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PROJECT COURSE

Mid-term REPORT ON:

BIOGAS SUPPLY CHAIN DYNAMICS

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WWTP Waste Water Treatment Plant

CHAPTER ONE

1. INTRODUCTION

1.1 BACKGROUND

In the long term, Energy supply must be secured in a sustainable way. At the same time, the consumption of fossil fuels have to decrease, the reason behind is due to a limited and uncertain future supply of fossil fuel and undesirable effects on our environment. So there is no question to develop renewable energy sources in order to meet environmental and climate related targets, reduce emissions of greenhouse gases, reduce the dependence of oil and secure the supplies of future energy. It is known that the EU renewable energy directive mentioned that 20 % of the final energy consumption has to be provided by renewable sources by 2020. According to a study of the European Environmental Agency the potential from agricultural is still largely unexploited and this sector is expected to have the highest growth rates in the coming years. Biomass currently used as a renewable energy in Europe and Bioenergy will play a key role in achieving the ambitious targets approved by the renewable energy directive [12].

One of the EU countries, Sweden, Bioenergy has been used to reach the targeted energy directives. Traditionally, heating has been the primary application for bioenergy, but the markets for electricity generation from biomass and biofuels for transport have developed strongly. The use of biofuels for transport is widespread in Sweden, where biofuels such as biodiesel, ethanol and biogas are relatively available and many cars have flexible-fuel technology.
Here in this project, it will be considered how the biogas supply chain plays its part. Basically, Sweden uses four types of plants. These are Waste Water Treatment Plant (WMMP), co-digestion plants, farm-based plants, and industrial plants. Not all produced biogas is used as vehicle fuel, although it is the single largest area of utilization today (44% WWTP, 25% Co-digestion plants, 1% farm-based plants, 8% industrial plants and 22% landfills) [6].In the past decade, Sweden has experienced a great market expansion due to both production and sales of biogas as vehicle fuel. Between year 2010 and 2011, the sales of biogas increased by 27% and approximately 121 million Nm^3 gas were sold in year 2011 as a vehicle fuel, constituting to 62% of biogas (remaining 38% were natural gas) [6].

At present, Biogas is upgraded to natural gas quality. And it is sold both as pure biogas and in admixtures with natural gas. In southern Sweden, the existing natural gas network offers an option for the users to purchase pure biogas. This option requires careful metering and reporting of delivered and consumed quantities of biogas to the system. Recently, distribution of upgraded biogas has increasingly been provided by parties other than the producers. Gas can be distributed

either by road tanker or by pipe [6]. In many case, biogas pumps at petrol stations are owned by the producer or distributor of the gas. Today, Sweden has 107 public outlets for motor fuel gas [3]. However, there are substantial differences between the density of the network in different parts of the country, with most of the gas refueling stations being in the south of the country and in the major urban areas [2].

Stockholm is the capital city of Sweden with 850,000 inhabitants; if the whole of Stockholm County is included, the number of inhabitants is more than 2 million. The Stockholm site comprises the cities of Stockholm, Linköping and Västerås and the following partners: the City of Stockholm, Stockholm Vatten AB (SVAB), AGA Gas AB, Svensk äxtkraft (Västerås) and Svensk Biogas (Linköping). Biogas as vehicle fuel is produced and used in the transport sector in all of these cities today.

Stockholm Water Company AB is a municipally owned company which is owned by Stockholm Stadshus AB (98%) and by Huddinge municipality (2 %). Stockholm Water Company produces and supplies drinking water for just over 1 million people in Stockholm and Huddinge and a further nine neighbouring municipalities. Wastewater from Stockholm, Huddinge and six neighbouring municipalities is treated by the two plants operated by Stockholm Water Company (Henriksdal and Bromma), in which a total of approximately 135 million cubic meters of wastewater are treated each year [13].

In the City of Stockholm, the main substrate for biogas production is sewage sludge, in Västerås mainly municipal organic household waste and crops are used, and in Linköping the main substrates are slaughterhouse waste and other industrial organic wastes.

In the City of Stockholm, biogas or CBG (Compressed Biogas) has been used as fuel since 1996. The municipality of Stockholm was the pioneer introducing biogas driven cars in Sweden. This was later followed by the introduction of city biogas buses, trucks, vans, taxis and company cars, thus further increasing the demand for biogas. However, in year 2006 the sale of biogas for vehicle fuel in Sweden increased by 47 percent and constituted the eleventh year in a row of increased sale, which meant the demand, exceeded the supply [14].

There are several reasons that explain the increased interest of biogas cars in the City of Stockholm. The municipality has introduced free parking in the city for clean vehicles and

biogas fuel is cheaper than petrol. Also the City of Stockholm has actively communicated the advantages of clean vehicles to the citizens [20].

In order to meet the supply demands in Stockholm CBG is transported from Linköping and Västerås where the production of CBG is higher than the local consumption. So far CBG is only produced in the wastewater treatment plants Henriksdal and Bromma, both owned by Stockholm Vatten AB. The produced gas is upgraded at each WWTP and distributed either through gas pipe to bus depot or by trucks with swap body units to gas filling stations [6][7].

In year 2004, it was tried to implement 15 to 30 Biogas buses at one depot and during 2009 it has expanded to supply approximately 100 biogas buses and further expanded to include biogas supply from another Waste Water Treatment Plant (Käppala) and additional biogas bus depots in the year 2010 [6][7].

In the City of Stockholm, in the year 2010 13 million Nm3 (126 GWh) biogas and 4.5 Million Nm3 (48 GWh) natural gas was consumed as a vehicle fuel; where the main consumer is Stockholm Public Transport (SL)[1]. From the above mentioned production plants, Henriksdal WWTP is the largest one. Annually with a capacity of up to 100 GWh has also planned to construct a large-scale biogas plant for anaerobic digestion of energy crops and industrial food by-products South of Stockholm City. Even if a large annual production, the supply for biogas is less than the demand. Therefore, it must be imported some of its biogas from other regions and use natural gas as a back-up. Due to the increasing biogas demand, it will be necessary to investigate other biogas production sources and the biogas potential, both in Stockholm and a greater area including the neighboring regions. In 2009, Researchers made a forecast till year 2020 on the production, distribution and demand of biogas as vehicle fuel for Stockholm City and neighboring Cities of Uppsala, Västmanland, Södermanland, Örebro and Östergötland. And it was based on current Waste Water Treatment Plant with biogas production, existing and planned expansions and new biogas production plants in the region, and an increased source separation of food waste from households as a contributor of good biogas substrate [6]. The projection of demand was in turn based on decisions and visionary plans to expand biogas bus fleets, taxis, company cars and estimations of interest within the private sector [1][7].

Investments in public transport have a considerable impact. Public transport has a market share to and from the city centre of 75 per cent during the rush hour periods. Over the entire day, an average of 66 per cent of all passenger transport is by public transport. Only 5.3 per cent of all greenhouse gas emissions within the transport sector come from public transport. Investments in biofuels to power buses have led to further reductions in emissions [9] [11].

Altogether, greenhouse gas emissions in the transport sector are expected to increase by 14,000 tonnes by 2015 compared with the year 2009. The growth is a result of increased passenger transport mileage, but is at the same time compensated by an increase in the number of clean vehicles [9].

1.2 STATEMENT OF THE PROBLEM

1. Market issues
    - The high initial investment cost for production and distribution of biogas and needs for a change of tax system that favors the use of biogas for buses.
2. Less availability of fuel stations
    - Few fuel stations make many potential buyers and users hesitate to buy.
3. Production problem and low availability of fuel pumps can undermine the support for biogas as a fuel.
4. Problems to get more buses to use biogas as a fuel on the market

1.3 SCOPE OF THE PROJECT

Our project will focus on the biogas production potential specifically the fuel produced from biogas within the Stockholm city and also it will asses an analysis of biogas usage development and distribution system. The project also addresses one of the largest biogas consumers in Sweden, especially Stockholm Public Transport (SL) and their collaborative partners/stakeholders. Today 250 biogas buses operate in Stockholm County, the most densely populated region in Sweden, with slightly over 2 million inhabitants [7].

In 2010, fuel shortage once again occurred in Stockholm as well as across Sweden. Usage increased by 70% in Stockholm alone. However, filling stations, supplies, and pumps did not match the increase in demand. Drivers often complained of driving long distances before finding a filling station, receiving poor supplies, and event experiencing malfunctioning pumps [19]. While the gas industry hold a partial responsibility for the failure to meet the increased demand, the government also need to establish clear set goals for a national strategy to modulate the gas supply situation [6][20].

The report aims to document and investigate biogas share of transport sector in Stockholm city. Through this investigation, further knowledge about the process is expected to be gained and passed on to internal and external interested parties. The report is expected to investigate results from the biogas consumption of Stockholm transportation system and to discuss operating

scenarios on the basis of results achieved. In addition, the aim of the report is to share operating experience with various operators within the biogas arena.

This also will give an emphasis on the flow of materials from the feedstock up to the final product. The project will give a recommendation and/or suggestion based on the current situations how it continues the use of biogas in the coming years within the target of Sweden Government and European Union.

1.4 OBJECTIVE

The main focus of this project is to identify key stakeholders and bottlenecks within the biogas supply chains in Stockholm city.

Specific objective

Selecting a biogas supply chain

- To map its flows
- To identify key stakeholders
- To analyze interaction
- To identify policy instruments

1.5 METHODOLOGY

The methods to be employed to achieve the objectives of the project are:

- Literature review
- Data collection for the analysis: In this part important data and information will be gathered from other thesis, journals, sight survey in different companies and related web sites.
- Data analysis: using available tools (Excel, LEAP, etc)
- Discuss the obtained result
- Conclusion and recommendation

CHAPTER TWO

2. BIOGAS SUPPLY CHAIN STRUCTURAL MODEL AND ITS BOUNDARY

2.1 BIOGAS SUPPLY CHAIN STRUCTURAL MODEL

Biogas is produced by the process of anaerobic digestion (it is an oxygen free process and the places that will be used to process are: in the earth, peat land, human & animal bowels and sea bottoms) mainly by using microorganisms to break down organic material and producing methane and carbon dioxide. And there are a wide range of organic material that can be use to produce Biogas like sewage sludge at Waste Water Treatment Plant (WWTP), energy crops and cattle manure, source separated household food waste, industrial food waste, slaughterhouse waste and agricultural by products. Heat, Electricity or vehicle fuel production are the results of the process of Biogas and in addition the digestion residues (bio solids) which is the left one can be used as bio-fertilizer. The raw materials are first digested to produce a crude gas, the quality of which must be upgraded before it can be used as motor fuel gas or for admixture with natural gas. The whole process of Biogas can be seen in figure1. [3]

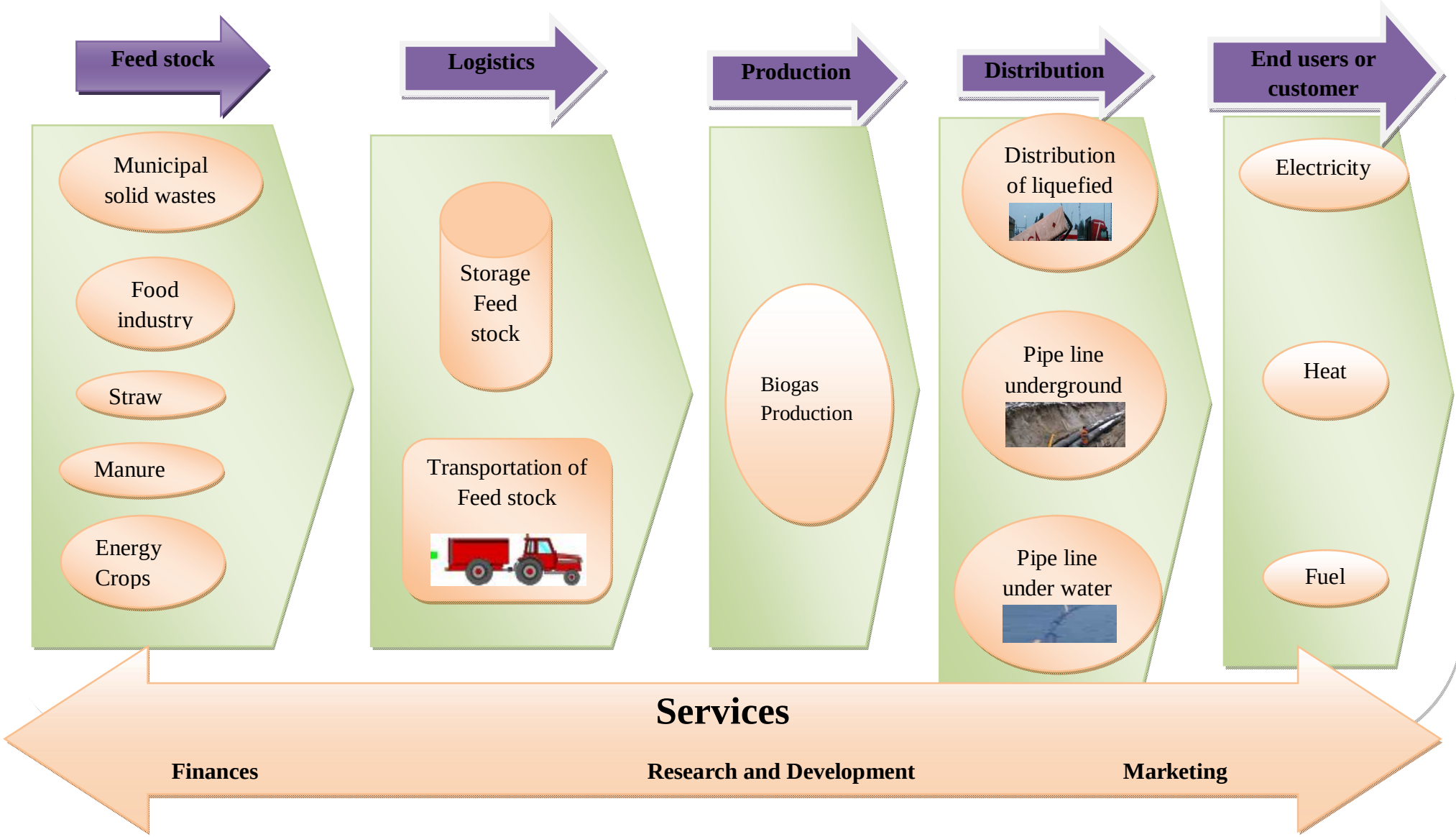

Figure 1: Structural Model of Biogas

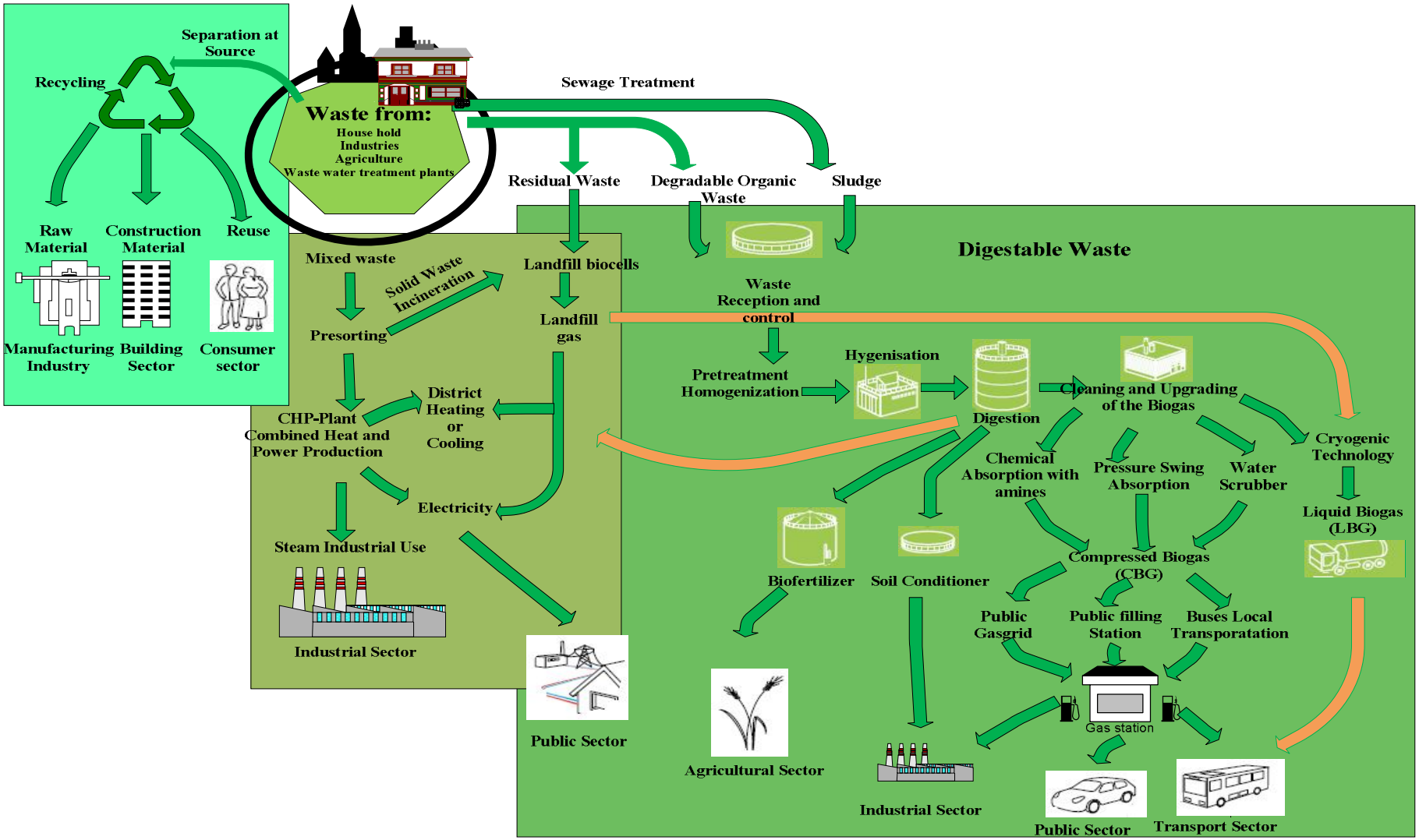

Figure 2: Overall Flow Diagram of Biogas Production[10]

2.2 BOUNDARY OF THE SYSTEM

As you can see the model from below Stockholm is the focul point for this project. The model shows how biogas production interacts in a Stockholm city and the different interactions related to the production and distribution systems of upgraded biogas.

The Population in the County is about 2 million, the city has 26 municipalities. The Land area of the county is 6 500 km2, 160 km from north to south. The responsibility for the transport sector goes to the county council [20].

The main intention of this project is on waste water as a feedstock for the production of upgraded fuel we do not focus on what is going on in the internal system of the plant. And also the analysis will be done how the distribution and fuelling stations affects the Biogas distribution efficiency. Finally, the project will focus on the public bus transport sector as it is shown in figure 3.

Figure 3: Boundary of the Project

The role model of using biogas products for transport use is the stockholm public transport,SL, owned by the stockholm county council.

SL, has planed long term vision to introduce completely fossile fuel free buses, as the company has own about 2000 buses throughout Stockholm county.

At the very beginning where SL, took the initiation for environmental program development the first option they had was use of bioethanol. But dueto the difficulties they faced they start to sought other options the first thing that they got was to use bio gas.

The largest wast water treatment plant in stockholm is **Henriksdal** WWTP, owned by the stockholm water company and have been producing biogas for over 80 years. But was doing for the purpose of reducing and to stabilize the sluge from the wast water.

After discusions among SL and water company and different researchs were conducted they decided to upgrade and distribute the produced biogas from the wast water treatment plant by the help of pipe lines to SL bus depotes soderhalen.

Figure 4: Location of Henriksdal WWTP Biogas Production Plant and Söderhallen Bus Depot

The first assessment of biogas supply for 15-30 buses at one depot in year 2004, expanded to approximately 129 biogas buses in year 2009, and further expanded to include biogas supply from yet another WWTP (Käppala) and additional biogas bus depots in year 2010. Today (June 2012) there are over 250 biogas buses running on the streets in the Stockholm region and currently five bus depots equipped with biogas fuelling stations [6].

As SL is the largest transport sector in Sweden specifically in Stockholm we are very quite sure that the sector will grow very fast interms of number of transporting vehicles.

As a result of this parallely it needs to keep going ahead for the sustainable development of the fuel which is environmentally friendly and hence, the wastwater is our basic concern.

Even though there will always be a possibility to increase the biogas production from wastwater but it is the most abaundant resource for the biogas production at least at constant rate [16].

2.3. KEY STAKE HOLDERS

Production

- Farmer: can deliver feedstock for biogas production.
- Sewage treatment and waste company's which produce and upgrade biogas

Users

- Public transport authorities
- Local and regional authority

Distribution

- Fuel distributors

CHAPTER THREE

3. STOCKHOLM CITY EXISTING CONDITIONS

3.1. DATA'S FOR TWO WASTE WATER TREATMENT PLANTS IN STOCKHOLM CITY

3.1.1. HENRIKSDAL BIOGAS PLANT

Basic Data [17]:

- Sewage water treatment plan
- Upgrading method, water scrubber
- Digester volume, 39.000 m3
- Investments, 99 million SEK

Inputs:

- Feed stock, Sewage sludge, 600.000 tons per year
- Solid organic waste, households, restaurants etc
- 600.000 Inhabitants in Stockholm
- Daily inflow 370.000 m3 sewage water

Outputs:

- Biogas 65 GWh
- Upgraded Biogas 5,8 Million Nm3
- 130 gas buses

3.1.2. KÄPPALA BIOGAS PLANT

Basic Data [17]:

- Sewage water treatment plant
- Upgrading, water scrubber
- Digester volume, 19,000 m3
- Investments, 35 million SEK

Inputs:

- Feed stock, Sewage sludge, 600,000 tons per year
- 500.000 Inhabitants in the region
- Daily inflow 350,000 m3 sewage water

Outputs:

- Biogas 40 GWh
- Upgraded Biogas 4 Million Nm3
- 100 gas buses

3.2. UPGRADED BIOGAS CONSUMPTION IN STOCKHOLM CITY

The consumption of Biogas in Stockholm city is increasing as it can be seen in table 1 and figure 5 below. And from the total consumption of biogas, bus consumption held its proportion due to the increment of buses starting from 2003 to 2011. So the demand of Biogas for buses in Stockholm city holds the market till now. The number of buses can be seen in table 2 and figure 6 how the city increases its interest towards biogas. Here it has to see that even if the biogas consumption increases starting from 2003 till 2011, the project will be addressed the production of biogases and also how much feedstock have been supplied fulfilled the market demand.

Table 1: Total Upgraded Biogas Consumption in Stockholm City [21]

Year	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Upgraded biogas (thousand Nm3/year)	527	1,096	2,192	4,520	6,375	8,008	7,839	13,065	19,496

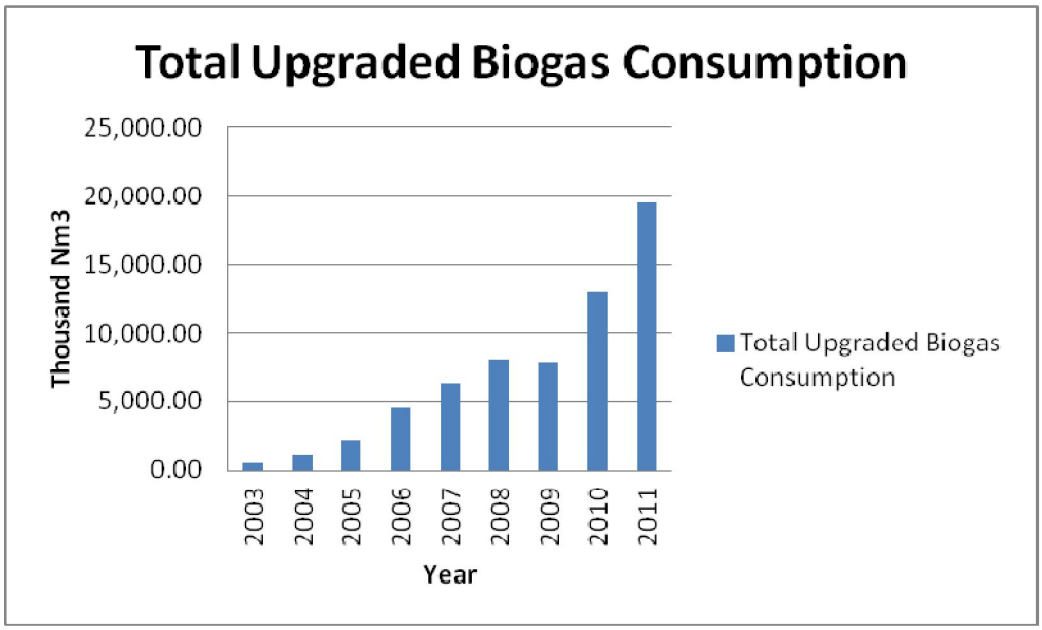

Figure 5: Total Upgraded Biogas Consumption

Table 2: Total Upgraded Biogas Consumption for Buses in Stockholm City [21]

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011
Number of Biogas buses	1	21	30	55	61.00	81.00	129.00	159.00	229
consumption of biogas in thousand Nm3/year	35	735	1050	1925	2135	2835	4515	5565	8015

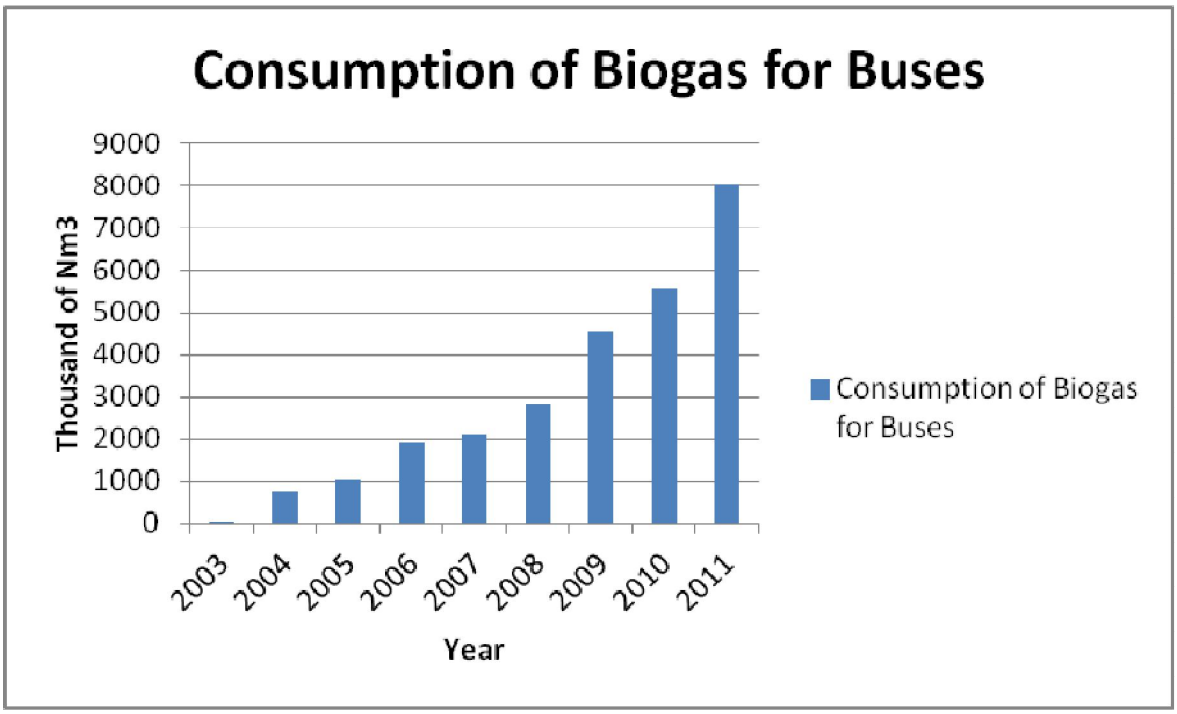

Figure 6: Biogas Consumption by Buses

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APPENDIXES: