuel independent fleet by 2030. In addition there is Environmental Program 2012 to 2015 is based on a vision of making Stockholm as an attractive and growing city **[25]**. To make all these possible one of the priorities is using environmentally efficient transport. In this case biofuels have important role. In sweden there are more than 600 ethanol buses of which Stockholm has more than 500 ethanol buses. The bioethanol fuel demand is not fulfilled by local potential, for example, in 2010 Sweden consumed 440 million liters of bioethanol of which 47% was produced locally the rest 53% was imported mainly from Brazil. When comparing the produced and the imported bioethanol, it is seen that Sweden is highly dependent on imported ethanol therefore ethanol security becomes an issue in addition to future energy price and environmental issue. Hence this project will contribute how the future bioethanol supply chain dynamics looks like by considering both the local potential and imported ethanol so that to give information.

In general, the increasing energy demand combined with the declining availability of fossil fuels is driving forces for the investigation of renewable energy sources. In this context, bioethanol is considered as one of the most appropriate solutions for gasoline

substitution. It is clear that to alleviate the problem associated with bioethanol, it is better to see the supply chain dynamics. Then, the motivation of this project is to study supply chain dynamics of bioethanol by taking Stockholm SL buses as a case study.

1.3- Objective of the Project

The general objective of the project is to conduct a study on the supply chain dynamics of bioethanol that can verify the feasibility to invest to the client. To achieve the main objectives the specific objectives are:

- ☞ To select the optimal supply chain of bioethanol
- ☞ To map the flow of the supply chain
- ☞ To identify key stakeholders
- ☞ To analyze interactions

1.4-Significance of the Project

This project is dedicated to investigate the bioethanol supply chain dynamics for transport in Sweden with special reference to Stockholm by understanding the challenges and model the overall system circumstances on the demand of bioethanol, the main customers, the local potential and the imported bio-ethanol at existing time and for the future to see sustainability of the market. Important information will be presented from various literatures, regarding what effect the supply chain dynamics is having on the bioethanol industry. In addition, investigation will be carried out on what perspectives other stakeholders from the bio-ethanol industry have on the supply chain dynamics. Therefore, the project will be useful for investors and can be used as an input for researchers, student, experts, officials to make further research, to set policies and strategies.

1.5-Scope of the Project

The scope of the project is generally described by the model boundary as shown in figure 1.2 below. There are several interactions along the supply chain of bioethanol. The model boundary of the project is selected so that it will play a vital role in the bioethanol supply

chain dynamics. On other hand, inside the boundary of the model are the intervention areas where the project work focuses.

The project is devoted to the bioethanol supply chain dynamics for Stockholm city for transport sector specially buses. Stockholm has sound experience in using bioethanol in the transport sector specially buses. There are experienced companies in Stockholm who has experience on doing research on biofueled vehicles and implementation. For example SL and Scania have, for a long period, worked in close collaboration to produce vehicles for a long period of time, most notably buses **[12]**. In 2010, SL has 545 ethanol buses which are the largest in the world. In the number of SL ethanol buses in 2010 was increased from 2009 which 416. In addition SL tested six ethanol hybrid buses between June 2009 and June 2010 together with the bus manufacturer Scania and the transport contractor Nobina. These buses have good potential for reducing fuel use for the future but still more work is needed **[18]**. Consumption for ethanol by buses is summarized in table 1.1 **[18]**.

Table 1.1: Consumption of ethanol by buses in Stockholm

Consumption of ethanol (million liters)			
Year	2007	2008	2009
Volume	19.92	21.68	24.32

People in Stockholm are unique in terms of the extent to which they use public transport. During the morning rush hours as many as eight out of ten travel by public transport in to the centre of Stockholm. This portion is considerably higher than for most of other capital cities in the world. Thus, the commitment to renewable fuels has to be continued and the best possible, commercially available technology is always adopted **[18]**.

First generation bioethanol generation is considered as it is a matured technology for mass production; and both local produced and imported bioethanol is mostly produced from first generation feedstock. In addition, since generating bioethanol using first generation feedstock has negative impacts and therefore they need more attention in supply chain dynamics to ensure sustainable production and consumption.

This project does not focus the carbon dioxide release during the life cycle of bioethanol because life cycle assessment is not the objective of the project rather the project will analyze the saved carbon dioxide emissions in using ethanol by comparing the fossil fuels. Also this project does not touch suppliers of gasoline this is not the main concern but it will focus on the blending composition with ethanol because blending composition affects the heat content and consumption of the blended fuel.

As the project targeting towards bioethanol supply chain dynamics, it does not concerned with water supply, farming and food market on the upper stream of the supply chain because analyzing thus are very complex and even does not have significant impact as feedstock goes to the supply chain of bioethanol. And hence the project focuses of the feedstock consumed for bioethanol production.

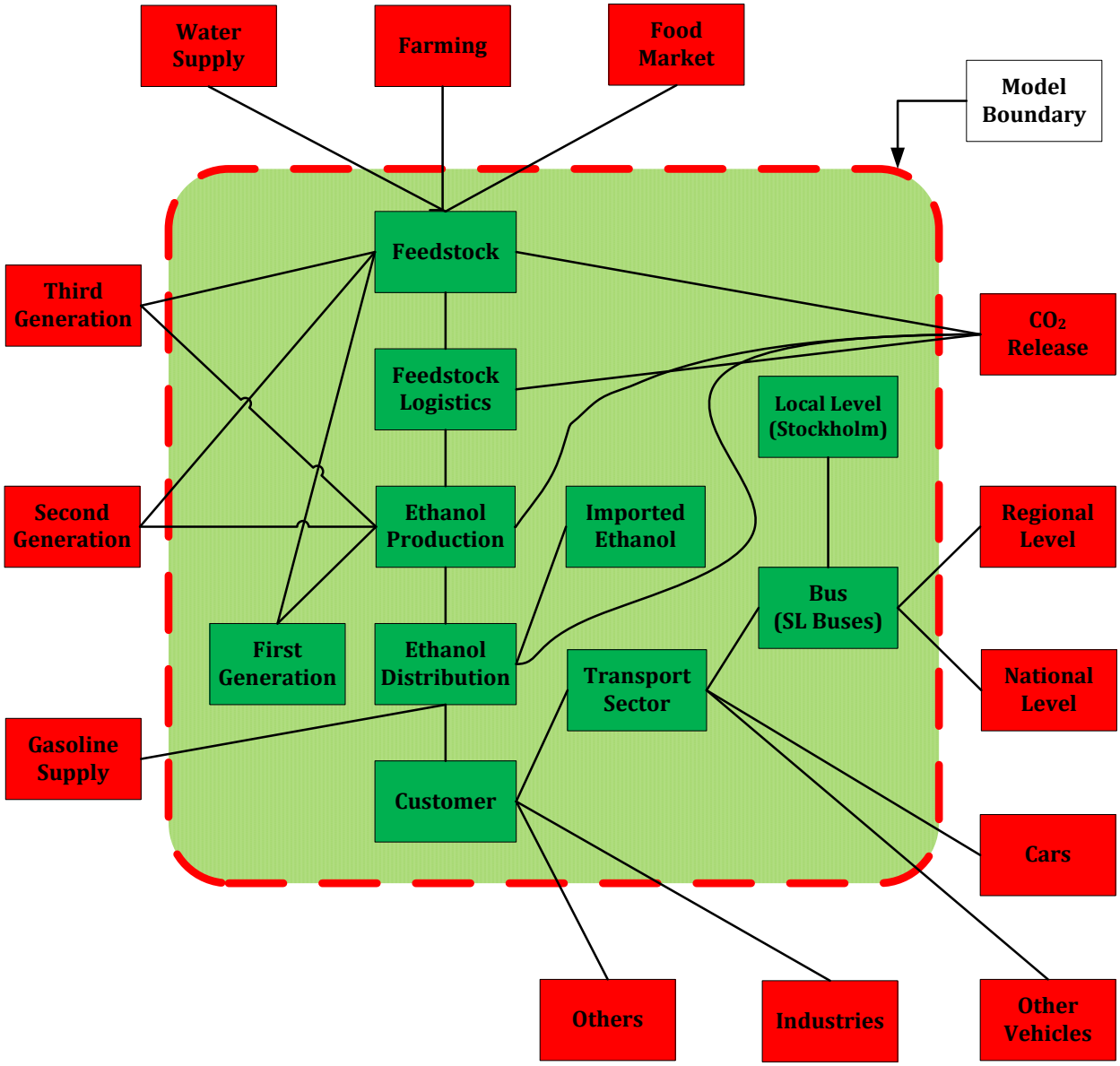

Figure 1.2: Model boundary of the project

To summarize, the main task of the project is to analyze the supply chain dynamics of bioethanol mainly in terms of material flow both in quantity and energy content. It starts with assessing the existing demand of bioethanol by Stockholm SL buses and then forecasting the demand until 2020 so that to see the dynamics of bioethanol dynamics. The project assesses the type of ethanol distribution channel and the stations. It identifies the existing local ethanol production using first generation technology and at the same time it focuses on the imported bioethanol especially the amount and type of transport mode.

Analyzing the type transport mode for local feedstock transportation and the capacity of warehouse is one of the main tasks of the project. The project will also, for locally produced ethanol, analyze the type of feedstock, amount consumed in terms of quantity and energy content.

1.6-Methodology

The project is an exploratory study that could provide the basis for on-going research, and can be a follow-up study of the impacts of bioethanol supply chain on investment, As such, evaluation of the impacts of the supply chain could be carried out, but preliminary data could be gathered. Thus, in order to conduct the project, various literatures (books, journals and thesis) are being surveyed from various sources; both primary and secondary data is being collected from different sources; then the collected data will be organized, analyzed and presented.

1.6.1-Literature Survey

A survey has been conducted on the existing literatures to get empirical knowledge about concepts of bioethanol supply chain dynamics. The literature survey furnished an overview of bioethanol, goals and policies that promote the use of bioethanol in Sweden especially in Stockholm.

1.6.2-Data Collection

Group discussion is one of the key tools to share and organize ideas and data. Every member of the group has nine hours per week and every Friday the group meets together and discussion is being carried out carried out. In addition, valuable and timely feedbacks and directions are being found from consultation by the project advisor. Books, journals, thesis, statistical data and organization documents are being referred to have an overview and construct the project even to take relevant data.

Currently the following data types are identified to be collected by interviewing researchers and officials of the organizations; and from their website.

- ☞ Historical data that states consumption of ethanol by buses in Stockholm it is targeted to be found from SL and Swedish Bioenergy Association.
- ☞ Data on existing demand of ethanol in Stockholm source to be collected from Swedish Energy Agency, Swedish Bioenergy Association and SL.
- ☞ Data on conversion efficiency of the buses engine to be collected from SL
- ☞ Data on mode of distribution and the associated distribution loss; and number and capacity of stations to be collected from SL and Swedish Bioenergy Association
- ☞ Historical data on the imported ethanol, mode of transport and the associated loss while transporting, to be collected Swedish Energy Agency and Swedish Bioenergy Association.
- ☞ Data on the installed capacity and actual production of local ethanol production plants also on the conversion efficiency to convert the feedstock to bioethanol. These data are expected to be collected Swedish Energy Agency, Swedish Bioenergy Association and the plants' document.
- ☞ Data on the types of feedstock and their consumption for local ethanol production, type and capacity of warehouse to store them, and mode of transport of the feedstock, these data are also expected to be collected from Swedish Energy Agency, Swedish Bioenergy Association and the plants' document.

1.6.3-Data Analysis and Presentation

Microsoft Office Visio is being used for drawing and mapping. Microsoft Office Excel for organizing the data. After collecting and organizing the data, analysis will be carried out using LEAP (Long Range Energy Alternatives Planning System) software.

In the tool selection for analyzing the data, three tools were proposed based on familiarity and the tools are Microsoft Excel Spread Sheet, Matlab and LEAP. From these alternative tools LEAP is going to be used for the analysis.

Microsoft Excel is not a dedicated tool for energy system analysis. Coming to Matlab, it needs algorithm formulation and writing a code and executing the code which becomes complex for such type of project. In addition, Matlab is not energy system dedicated software.

LEAP is software which is dedicated to energy system analysis; it is flexible to analyze energy system dynamics at present and in the future also which one of the major tasks of the project. The data that is being collected are in terms of energy content which can be easily encoded in the LEAP software. Moreover all the team members are doing another project using LEAP which is an opportunity to be effective and efficient to use LEAP for this project too. Thus are the main reasons to for choosing LEAP for data analysis of the project.

Finally, conclusions will be drawn; and important recommendations will be forwarded on how to achieve optimum bioethanol supply chain dynamics.

Chapter Two

2-Bioethanol Supply Chain Structural Model and Model Boundary

2.1-Structural Model of Bioethanol Supply Chain

The structural model of bioethanol supply chain of biofuel has five major interrelated stages namely, feedstock, feedstock logistics, ethanol production, ethanol distribution and customer. The supply chain structural model of bioethanol is shown in figure 2.1.

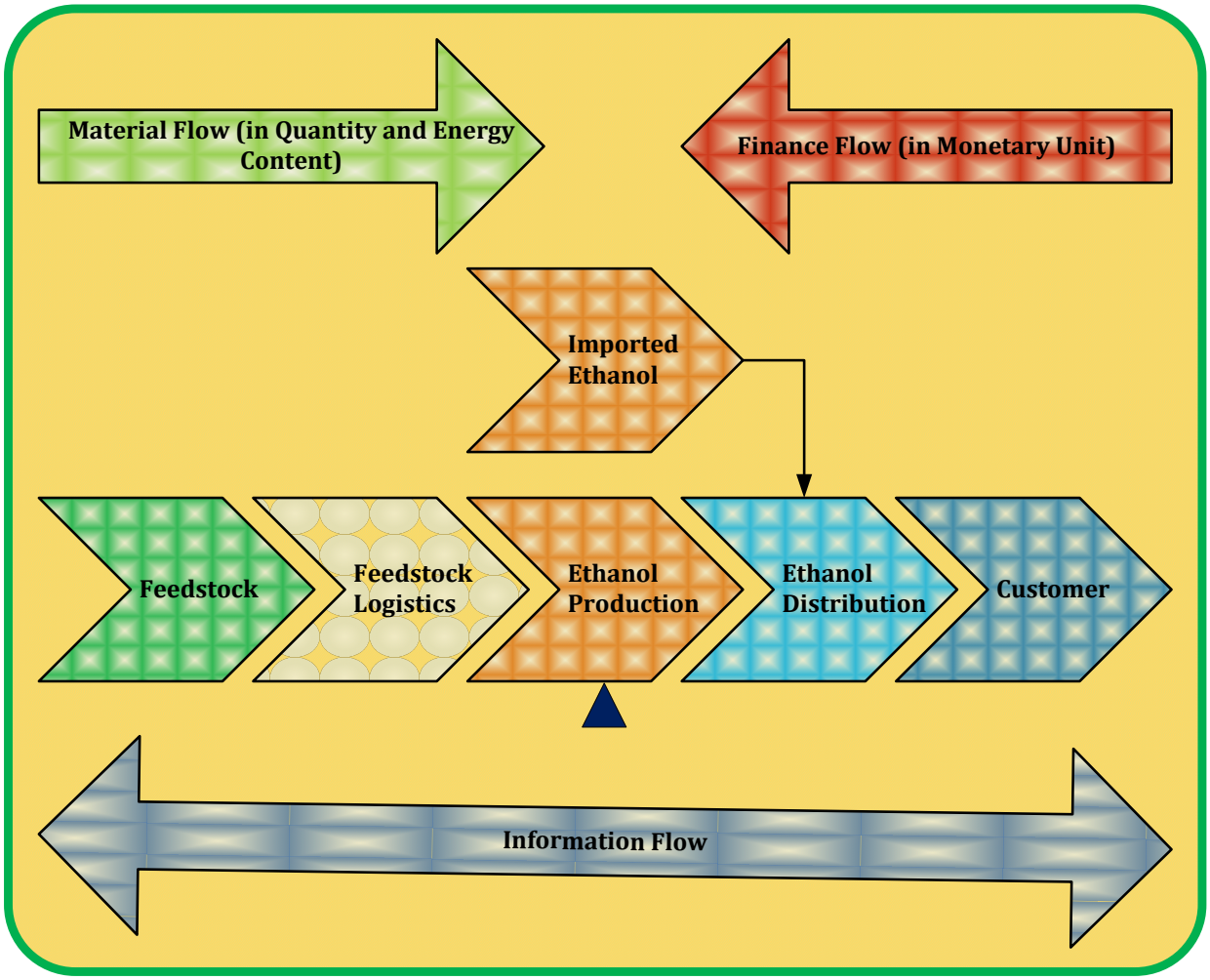

Figure 2.1: Bioethanol supply chain structural model

2.1.1-Feedstock

The main types of feedstock used for the production of bioethanol are corn, wheat, sugar beets, switch grass, woody fibers, sweet potatoes, sugar cane and sweet sorghum **[12]**. In Sweden ethanol is mainly produced from wheat gains, sugary liquor from sulphite pulp and wood residues **[14]**.

2.1.2-Feedstock Logistics

Feedstock logistics mainly concerned in storing and transportation of the feedstock.

2.1.3-Ethanol Production

Ethanol production involves the conversion of feedstock into ethanol with the various feedstock used there are different production pathways. Figure 2.2 below gives an overview of current common pathways of ethanol production as well as those being tested **[10]**.

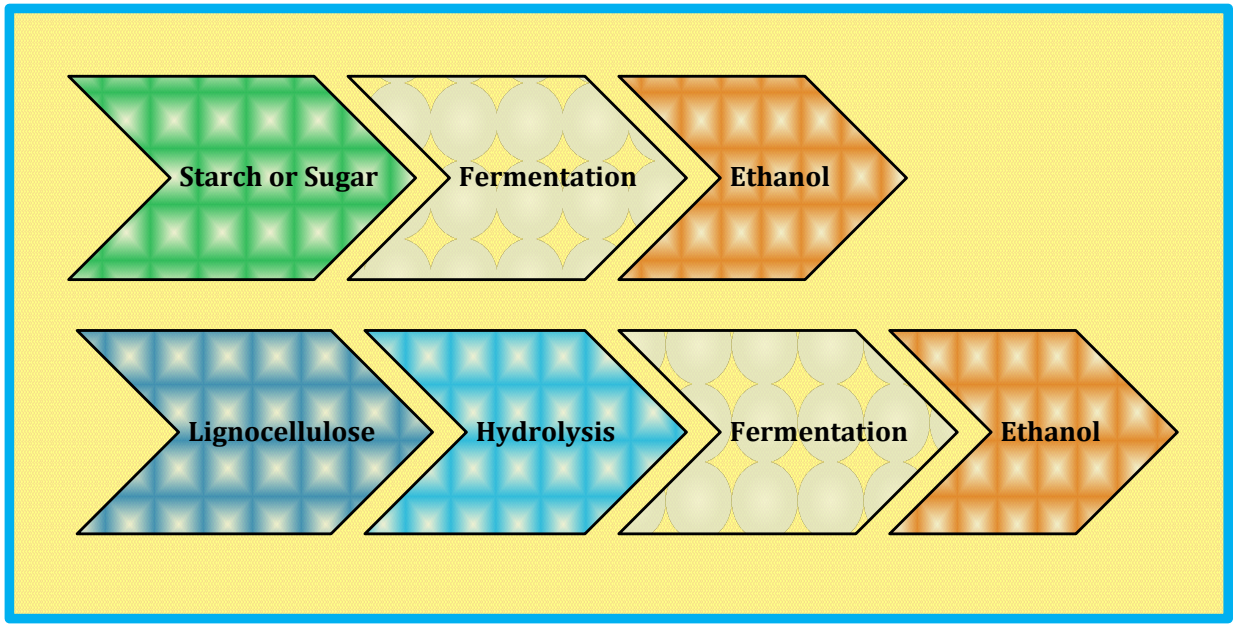

Figure 2.2: Production processes of bioethanol

In Sweden there are two main ethanol producers, the first is Agroetanol which is located at Norrköping with installed production capacity of 210 million liters and uses wheat grain as

feedstock. The second is SAKAB which is located at Örnsköldsvik with installed production capacity of 70 million liters and uses sugary liquor from sulphite pulp and wood residues as feedstock **[22]**. Figure 2.3 shows the location of Agroetanol (A) and SAKEB (B).

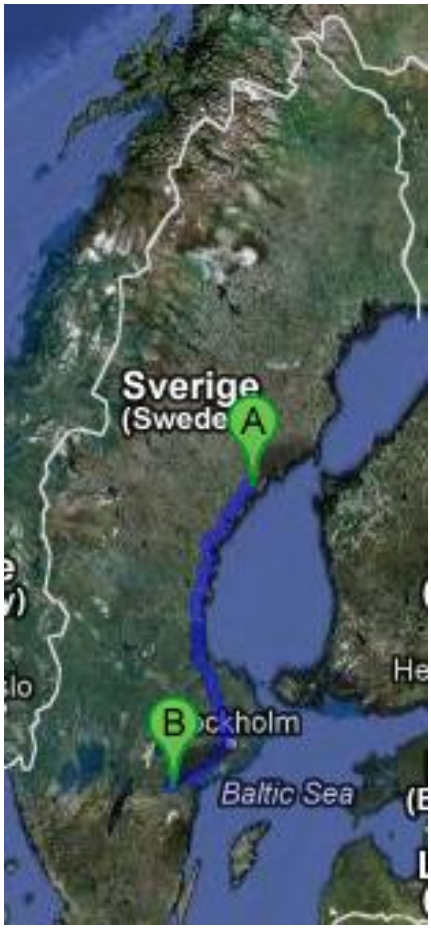

Figure 2.3: Location of ethanol production plants in Sweden

2.1.4-Ethanol Distribution

This is mainly concerned with mode of distribution, blending and filling stations' location, number and their capacity.

2.1.5-Customer

The customers are the end users of the produced bioethanol. The customers of bioethanol are mainly transportation sectors like buses, cars, etc; and industries mainly food and beverage manufacturing companies.

Conclusion

Up to know it is found that, there are different motives, policies and incentives at global, continent and national level to promote the use of biofuels in transport sector so that to achieve the target. Sweden is one of the European countries highly encourage the use of biofuels to meet carbon free transport by 2030. It has more than 600 bioethanol buses of which more than 500 are found in Stockholm city. In 2010 about of 53% consumption of ethanol is covered by importing mainly from Brazil which makes Sweden highly dependent on imported and hence security is an issue. This project is expected to address the future bioethanol supply chain dynamics using figures from the existing conditions. It is found that one of the critical task to analyze the supply chain dynamics of bioethanol is to formulate boundary of the model.

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