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-An Approach to Göteborg's Management of Waste

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Cover: Pictorial presentation of the screw press.

Reproservice, Department of Civil and Environmental Engineering,
Göteborg, Sweden 2005

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ABSTRACT

Municipal solid waste cause big problems in urban communities. Large quantities of solid wastes are generated from industry, households and agriculture. Treating the organic part of the household waste by anaerobic digestion has gained consideration both from public and municipalities across Europe. Anaerobic digestion is an environmental friendly way of treating household waste as methane gas can be produced, and the residual after treatment can be used as soil improver. Since the household waste is quite heterogeneous and anaerobic digestion can only be applied to the sorted organic waste, pre-treatment is essential in anaerobic digestion. There are numerous methods used for pre-treatment in plants across Europe, and disc screen, screw press, pressure press, shredder magnet and food waste disposers are most commonly used in Scandinavia. Particularly in Sweden, there is a trend in using new pre-treatment methods. For instance, Västerås municipality has invested in Turbo mixer and Uppsala municipality in a pulp mixer. This study presents results of biogas potential after pre-treatment with screw press used at Eslöv municipality. Screw press is a newly developed technique for pre-treatment and it is still used as a prototype. After screw press the waste is sorted into two parts: wet and dry part. The wet part is directed to a plant for biogas production and the dry part to composting. This process is very interesting for Göteborg municipality who wants to increase the biogas production in the region. Today source sorted organic waste from households in Göteborg is 9500 tons. This amount can be processed by screw press and used for producing biogas. A prototype screw press at Eslöv was tested in this study. The process lines at Eslöv are implemented to Göteborg as scenarios. In the screw press test it was seen that 30% of the bio-waste could be directed to biogas reactors. With this percent Göteborg’s sorted waste could have 1 600 Mwh energy potential per year. This means 200 000 litres of gasoline for cars and between 300-500 cars can be driven with this energy throughout a year. Some modifications can make the screw press pre-treatment more efficient and the energy produced could be more.

Key Words: pre-treatment; screw press; biogas potential; household waste; anaerobic digestion.

ACKNOWLEDGEMENT

First I would like to say a big thank to my supervisors Kurt Lindman at Renova AB and Ann-Margret Strömvall at Chalmers University of Technology for all the assistance and guidance through out the thesis period.

I would also like to thank Gabriella, Paul and Jerry at the treatment plant at Eslöv. Without your help and assistance there would have been no samples and results.

Special thanks to my family at home in Turkey for their support. Especially I thank my father Mehmet Uluyol. Thank you father without you I would never had the courage to go abroad and study. You will always be my light and ambition in life.

Contents

1. Introduction

1.1 Background

Municipal solid waste (MSW) is a big problem in urban communities. Large quantities of solid wastes are generated from industry, households and agriculture. Municipalities have to deal with this waste, and they use several methods for disposal. In Europe, landfill, incineration and composting are the most commonly used methods. In Sweden, anaerobic digestion (A.D.) has been used to treat sewage sludge and agricultural wastes for several years. During the last two decades, there have been discussions of starting facilities for anaerobic treatment of solid wastes. Since methane gas is produced and the digested residue can be used as fertilizer, this process seems very attractive both to municipalities and to public.

On a commercial scale, aerobic composting is more widely accepted than anaerobic composting. However, in many situations A.D. should be a preferable method for treatment of MSW because this process does not require energy and machinery for aeration and does produce additional energy from methane (Water Science &Technology, 1993). Eventually, A.D. becomes more economic if the limitations including mixing, pH, pre-treatment and process instability are managed properly.

The biodegradable fraction of the waste requires separation from the other components. Source separation, mechanical separation and hand sorting may be used. Pre-treatment involves removing contaminants, homogenizing the waste, and protecting the down-stream processes (IEA Bioenergy, 1996).

The main steps in A.D. can be seen from Figure 1.1 below.

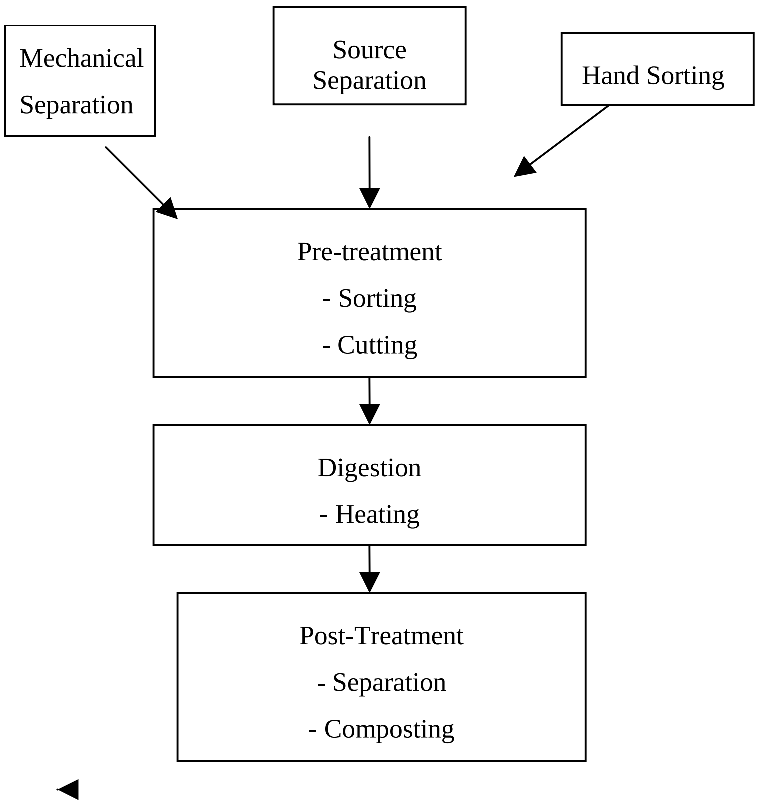

Figure 1.1 *The main steps in the anaerobic digestion of municipal solid waste.*

Pre-treatment varies with the property of waste and the kind of system that will be used in the treatment process. There could be well-separated collection system before the anaerobic plant. Thus, sometimes pre-treatment could be by-passed for some fast degradable organic wastes like household organic waste and animal manure etc. Clean and fast degradable organic waste does not require complicated pre-treatment.

Under this thesis work five biogas plants have been visited. These were Helsinborg, Kil, Vänersborg, Borås and Eslöv biogas plants. Among these plants the most interesting pre-treatment was in Eslöv, where the waste is processed with a screw press. Screw press separates waste smaller than 6 mm. In the end, two parts of processed waste are produced. One is the feedstock that is transported to composting and the other one is the slurry that is directed to biogas reactors. The biogas plant at a wastewater treatment plant is used for production of biogas from the screw press slurry. In their treatment a screw press with a mixing chamber is used. In Eslöv they do not have a separate biogas plant for digestion. This prototype screw press is very interesting for Göteborg, because the wastewater treatment plant has already an available biogas reactor and there is a compost plant at Marieholm that can take care of the other feedstock from the screw press. Investments in a screw press can reduce the future costs for an anaerobic digestion facility of solid wastes in Göteborg.

Göteborg's municipality aims to increase the biogas produced in Göteborg by using anaerobic treatment for solid wastes. The solid waste generated in Göteborg is heterogeneous. Obviously, biogas production will not be as easy as in a small agricultural village where waste mostly contains wet organic that is "pre-treated" by animals as manure.

1.2 Aim and Scope

After visiting the five biogas plants, the most available pre-treatment system for Göteborg seems to be screw press. The screw press alternative was most preferable technique based on the observations from visits and discussions with responsible people at the different plants. There is neither a technical report nor a study about screw press that focused the interest on this technique.

This thesis is a part of a pre-study that aims to investigate the available biogas production from organic household waste in Göteborg. Alternative ways of handling solid waste is presented. The pre-treatment lines in Eslöv were studied for biogas potential in Göteborg.

The aim of this thesis was to examine the solid waste after screw press and to use the data for scenarios of biogas potential in Göteborg. Nutrient content, total solids (TS), volatile solids (VS), heavy metals will be measured and mass balance will be calculated. In the measurement campaign samples of solid waste were taken. Samples will be taken from Eslöv's commonly used process where they add water to transport the waste slurry with sucking tanks more easily. Samples will also be taken from the 'dry process' where the screw press is running without addition of water.

2 Anaerobic Digestion

Anaerobic digestion is a biological process where microorganisms convert organic compound to methane, carbon dioxide, cellular materials and other organic compounds in the absence of oxygen.

This is a complex process, which requires specific environmental conditions (Corbitt, 1998). Anaerobic bacteria's degrade organic wastes into three main reactions: (1) hydrolysis of suspended organic solids into soluble organic compounds; (2) acetogenesis, or conversion of soluble organics to volatile fatty acids (mostly acetic acid) and (3) finally volatile fatty acids are converted to methane.

Generally MSW contains package and soft paper. In this case hydrolysis can be a rate limiting process for MSW. The size of the waste and the chosen digestion process plays a major role in Hydrolysis. In addition, there are some environmental requirements for A.D. They are listed below:

- ***pH and Alkalinity Requirements:*** The optimum pH range for methane fermentation is between 7 and 8, but the methane bacteria are generally not harmed unless the pH drops below 6.

- ***Nutrient Requirements:*** Anaerobic microorganisms require nutrients to sustain growth. The nutrient requirements for anaerobic microorganisms are different from aerobic requirements; the nitrogen and phosphorus requirements for anaerobic treatment are less than the requirements for aerobic treatment. Whereas a COD: N: P ratio of 100:5:1 is typical for aerobic treatment, a COD: N: P ratio of 100: 1: 0, 2 is typical of anaerobic growth (Corbitt, 1998).

- ***Temperature:*** There are two classes of microorganisms active in the methanogenic stage, the mesospheric bacteria active in the temperature range 30-35 °C, and the thermophilic bacteria active in the range 45-65 °C (Williams, 1998).

Methanogenic microorganisms are very important for A.D. Their constant biodegradability affects all the process. Consequently, the pH, temperature and nutrient level must to be controlled to have maximum efficiency. This needs educated personal in this field and it is one of the biggest operating obstacles in managing A.D.

3 Composting

Composting is an aerobic process in contrary to anaerobic digestion. It takes 4-6 weeks to reach a stabilized product. This product can be added to soil to improve its structure, especially for clay soils, acts as a fertilizer to improve the nutrient content and to retain moisture in the soil (Williams, 1998).

The simple carbon compounds such as soluble sugar and organic acids are easily metabolized and mineralized by heterotrophic and heterogeneous microorganisms. High metabolic activity and exothermic processes produce an increased temperature in the compost. This rise in temperature allows only thermophilic microorganisms to be active. High temperature disinfects the rest product.

The six main factors influencing composting are listed below.

1- Suitable oxygen content to maintain aerobic conditions; minimum oxygen content in the compost should be 18%.

2- Temperature: maximum microorganism activity is observed in the temperature range 30-35°C. However it is an exothermic process, temperature in a compost pile can reach up to 70°C.

3- Moisture content: below a minimum of 40% moisture content biodegradation is significantly reduced; high moisture contents are also to be avoided since the moisture occupies spaces for aeration and thereby produces anaerobic conditions.

4- pH range of the waste material: optimal composting is achieved in the pH range 5.5-8. Bacteria prefer a near neutral pH, whereas fungi develop better in a slightly acidic environment.

5- C: N ratio of the waste material: optimal C: N ratio in the starting waste material is about 25, higher values result in a slow rate of decomposition, and lower ratios result in nitrogen loss. The organic fraction of Municipal Solid Waste has a C: N ratio between 26 and 45.

6- Size range of waste material: shredding of the starting waste material increases the surface area and results in enhanced rates of composting (de Bertoldi, 1983).

4 Pre-treatment Processes

Anaerobic digestion is a natural process controlled by anaerobic bacteria. Hence it can only degrade the organic fractions in waste. Not all wastes are suitable for anaerobic treatment. Every intention to make solid waste suitable for anaerobic digestion is called pre-treatment. Pre-treatment has a wide scope. Sorting out waste at home as degradable and non-degradable can be pre-treatment or adding chemicals to enhance the reaction inside the anaerobic reactor could be another method for pre-treatment.

In this thesis work, wide scope has been restricted to reception of waste at the plant and pre-treatment right after entering the reactor. However, pre-treatment is also depended on type of digestion. For instance, substrate types can vary depending on wet or dry process.

Many processes, especially the dry process includes source sorted organic waste from households. In some countries like Germany, Belgium and Switzerland this waste type includes a high amount (up to 80%) of garden waste. In others continued as Sweden and Denmark, organic fraction of municipal solid waste does not include this structural and TS-raising waste. While digestion plants for mixed waste (no source sorting) with low VS-content (<60%) can be found in Southern Europe, for example in Spain, France and Italy, where source sorting is almost not existing (Svärd, 2003). Therefore another restriction will be the country chosen for pre-treatment. Since municipalities tries to implement source sorting in Sweden, it would be irrelevant to give examples from other countries using different processes.

In Sweden, for reducing the size of municipal solid waste generally disc screen, screw press and pressure press equipments are used. Bag opener, disinfection, volume buffer or cutting pipes are some common techniques used in most of the plants across Europe.

4.1 Screw Press

Screw press is generally used in dewatering of sludge. Screw presses are most effective for primary sludge, producing cake solids of 50-55% at wastewater treatment plants (Water &Wastewater Treatment Technologies Inc.,2004).

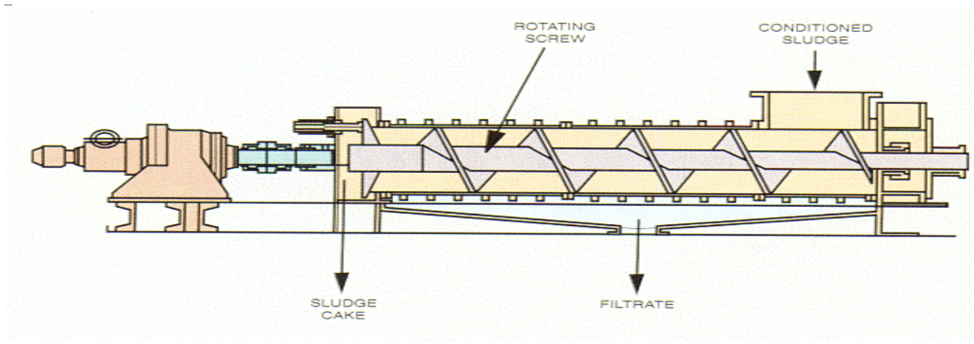

Figure 4.1 *Screw press for wastewater sludge.*

For pre-treatment of solid wastes screw press is not an established technology. It is still a prototype and the only machine is under test at Eslöv's plant (Fredriksson, 2004). A screw press consists of a shaft covered with a metal filter, which is separating the solid part and the liquid part of the sludge. As seen in Figure 4.1 rotating shafts conveys and compresses the sludge towards a metal filter. In solid waste treatment, the dry portion or the filtrate is taken to composting and the liquid part draining is taken to the biogas plant. Before pressing, the organic solid waste has to be well mixed and homogenous.

Figure 4.2 *Mixing chamber with mills and screw shaft in the bottom followed with screw press.*

The Screw press used in Eslöv is a combined process with a mixing chamber before pressing. Not only mixing occurs in this chamber but also wanted TS could be achieved by adding water to the process. The mixing chamber consists of two turning mills and one pushing screw in the bottom. At the end of the chamber there is one more screw covered with a 6 mm drilled filter. The feedstock for composting falls down from the metal shield (See Figure 4.2).

The filter has an 8 mm thickness. Soon a new 10 mm thick metal filter will be attached to the system. With this new filter the process will be faster and the retention time in pressing out the feedstock will be lower. In the 8 mm press the retention time for 15-18 tons of waste is 3-4 hours with low operation. The retention time will be 20-60 min after implementation of the 10 mm thick metal filter (Jerry, 2004).

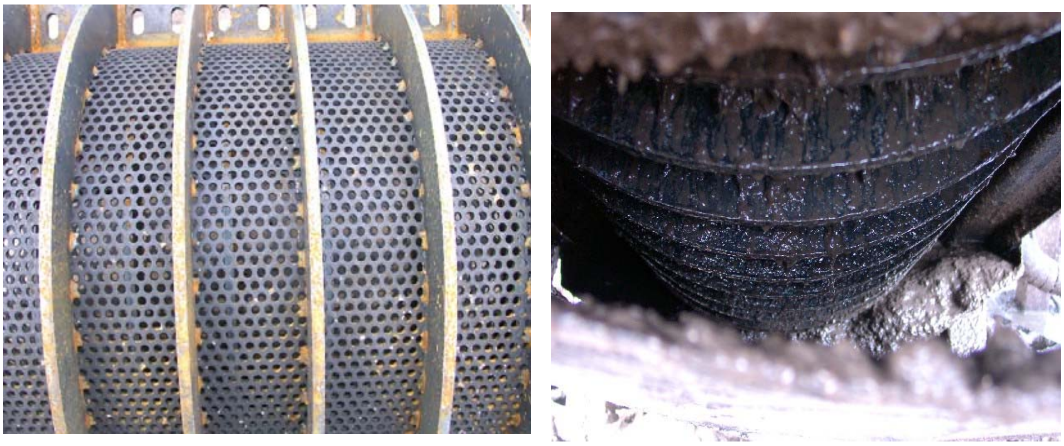

***Figure 4.3** Filter separating feedstock to compost and to biogas plant. Right picture is taken when filter is under operation.*

The stripes around the filter strengthen the filter against pressure from screwing (See Figure 4.3). The stripes and the thicker filter will improve the retention time (Fredriksson, 2004). The filtrate from screwing which has around 10-15 % TS is taken to the biogas plant through sucking tanks.

The volume of the mixing chamber is 15 m^3 with the mills and the shaft inside and the capacity is 15-18 tons of organic solid waste.

5 Pre-treatment and Screw Press in Eslöv

Table 5.1 *Household waste received at Merab in Eslöv year 2001 and 2002 (Merab, 2002).*

	2002	**2001**	**Change**
Combustible (ton)	5 804	6 295	-491
Compostible (ton)	8 505	8 739	-234
Deponi waste	3 548	3 404	+144
Total	17 857	18 438	-581
Solid waste kg/residual	313	319	

* Waste having neither energy value nor organic content is referred as deponi waste.

MERAB (Mellanskånes Renhållnings AB) operates the solid waste treatment plant in Eslöv owned by three municipalities. Solid waste is collected from Eslöv, Hörby and Höörs municipalities. Source sorted household waste has two fractions one is compostible and the other is combustible. Compostible fraction contains fruits, vegetables, food etc. Combustible fraction contains wooden waste, plastic, napkins etc. (Merab, 2004). The amount of household waste collected yearly is shown in the Table 5.1 Household waste received at Merab.

Figure 5.1 *Pre-treatment processes in Eslöv.*

Roughly, wet part and the dry part of the solid waste are sorted at source. Three plants near to this region accept solid waste after pre-treatment. Malmö incineration plant takes the combustible portion. The compostible part is treated at a pre-treatment station and the organic slurry after pre-treatment is transported to the wastewater treatment plant's biogas reactors.

Solid waste is first sent to the stationary plant and after transported to the related plants. The Screw press is situated 17 km away from the residential area (Fredriksson, 2004).

Bag opener is the first process for the household waste. Bag opener has two mills with blades turning very close to each other. These two turning mills tear and open up the plastic sacks. However, plastics bags create difficulties in feeding and outflow as well as stirring in digestion. The plastic material accumulates in the tank and forms a layer in the top of the digester (Christensen, 2003).

In Eslöv plastic material is separated by a turning screen. The holes on the cylinder screen allow organic particles to pass and unwanted material is fenced inside. Figure 5.1 shows the process. Metals inside the waste should also be taken out. Magnetic separation cleans the waste from metals. Until the third step this process is almost the same as at all anaerobic digestion plants visited in this project.

Feedstock should be homogenous to be pressed effectively. That is the function of the mills before the screw press (see chapter 4.1).

The dry part after pressing is collected in the yellow container as seen in Figure 5.1 and then taken for composting. The wet part is the slurry for digestion and taken to the biogas plant. The wet slurry is transported by gully emptier that vacuums the slurry inside the tank.

6 Sampling

For the normal process, Merab adds water or industrial wastewater to get appropriate TS. On the other hand, dry processed solid waste would be more suitable for Göteborg, as the compost plant and a biogas plant is nearby the Center; the less water it will be the less would be the cost for transportation. Thus, the screw press was tested under two different pre-treated waste inputs. One was without water and the other the standard way of Merab.

Three samples were taken for each test. Named as, pre-treated organic waste before screw press (POW), feedstock to composting (FTC) and slurry to biogas plant (SBP). Mass balances were controlled for each test by measuring the input of organic waste and the output for composting.

Figure 6.1 *Sampling from pre-treated organic waste before screw press at Eslöv.*

POW samples were taken from the heap as seen in the Figure 6.1. To have more representative samples they were taken from the area which is 30-40 cm below from the top and 1m towards the back. The pile was quite inhomogeneous. In every 10 cm to 1 m towards back, one liter sample was taken and collected in a 15 liter bucket. Then it was mixed properly with a wooden stick. The equipment is shown in Figure 6.1.

The Screw press was loaded from mixing chamber by a tractor. The first test was without any water and it was loaded with two tractors of POW weighing 4.22 tons as total. The mass going to compost (FTC) was measured 3.00 tons and the slurry for biogas (SBP) was measured 1.22 tons.

Figure 6.2 *Sampling from slurry after screw press.*

Samples from the lines to composting and to the biogas plant were also taken in the same way. The retention time for 4.22 tons of waste was fixed to 30 minutes. Each 3 minutes, one liter of sample was taken from SBP and put to the red bucket in Figure 6.1 After mixing properly; approximately one liter of homogenous sample was taken for analysis. SBP was not taken from the basin, but instead taken from the pipe discharging slurry to basin as seen in the Figure 6.2.

For the second test, only one tractor of POW was loaded to the screw press. The weight of this loading was 2.58 tons. The operators added water as they normally add during their processing. The added water was measured to 0.96 tons. The retention time was again fixed to 30 minutes, and samples were taken each 3 minutes and mixed properly as well. In the second test SBP was measured to 0.58 tons and FTC to 2 tons.

Totally six samples were taken from a dry and a normal process. The analyses were carried out at AnalyCen Laboratory Company. Standard methods were used for each parameter. The parameters to be measured were;

1. ***TS:*** Total solids is important to identify because it decides if the sludge can be pumped or not. High TS can no be pumped. In addition, the pipes conveying slurry can be damaged.

2. ***Substrates:*** Carbohydrates, fat and protein is the main source of biogas in the slurry. To evaluate the biogas potential it is essential to know the substrate content.

3. ***VS:*** All nutrients are in volatile solids. The amount of loss in volatile solids is very important for the performance of screw press.

4. ***N-tot, N-ammonia:*** Nitrogen is important for the wastewater treatment plant. Extra addition of nitrogen from household waste will be an economical burden on the wastewater treatment plant in Göteborg because they use ethanol for treating ammonium, and extra ammonium will be an extra cost for the treatment plant.

5. ***Metals:*** The residue after processing, both feedstock and slurry, can be used as fertilizer in agriculture and it is very important not to exceed the metal guideline limits.

7 Results and Discussion

The data in the following tables are arranged with results according to the treatment process and includes the necessary parameters. To read the tables more easy, the results for heavy metals measured are presented in a separate table.

Table 7.1 *Characteristics of the bio-waste from Merab's standard screw press procedure.*

Parameter	unit	Before Screw Press	Wet part to Biogas	Dry part to compost
Total Solids	%	39.4	25.2	36.4
Volatile Solids	% TS	67.7	71.3	72.7
N-tot	mg/kgTS	18 000	24 000	21000
$N\text{-}NH_3$	mg/kgTS	4300	5200	4100
Raw fat	mg/kgTS	119 000	136 000	116 000
Raw protein	mg/kgTS	112 500	150 000	131 250
Carbohydrates	mg/kgTS	444 000	429 000	481 000

The TS in household solid waste is measured in interval of 28-40% (JTI, 1997) and generally the average is taken in evaluating the TS of household waste. By testing the organic waste, the standard procedure of Merab gave a result of 39.4%TS (See Table 7.1), which is higher than average and nearly the maximum value according to JTI.

In this test 2.58 tons of pre-treated waste was mixed with 0.96 tons of water. As operators could not predict the TS of the waste before processing, they put a fixed volume of water inside the mixing chamber. Therefore TS in the wet part is high. In such cases they put additional water in the basin to get a fluid that can be pumped and transported.

Table 7.2 *Characteristics from bio-waste pre-treated with Komptech screw press (Renova, 2003).*

Parameter	unit	First test	Second test	Third test
TS	%	14.7	19.8	18.2
VS	% TS	78.2	78.8	85.6
N-tot	mg/kgTS	22 000	25 000	27 000

There is one study about wet part of the solid waste after pressing by Komptech, another supplier for screw presses. The results here gave an indication more than exact values for comparison with the Doppstadt pressing, used in this thesis. Because, these systems are developing and new filter sizes are attached, the size and the type of filter used in Komptech are unclear.

The average of TS from Komptech is 17.6%, which is lower than the value from Doppstadt screw press. With this low value the TS wet part transportation will be easier, and the sucking pumps will more efficient.

But transporting low TS means carrying less VS, which is the main source of biogas. According to JTI the VS in household waste has an average value of 87% of total TS. The pre-treatment keeping VS as high as possible is beneficial for the biogas producion. From Table 7.2 it could be seen that Komptech is more relevant in keeping VS. The loss of VS is not very high and this makes Komptech more advantageous.

Before making a concrete and reliable note we should keep in mind that in testing Doppstadt, fresh pre-treated solid waste was used and the large food particles such as potatoes, carrots etc. were not soft enough to pass the screw press. They were all directed to compost and this is the main reason of the lower VS in comparison to Komptech, See Table 7.1 and 7.2. This also shows that most of the organic degradable waste is directed to compost. Operators generally wait one week or a few days after pre-treatment to have softer waste, to be collected more organic waste to the wet part.

Total nitrogen from Doppstadt correlates with the characteristics measured by Komptech. This means both presses will send nearly the same amount of ammonium to the wastewater treatment plant.

Characteristics of the waste in the dry process are more interesting to evaluate for this work. The transportation issue in Göteborg is vital. Using the standard procedure in Eslöv, which has more water to transport, is not relevant to be used in Göteborg. However, the values from the dry process are quite similar to the standard process. There were no peak values, why the sampling was assumed to be good and representative (see also Table 7.3).

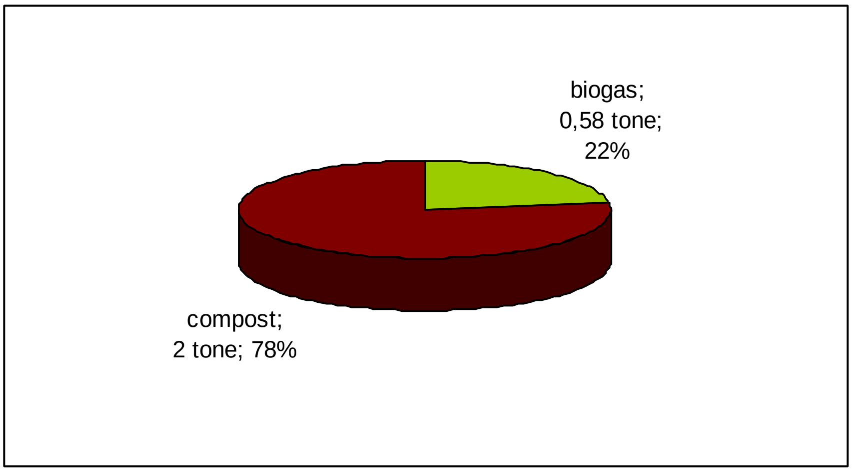

Figure 7.1 *Mass balance for bio-waste flow, after the standard screw press procedure at Eslöv.*

The mass balance presented in Figure 7.1 shows that only 0.58 tons from 2.58 tons of the organic waste was taken as wet part to biogas. This means that only 22.5% of the bio-waste was able to pass Doppstadt screw press and directed to a biogas plant. The compost part contained more organic waste.

Table 7.3 *Characteristics in dry pre-treatment of bio-waste at Eslöv.*

Parameter	unit	Before Screw Press	Wet part to Biogas	Dry part to compost
Total Solids	%	31.4	32.1	37.2
Volatile Solids	% TS	72.3	71.0	71.4
N-tot	mg/kgTS	24 000	23 000	19 000
$N\text{-}NH_3$	mg/kgTS	4100	5000	3500
Raw fat	mg/kgTS	147 000	136 000	106 000
Raw protein	mg/kgTS	150 000	143 750	118 750
Carbohydrates	mg/kgTS	430 000	427 000	495 000

Dry solid waste was particularly tested for this thesis and the results are presented in Table 7.3. At the beginning, it was doubtful concerning the availability of equipment, because mixing and pressing wet material is not the same as processing relatively hard waste. The test was not carried out with full speed as in the standard procedure. With some modification in filter size and thickness the pressing will be more suitable for dry wastes.

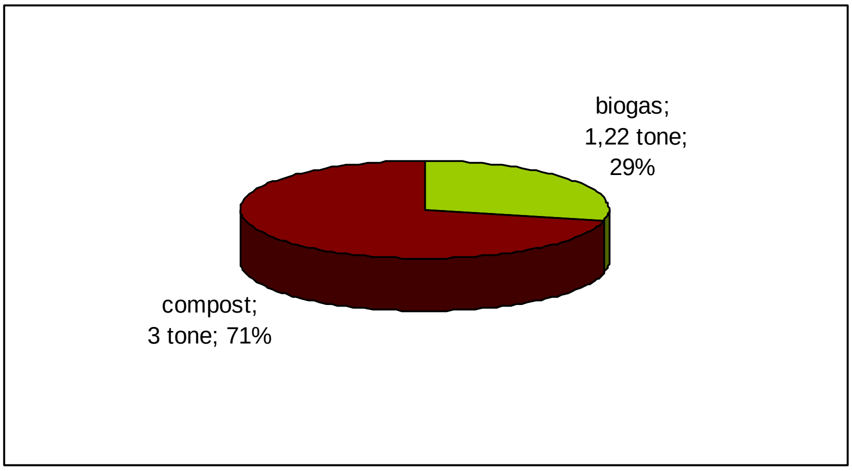

Figure 7.2 *Mass balances in bio-waste from dry process at Eslöv.*

The mass balance calculated from the dry process does not exceed half of the total waste as used in the standard procedure, but the results are more satisfying. The wet part directed to biogas production was 5% more than the one produced with the standard method. The total amount of pre-sorted organic waste into the screw press was 4.22 tons and was put to screw press and 1.22 tons of wet part was taken out. This means that nearly 30% of the organic waste was directed to the biogas plant. It is important to remind that the actual mass going to biogas production could be nearly 50% if the bio-waste is stored a few days before pressing. Anyhow, the results from this experiment will be used in evaluating the biogas potential for Göteborg.

TS of the wet part from the dry process was too high to be pumped. If such a wet part would be transported to the wastewater treatment plant in Göteborg (Gryaab), a special truck that can suck high TS should be used. High TS can disturb anaerobic bacteria, which are familiar to sewage sludge with low TS. For a homogenous mixture inside the reactor the wet part has to be mixed with water or with low TS sludge. There is about 7% difference between the TS from the two processes.

For the time being source sorted organic waste in Göteborg is 9500 tons yearly (Renova, 2003), and the amount is growing every year. For several years it is clear that the capacity of the biogas reactors at the wastewater treatment plant will be enough. The production of bio-waste should be 35 000 to motivate investments in a new biogas plant in Göteborg (Förstudie biogas, 2004). The strategy is to use Gryaab's reactors until the organic waste reaches the limit value of 35 000 tons.

However there are difficulties in such a solution. The most important is the acceptance of the wet part, with a content of nitrogen that will affect the discharge quality and result in an extra load for the wastewater treatment plant. The results for nitrogen presented in Table 7.1 and 7.3 are relatively low and in the in the range of JTI's classification (Renova, 2003). But the accumulated nitrogen will be a problem for the wastewater treatment plant.

Almost 60% of the total nitrogen is converted to ammonium (N-NH_3) in the reactors. N-NH_3 is harmful to aquatic environments (U.S. EPA, 2002). The N-NH_3 is converted to nitrate after anaerobic digesters by nitrification bacteria. Finally, nitrate is converted to nitrogen gas. In this gasification, ethanol is added to the process. Extra nitrogen coming from household waste will have extra cost and load on Gryaab's treatment lines. This cost will be mainly from ethanol added and the extra load on the nitrification process (Fredriksson, 2004).

According to the dry process data, 2850 tons of organic waste would be directed to the biogas reactors after screw press and this amount of wet part would contain;

- 2580(wet part)*0, 32(TS in wet part)*2, 3(%tot-Not in TS) = 19 tons tot-N

and the N-NH_3 that will be produced in 19 tons of tot-N is;

- 19 tot-N*0,60=11,4 tons N-NH_3

This ammonium will be the additional amount in calculating the load and the cost. The discharge limit in effluent from Gryaab is 10 mg/l (Mattsson, 2003).

Table 7.4 *Heavy metal content in bio-waste after dry pressing at Eslöv, and limits for heavy metals in agriculture.*

Parameter	unit	Before Screw Press	Wet part to Biogas	Dry part to compost	Maximum content[1]
Pb	mg/kgTS	10	17	11	100
Cd	mg/kgTS	0.25	0.23	0.25	1
Cu	mg/kgTS	19	21	23	100
Cr	mg/kgTS	12	13	10	100
Hg	mg/kgTS	<0. 05	0.26	0.16	1
Ni	mg/kgTS	4.9	3.7	3.8	50
Zn	mg/kgTS	78	86	110	300

[1] Eco-Label Criteria for soil improvers.

Heavy metals are very important if the residual from compost or anaerobic digestion will be accepted as fertilizer. The criteria for heavy metals are approved by Swedish National Testing and Research Institute (SP). The allowed limits of heavy metals in fertilizer are shown on the Table 7.4.

According to the heavy metal guideline values it seems to be suitable to use the residual from the composting as a fertilizer. However the wet part will be digested at the wastewater treatment plant. Then there might be a risk to use the residual, which will contain both wet part from screw press and sludge from household wastewater. The accumulated heavy metals can exceed the limits. Although heavy metal analyses were with certified techniques, sometimes there are differences in results depending on the extraction method used. The values could be higher or lower and depends on if the solution extraction was strong enough.

8 Scenarios for Methane Gas Production

In this section, the results will be discussed with future waste quantities in Göteborg. Inhabitants in Göteborg's region increased roughly 5000 - 6000 persons per year under the last 50 years period. Today the population is approximately 850 000 inhabitants and with the same rate it will reach 1 million within 15-25 years. The population in the city increased from 432 000 inhabitants in 1990 to 475 000 inhabitants by the end of 2002 (Kretslopsplan, 2003). The prediction for the coming years for Göteborg City is, 540 000 citizens by year 2015.

Waste management association (Renhållningsverksföreningen) has carried out a scenario study about the consumer's tendency and waste disposal. The change in society's living has come up with new products and services. This change has produced more waste. For example, 40% of the population lives alone and 2/3 of the population have lack of time. This leads to new consumption trends like fast food, which affects the waste quality and quantity.

With these changes in society and the present need for alternative energy, anaerobic treatment has become important for Göteborg. In order to have satisfying results, starting with collection system many things will change. There will be more source-sorting at home and more awareness of organic waste in the region. For now source sorted waste in a year is 9500 tons.

There are two scenarios for the present situation, and the situation in 2008. But practically biogas production will not meet the theoretical biogas potential. The retention time and the environment in the reactor affect the biogas production. For 10-20 days retention time, we can expect 50% of calculated biogas and if the retention time is prolonged to 40-50 days, we can expect 80% of calculated biogas (Svärd, 2004).

With the given assumptions, there will be two scenarios as follows;

1. ***9500 tons organic waste in the year 2004 with 10-20 days retention time***

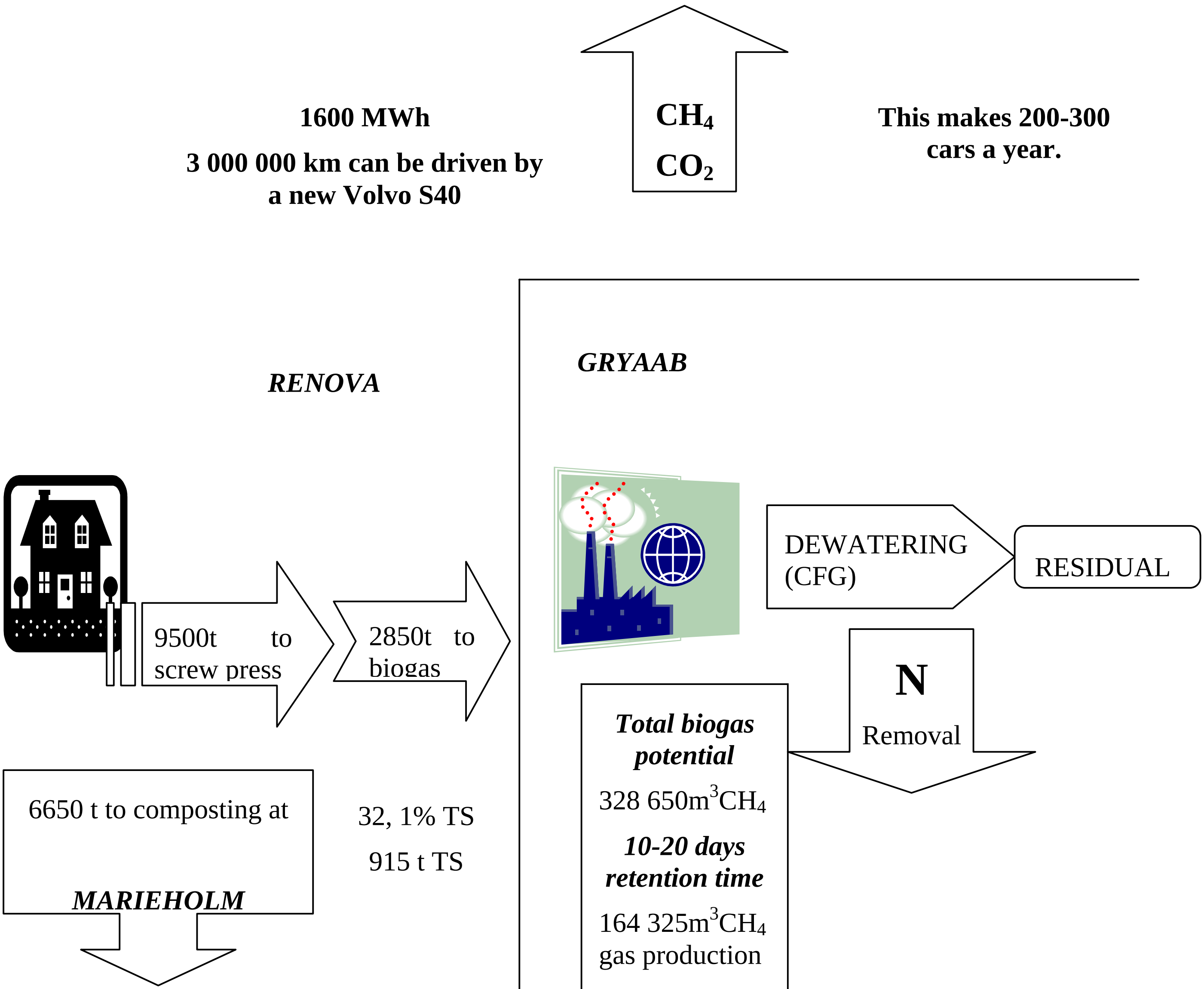

Figure 8.1 *Biogas production in Göteborg, after 10-20 days retention time for organic waste in 2004.*

As seen in the Figure 8.1, 68% of bio-waste after screw press is processed at Marieholm and the other part is transported to Gryaab's reactors. There is a big loss of organic waste in the reactor and 68% dry part to compost is high. However with improvement in using screw press the amount directed to the biogas reactors can increase and the process will be more efficient.

The biogas production would be 164 325 m^3 CH_4 in the year 2004 if such a system had been used. Biogas potential is calculated from substrate values;

Raw fat: %13, 6 TS*915 t TS= 125 t fat

Raw protein: %14, 4 TS*915 t TS= 132 t protein

Raw carbohydrates: % 42, 7 TS*915 t TS= 391 t carbohydrates

and the theoretical biogas values are (Mattsson, 2001);

Table 8.1 *Theoretical biogas and energy potentials.*

	Theoretical Biogas Potential m^3 CH_4/tons	Energy MWh/tons
Fat	850	8,3
Protein	500	4,9
Carbohydrates	400	3,9

If the biogas potential from Table 8.1 is calculated it will be;

Fat: 125 t* 850 m^3 CH_4/t = 106 250 m^3 CH_4 = 1038 MWh

Protein: 132 t* 500 m^3 CH_4/t = 66 000 m^3 CH_4 = 647 MWh

Carbohydrates: 391 t* 400 m^3 CH_4/t = 156 400 m^3 CH_4 = 1525 MWh

Totally: 328 650 m^3 CH_4 biogas and 3210 MWh power.

In 10-20 days of retention time (practically), 50% of theoretical biogas can be produced then the value will be;

- 164 325 m^3 CH_4 biogas and 1600 MWh power

This scenario is for the year 2004 and shows how much biogas (energy) is lost. But on the other hand nitrogen removal and adaptation of Gryaab's treatment system remains unanswered. The residual after treatment is taken by a private company.

The calculated energy of 1600MWh equals to 200 000 liters of gasoline for cars. This calculation is based on the low performance of the screw press. The gain will be more with modification and development in pressing. If the performance of the press would be 50% instead of 30%, the energy production would be 5358 MWh, which is equal to 560 000 liters of gasoline for cars. As seen the performance of screw press is very important.

2. ***35 000 tons organic waste in the year 2008 with 10-20 days retention time***

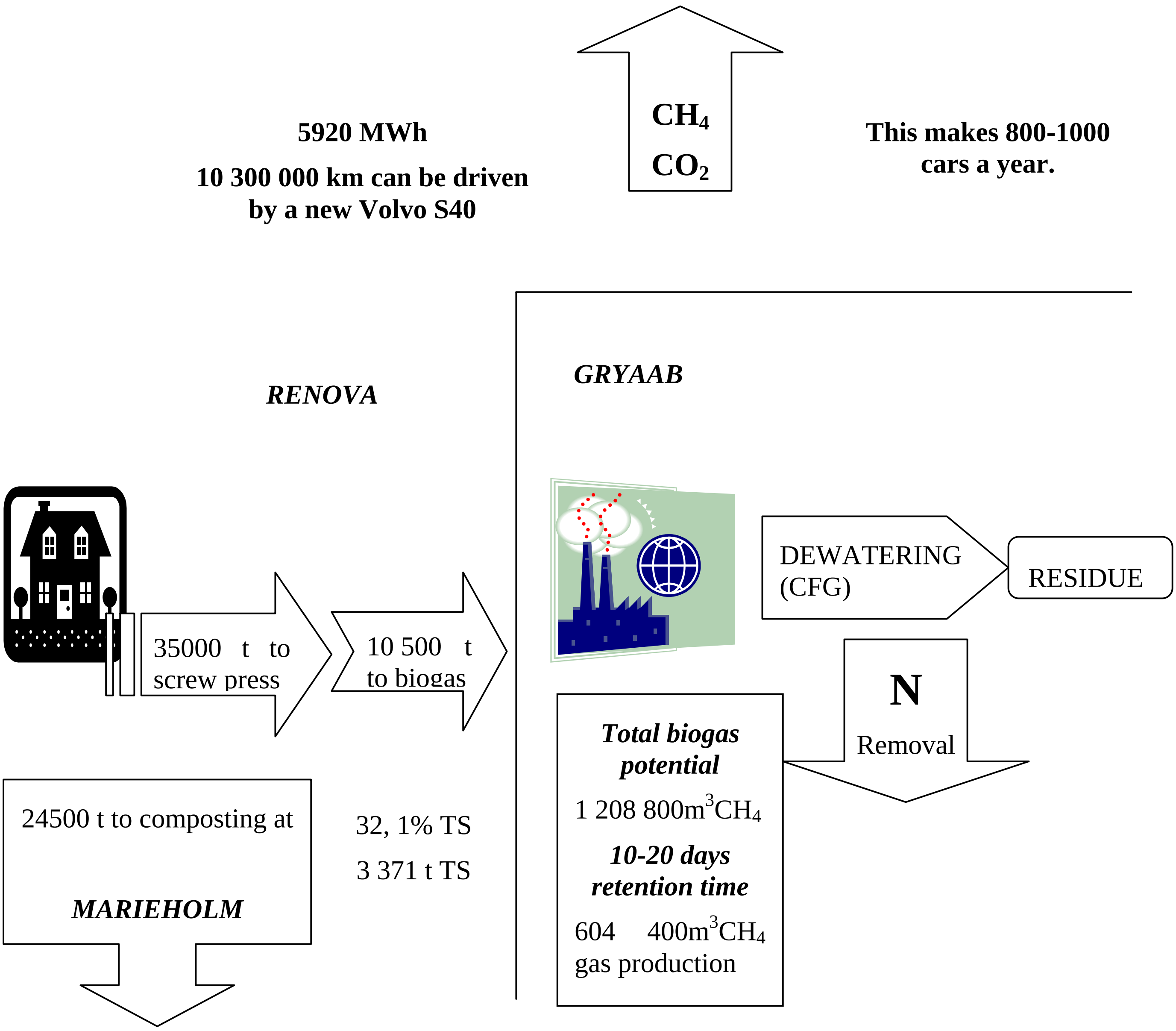

Figure 8.3 *Biogas production after 10-20 days retention time for organic waste in 2008*

The biogas production would be 164 325 m^3 CH_4 in the year 2008 if such a system had been used. Biogas potential is calculated from substrate values;

Raw fat: %13, 6 TS*3 371 t TS= 458 t fat

Raw protein: %14, 4 TS*3 371 t TS= 487 t protein

Raw carbohydrates: % 42, 7 TS*3 371 t TS= 1 440 t carbohydrates

If the biogas potential from Table 8.1 is calculaed it will be;

Fat: 458 t* 850 m^3 CH_4/t = 389 300 m^3 CH_4 = 3 815 MWh

Protein: 487 t* 500 m^3 CH_4/t = 243 500 m^3 CH_4 = 2 386MWh

Carbohydrates: 1440 t* 400 m^3 CH_4/t = 576 300 m^3 CH_4 = 5 645MWh

Totally: 1 208 800 m^3 CH_4 biogas and 11846 MWh power.

In 10-20 days of retention time (practically), 50% of theoretical biogas can be produced then the value will be;

- 164 325 m^3 CH_4 biogas and 5 920 MWh power

This scenario is for 2008 and at this time a separate biogas plant could be built. However, the theoretical amount of biogas will be the same as calculated here. As a note, 5 920 MWh energy is equal to 740 000 liters of gasoline for cars. This makes 10 300 000 km distance that can be driven by a new Volvo S 40.

9 Conclusions

Pre-treatment with screw press is not fully developed yet, and further modifications in the process will make it more reliable. The results in this thesis show that there is a big mass loss during pressing, which leads to energy loss. However the output from screw press is homogenous and can be used at wastewater treatment plant's biogas reactors, and the adaptation of bacteria will be fast.

It is also seen that screw press can be used without adding any water at a lower speed. This is good if the findings in this thesis will be implemented for Göteborg. The screw press can only be used during a transition period while building a special biogas plant for the city. For long term neither the capacity of screw press nor the capacity of biogas reactors at wastewater treatment plants will be enough. In Sweden there is need for special certifications to treat household waste at wastewater treatment plants and generally two different companies are responsible for wastewater and household waste. So, it is inconvenient for long term to treat household waste at the wastewater treatment plants.

Heavy metals in wet part of pre-treated waste are encouraging to use the residual part as soil improver. The ammonium is not a big problem or does not require extra investments for the process lines at Gryaab.

This study focuses on the available biogas production by using screw press and sending the pressed waste to a wastewater treatment plant and composting. As a conclusion this is possible but the economical aspects has to be studied. Due to the short time for a master thesis work, samples were measured at a commercial lab. Different extraction methods should be tested to get more reliable values of heavy metals in the solid waste fractions. More sampling and analyses would give more accurate results.

10 Further Studies

A master thesis is 20 weeks and this time is not enough to study all aspects. Especially in this study, on a new developing method there is always a lot of questions remained unanswered. New studies could be carried out with the questions below as a starting point:

- Bio-waste before pressing is stored for some time. It is depending on operators will. How does this storing affect pressing? Will there be loss in substrates? or will there be better pressing and better result in the wet part to biogas?
- This study shows the theoretical biogas potential. What will be the real biogas production after digestion tests?
- There was not enough time to evaluate economical aspects in investment of a screw press in Göteborg. Another study could be done concerning the investments and the profits.
- Pressure press is an alternative for screw press. What is the difference between these two methods? How should a municipality choose press method?
- Mass loss is the biggest problem in pre-treatment. How could this be improved?

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Appendix A

Interview with Merab:

A. General Questions

1- Is pressing the standard method? Or did you specially choose this method?

It is not the standard method. There are several methods for pre-treating solid waste. Furthermore pre-treatment equipment in biogas plants is newly growing and I think screw press which we use is the only one in process in the world. The TS content after screw press is suitable both for digestion and transporting and of course after that we have homogenous slurry which is also very important in digestion. These results satisfied us and we want to use this machine.

2- What kind of advantages did you think you would have in choosing screw press?

As I said before; the slurry is very suitable for digestion. It is mixed, homogeneous and we can arrange the TS content during the process. We can separate the material which is bigger than 9 mm and this means we have only organic waste in the slurry. Materials which are bigger than 9 mm go to composting. There are three grinding or mixing mills inside the container. They mix the waste properly. I think one of the most important points is we can control the process with adding water or mixing household waste with industrial waste. Household waste has more solid content than industrial waste so if we can find the optimal portions in mixing; we might skip adding water to the process. This will be a big improvement for us. We don't want to add water and loose space in transportation. This is only a prototype rather than an established process and we are in the beginning of testing it. (4 months in process) We will get more confident results in the time we are working with it. I think we are the only company in the world using screw press.

3- What kind of researches have you done before choosing screw press?

We have seen several plants and we asked our supplier about this. They have advised screw press which is prototype and is not tested yet. It seemed more advanced than the others and we have chosen it. There is not much information about pre-treatment in the market. Companies try different machines and methods and municipalities choose the one which they think is the best. We have expected advantages and it come true. So far, it is working without any problem.

4- **Have you looked for pressure press? If you have searched it, why did you choose screw press instead of pressure press?**

I have seen its picture and got some information. For me, difference is that in screw press you have whole solution. You can make any kind of mixture and I suppose the digestible part is better than pressure press.

5- **Which laboratory/laboratories do you work with?**

We send our samples to Eslövreningsverket. They have a lab. And we have contact with Al-control labs in Malmö.

6- **Do you measure TS, VS (Protein, Fat, and carbohydrates), COD, N, P, K Particle size, and heavy metals Cd, Pb? What are the TS before and after the screw press?**

We measure TS, VS, N, P, and K. and I have no idea about content of VS. TS changes with the waste we put to the container of screw press. One time, we put very low TS industrial waste and we couldn't press it because it was leaking very much from the container. We can arrange the TS while mixing inside the container. There is not fixed TS. But to suck from the basin we put, it should be nearly (? 10-15%) TS.

B. Technical Questions

1- **How did you choose the place for treatment plant? What were your motivations in choosing place?**

We have only composting and pre-treatment area and they are at the same place. Merab has its own land and it is also suitable for pre-treatment. We are using that area and screw press doesn't take too much space and it has no smell problem. Biogas plant belongs to Eslöv municipality and it is at the same place where they are treating waste water. We are transporting the slurry there. I mean there is no special thought behind choosing the place.

2- **How near is the plant to residential area?**

Residential areas are 17 km away from the pre-treatment place. We had no smell problem and no complaints from residents. We transport the waste immediately to the biogas plant.

3- **Which parts are related to pre-treatment at this plant? (Reception tanks, containers, screw press, sieving etc.)**

Bag opener (shredding) - Magnetic separation + Mixing chamber - Screw press

4- **How much water do you mix with the waste before screw press?**

It is impossible to say it now. We are testing it right now and it depends on the mixture of waste proportions. House hold waste mixed with fruit industry waste will not be the same as the mixture with household waste with potato industry waste.

5- **How do you transport wet and dry portion of the waste?**

We have trucks for slurry in the basin after screw press. Trucks have tanks sucking the slurry and it is transported directly to the plant. We compost the dry part at the same place as we pre-treat the waste. The combustible part is transported to Malmö combustion plant.

6- **You also take industrial waste I suppose, so how can you be sure about the samples that they are 100% household waste when you intend to make measurements on household waste?**

We can stop mixing industrial waste to the mixing chamber and after one process, we can be sure that the waste is household waste inside.

7- How many samples should you think be taken and which days are best to take household waste samples?

Three samples in three days in one week could be convenient. There are not much peak results in different days. As we are still testing the equipment, we can run it with only solid waste for your thesis work.

8- Do you consider doing some changes for the pre-treatment process?

We are planning to change the filter covering screw press fixed on the end of the mixing chamber. The metal stripes (holding the cover flat and firm) are not enough. We added two more stripes between each stripe on the filter. It will be more rigid. So far we are very satisfied with it. We don't think any change for now.