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Life Cycle Assessment of Biogas/Biofuel Production from Organic Waste

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MASTER THESIS

for

Student Tiril Jeanette Seldal

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Life cycle assessment of biogas/biofuel production from organic waste

Livsløpsanalyse av biogass/biodrivstoff produksjon fra organisk avfall

Background and objective

The background of this master thesis is the environmental impacts of waste management and the growing interest of resource recovery and waste/energy integration. Biogas and biofuel production and utilization offer important opportunities for energy recovery and utilization of resources from organic wastes, as well as environmental life cycle impact reductions when biogas and/or biofuel substitutes other energy carriers. Such solutions, on the basis of well-proven or emerging technologies, are expected to play a significant role in national waste to energy strategies. One of the recently implemented systems that make use of advanced technologies for organic waste separation and biogas/biofuel production is Romerike Biogas Plant (BRA) outside Oslo, fed by household and other organic waste substrates from inside and around Oslo.The student has in a pre-thesis project already carried out an initial systems analysis of BRA. This study included the developed of a Material Flow Analysis (MFA) model of the biomass and energy flows at BRA, with indicators for determining the system-wide energy and biomass recovery efficiencies.

The objective of this master thesis is to contribute to the understanding of environmental life cycle impacts from systems producing biogas/biofuel from organic waste. The student shall develop an LCA model for a defined system producing and utilizing biogas/biofuel from organic waste, with BRA outside Oslo as case study. The thesis shall discuss what are the critical components and activities of the system, and which factors to focus, in order to minimise life cycle environmental impacts and resource recovery efficiencies in such a system. The thesis work will be linked to on-going research projects at IndEcol, i.e. CENBIO and BIOTENMARE.

The following tasks are to be considered:

1. Carry out a literature study on state-of-the-art strategies, technologies and/or methods that are relevant for your work.
2. Provide a systems definition of the system you are analysing, including description of goal and scope, system boundaries, data inputs and assumptions, for selected scenarios and/or configurations of technological solutions within your system.
3. Develop a quantitative model and life cycle inventory for your system, including relevant indicators and/or metrics that can be used to document the environmental life cycle impact and resource efficiency performance of the system.

4. Report results from the performance of your system and the role of critical system variables, components or assumptions leading to these results.
5. Discuss the overall findings of your work, agreement with literature, strengths and weaknesses of your methods, and possible practical and/or methodological implications and recommendations of your work.

Within 14 days of receiving the written text on the master thesis, the candidate shall submit a research plan for his/her project to the department.

When the thesis is evaluated, emphasis is put on processing of the results, and that they are presented in tabular and/or graphic form in a clear manner, and that they are analysed carefully.

The thesis is to be written in the form of a scientific article for publication in a peer-review international scientific journal. The thesis could include also appendices with supplementary materials, if and when needed.

The candidate is requested to initiate and keep close contact with his/her academic supervisor(s) throughout the working period. The candidate must follow the rules and regulations of NTNU as well as passive directions given by the Department of Energy and Process Engineering.

Risk assessment of the candidate's work shall be carried out according to the department's procedures. The risk assessment must be documented and included as part of the final report. Events related to the candidate's work adversely affecting the health, safety or security, must be documented and included as part of the final report. If the documentation on risk assessment represents a large number of pages, the full version is to be submitted electronically to the supervisor and an excerpt is included in the report.

Pursuant to "Regulations concerning the supplementary provisions to the technology study program/Master of Science" at NTNU §20, the Department reserves the permission to utilize all the results and data for teaching and research purposes as well as in future publications.

The final report is to be submitted digitally in DAIM. An executive summary of the thesis including title, student's name, supervisor's name, year, department name, and NTNU's logo and name, shall be submitted to the department as a separate pdf file. Based on an agreement with the supervisor, the final report and other material and documents may be given to the supervisor in digital format.

☐ Work to be done in lab (Water power lab, Fluids engineering lab, Thermal engineering lab)
☐ Field work

Department of Energy and Process Engineering, 14. January 2014

Olav Bolland
Department Head

Helge Brattebø
Academic Supervisor

Preface

This report, “Life cycle assessment of biogas/biofuel production from organic waste”, was written in the spring of 2014 and concludes my master in “Science and Technology - Energy and Environment” at the Norwegian University of Science and Technology (NTNU).

During the work with this master thesis in Trondheim there have been factors that have stalled my work regarding the Romerike biogas plant (RBA) value chain. It has been time consuming to establish contact with the right people and receive required data from the plant. Therefore the author visited RBA to collect plant specific data with the intention to make models as similar to the present operation of the plant. The author even postponed the deadline in hope of getting adequate data. Some data was received, but due to among others holidays the data received was not adequate to use for the purpose wanted. In agreement with supervisor it has been necessary to do simplifications in the modelling to be able to finish within the deadline.

I want to thank my supervisor Helge Brattebø at NTNU for good guidance during the work with my master thesis. A thank goes to Reyn Joseph O’Born for help regarding the life cycle assessment (LCA) modelling.

A special thank goes to Espen Govasmark at Oslo Waste-to-Energy Agency (EGE) for the invitation to RBA and provision of operational data. Thank to Knut Jönsson at RBA who gave me a guided tour through the plant and help regarding collection of data for electricity demanding installations. This led to a better understanding of RBA. Ulf Børge Pettersen, Nils Finn Lumholdt and Kari Anne Sølvernes at Oslo EGE also deserve thanks for help regarding data collection for RBA.

Data regarding waste flows at Haraldrud and Klemetsrud and operational data for the optical sorting have been provided by Knut Erik Ramstad at Oslo EGE and Petter Thorbeck at Mepex Consult AS has helped with estimation of the electricity consumption for Optibag. Arne Jakobsen at Wärtsilä Oil & Gas Systems AS has been helpful regarding data for the liquefaction plant at RBA. Transport data for the liquefied biogas (LBG) have been provided by John Melby at AGA. Svein Erik Johnsen, Norsk Gjenvinning Norge AS, and Bjørn E. Bakken, RenoNorden Norge, have assisted with data regarding transport of household waste in the Oslo area. Oda Kjørlaug at Cambi has been helpful regarding general data for RBA and referring me to contact persons. I would like to thank all of the persons mentioned above for their contribution to my master thesis.

Trondheim, July 2014

Tiril Jeanette Seldal

Sammendrag

Diskusjonen rundt hvordan energietterspørselen skal tilfredsstilles er sentral i dag, men vil bli av enda større betydning i framtiden. Ved en økende befolkning hvor en stadig større andel blir mer energikrevende, er måten hvordan energi blir produsert på noe som påvirker oss alle. Etterspørsel samt miljøpåvirkning vil kreve at en stadig større andel av energien blir fornybar. I de siste årene har arbeidet med en best mulig utnytting av ressurser medført at avfallssystemer fått en økt interesse.

I denne rapporten har det blitt sett på produksjon av biogas/biodrivstoff fra organisk avfall. Biogassproduksjon fra ulike typer matavfall og oppgradering til flytende biogass (LBG) for verdikjeden tilknyttet Romerike biogassanlegg (RBA) lokalisert utenfor Oslo har blitt benyttet som et casestudie. Matrialstrømanalyse (MFA) og livsløpsanalyse (LCA) har blitt benyttet til å evaluere henholdsvis ressurseffektiviten og miljøpåvirkningen til den valgte verdikjeden. Indikatorer for materialgjenvinningsgrad (MRR), næringsgjenvinningsgrad (NRR) samt energieffektivitet (η) ble definert for å gi mål for ressurseffektiviteten. MRR ble funnet til å være 3.6 %. NRR for N og P resulterte i henholdsvis 26.1 % og 7.8 %. Tørrstoffinnholdet (DM) i den faste biogjødselen samt andelen av matavfall i restavfallet hadde stor påvirkning på disse indikatorverdiene. Energieffektiviteten som ble funnet var veldig lav, 2.5 %. Grunnen til dette var at gassmengden det ble mottatt data for var solgt mengde. Den solgte mengden var lavere enn den faktiske produserte mengden. En energieffektivitet på 26.1 % ble funnet da et estimert biogassvolum basert på mengde avfall kjørt inn på anlegget ble benyttet. Dette viser dermed at bruken av korrekte verdier for mengde biogass har en stor innvirkning på energieffektiviteten. Generelt var indikatorverdiene som ble funnet lavere en hva som hadde vært tilfellet dersom bedre data hadde blitt mottatt samtidig som at anlegget ikke hadde vært i en oppkjøringsfase.

GWP hadde hovedfokus blant kategoriene ved utførelsen av LCA. For den valgte verdikjeden ble det funnet en total GWP effekt på 455 kg CO_2-eq./FU. Av prosessene som ble definert var innsamling av husholdningsavfall det som hadde størst effekt. I alle bortsett fra en kategori utgjorde disse prosessene samlet mer enn 80 % av utfallet. Bidraget som ble funnet for disse prosessene er allikevel vurdert som mindre grunnet hvilke data som har blitt benyttet.

For verdikjeden tilknyttet RBA ble det funnet at ved å benytte dette systemet til sammenlikning med alternativet (diesel og kunstgjødsel), ville det bli sluppet ut 747 396 kg CO_2-eq mindre.

Grunnet store usikkerheter knyttet til modellene som er blitt laget, burde resultatene funnet i denne rapporten benyttes for å indikere hvor problemer finnes men ikke komme med spesifikke tiltak på bakgrunn av resultatene. Det er dermed fordelaktig at modeller utbedres ved å definere bedre systemer samt at mer spesifikke data vil behøves.

Abstract

The focus on energy production is important today and will be of even bigger importance in the future. With an increase in the world's population and at the same time a more energy demanding one the energy issue is and will be one aspect that will involve all of us. The demand and environmental impacts will require that an increasing share of the energy will be renewable. Waste systems has therefore become of bigger interests in the resent years.

This thesis has looked at biogas/biofuel production from organic waste. Production of biogas from different types of food wastes and the upgrading to liquefied biogas (LBG) for the value chain of Romerike biogas plant (RBA) located outside Oslo has been chosen as a case study. An evaluation of resource efficiency performance and environmental life cycle impact for RBA has been conducted using material flow analysis (MFA) and life cycle assessment (LCA). The resource efficiency performance has been found by using MFA and measured by definition of indicators for material rate of recovery (MRR), nutrient rate of recovery (NRR) and energy efficiency (η). The MRR was found to be 3.6%. NRR for N and P was found to be respectively 26.1% and 7.8%. It was found that the DM content in solid biofertilizer as well as the food waste share in the residual waste had large impacts on these indicators. The energy efficiency of the system was found to be very low, 2.5%. This was due to that data for sold gas was received that actually was much lower than the produced gas. Energy efficiency of 26.1% was found by using an estimated volume correlated to the waste amount delivered to RBA in the investigated period. This showed that the use of correct produced gas volume has a large impact. In general the indicator values found were evaluated to be poorer than would have been the case if better data had been provided as well as the plant had not been in a run-up period.

In the LCA conducted the GWP had the main focus. It was found that the RBA value chain had a total GWP impact of 455 kg CO_2-eq./FU. By the processes defined the collection of HHW had the biggest impacts. In all except one category these two processes contributed to over 80% of the impact. The contribution found was evaluated to be higher than it is in reality due to the data used.

It was found an avoided burden of 747 396 kg CO_2-eq by implementing the value chain in contrast to use the alternative option (diesel and chemical fertilizer).

Due to large uncertainties in the models established the results found in this thesis should be used more to indicate where there are problems than contribute to specific measures to be done. It is therefore beneficial that the models are improved by better definition of systems as well as more specific data should be provided.

Nomenclature

AD	anaerobic digestion
BABIU	bottom ash for biogas upgrading
C	carbon
CBG	compressed biogas
CH_4	methane
CHP	combined heat and power
CO_2	carbon dioxide
DM	dry matter
FU	functional unit
GHG	greenhouse gases
GWP	global warming potential
H	hydrogen
HHW	household waste
HPWS	high pressure water scrubbing
ISO	the International Organization for Standardization
K	potassium
LBG	liquefied biogas
LCA	life cycle assessment
LCIA	life cycle impact assessment
LHV	lower heating value
MB	membrane separation
MFA	material flow analysis
MRR	material rate of recovery
MSW	municipal solid waste
N	nitrogen
Nm^3	normal cubic meter, gas volume at 273, 15 K (0°C) and 1,01325 bar
NP	nutrients in products
N-P-K	give the % share in DM of Nitrogen-Phosphorus-Potassium in fertilizer products
NR	nitrogen rate of recovery
NRR	nutrients rate of recovery
NS	nutrients in substrate
O	oxygen
P	phosphorus
PE	primary energy
PEIO	primary energy input to output
PR	Phosphorus rate of recovery
PSA	pressure swing adsorption
RBA	Romerike biogas plant (Romerike biogassanlegg)
RTO	regenerative thermal oxidation
THP	thermal hydrolysis process
TSE	transmissible spongiform encephalopathy
VFA	volatile fatty acids
VS	volatile solids

WS	water scrubbing

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1 Introduction

1.1 Background

In a society with an increased focus on energy conversation from renewable resources different waste resources have become more important. Due to the growing interest of resource recovery and waste/energy integration from waste management it is important to detect the environmental impacts from this. By using life cycle assessment (LCA) it is possible to detect the extent of different environmental impacts.

In the Renewable Energy Directive, 2009/28/EC, it was decided that by 2020 10% of the fuels used in transportation should be from renewable sources. Production and utilization of upgraded biogas from organic wastes in the transport sector is therefore an important opportunity for energy recovery and utilization of waste resources. When substituting other energy carriers with biogas and/or biofuels this result in reductions in environmental life cycle impacts. Such solutions that are based on well-proven or emerging technologies are expected to play a significant role in national waste to energy strategies. One of the recently implemented systems that make use of advanced technologies for organic waste separation and biogas/biofuel production is Romerike biogas plant (RBA) outside Oslo. This plant utilizes household waste (HHW) and other organic waste substrates from inside and around the Oslo area. The author of this thesis has already carried out an initial system analysis of RBA in the work of a pre-thesis project. This study included a development of a material flow analysis (MFA) model of the biomass and energy flows at RBA, with indicators for determining the system-wide energy and biomass recovery efficiencies.

1.2 Objective

The objective of this thesis was to contribute to the understanding of environmental life cycle impacts from systems producing biogas/biofuels from organic waste. For this purpose a LCA model for a defined system, RBA, was developed. In addition the MFA model has been improved and further developed to also include indicators for nutrient rate of recovery (NRR). This contributes to data for the LCA as well as the resource recovery efficiency of the system is more thoroughly investigated. I order to minimize the life cycle environmental impacts and achieve good resource recovery efficiencies in such a system, critical components and activities of the system are found and discussed. This contributes to find the critical factors of the system and hence where in the system there is need for improvements. This work will be linked to on-going research projects at IndEcol, i.e. CENBIO and BIOTENMARE.

1.3 Scope of work

Due to the problems mentioned in the preface the MFA and LCA models have been conducted in a much less comprehensive way than was intended. This has resulted in models with higher uncertainties. The models can contribute to find the main critical factors, but caution should be shown using this study for a main basis of specific measures.

Point 1 in the master assignment related to a literature study on state-of-the-art strategies should be conducted has been omitted due to this was carried out in the pre-thesis project.

1.4 Report outline

Chapter 2 presents the literature study for this thesis. This includes description of the characteristics of wet organic waste as substrate in anaerobic digestion (AD), the AD process itself and the byproducts and their use. In the end of chapter 2 a review of results for resource efficiency performance and environmental life cycle impacts found in the literature are presented. Chapter 3 presents the case investigated in this study, the RBA value chain. Pretreatment, the AD and the handling of byproducts for the specific case is thoroughly described. In chapter 4 the general method of conducting MFA and LCA as well as the chosen approach in this study are described. The method for calculation of sensitivity for the models is also presented. Results found from the MFA and LCA models as well as the sensitivity analysis of the two are shown in chapter 5. In chapter 6 the results are discussed, the method evaluated and recommendations for further work are presented. Chapter 7 draws a conclusion based on the findings in this report.

2 Literature study

2.1 Characteristics of wet organic waste

Feedstock or substrate refers to what is fed into the anaerobic digestion (AD). There are several waste products that can be used for AD. Due to the statement in the report "Underlagsmateriell for tverrsektoriell biogass-strategi" (Sletten & Maas, 2013) published by the Climate and Pollution Agency (now Norwegian Environmental Agency) this thesis will emphasize on wet organic waste. The report stated that in the short run the remaining realistic potential for biogas production in Norway is dominated of substrates like wet organic waste and manure. Food waste sorted from HHW will have a main focus among the wet organic waste due to the current situation at the plant evaluated in the case study.

Wet organic waste is categorized as food waste from private household and institutional household, food industry and waste from parks and gardens (Miljødirektoratet, 2013). Substrates from different biological resources have a large variety of properties and compositions that will affect the decomposition and biogas production. How well suited a substrate is for biogas production depends on several aspects (Carlsson & Uldal, 2009):

- Dry matter (DM) content:
  The remaining compounds after the water content have evaporated at 105°C.
- Volatile solids (VS) content:
  Is the organic content of the DM. By exposing the material of a temperature of 550°C, the part that is organic will burn and the inorganic material will be left. High VS will in general give high transport efficiencies due to high biogas yield per transported unit.
- Nutrient composition:
  The C/N ratio is important for the anaerobic digestion. A ratio of approximately 30 will be favourable for the microorganisms. With a C/N ratio below 10-15 the pH will be high and can be toxic for the microorganisms. Ratio above 30 will reduce the degradation of the substrate.
- Risk of mechanical problems
- Influence on the digestate quality
- Need of pretreatment
- Risk of microbiological problems
- Odour problems
- Biogas yield and degradability:
  Biogas yield depends on DM content, the organic share of the DM content (VS), the composition of fat, carbohydrates and proteins in the organic material and the degradability of the organic material. Table 2-1 gives an overview of the biogas and methane yield for the substrate components.

Table 2-1Biogas and methane yield for different substrate components (Carlsson & Uldal, 2009)

Substrate	Biogas [Nm3/kg VS]	Methane [Nm^3/kg VS]	Methane [%]
Fat	1.37	0.96	70
Protein	0.64	0.51	80
Carbohydrate	0.84	0.42	50

The numbers given in Table 2-1 show the gas yields with complete anaerobic digestion. In reality these numbers will be lower. The degradability differs between different substrates and the retention time.

Varieties within the mentioned aspects are also present for source sorted food waste from households. It is therefore impossible in reality to determine fixed values due to the variations within food wastes. Therefore it is the best to use case specific mean values, for example yearly means. Sorted food waste gives though a high biogas production due to a general high DM content. In the literature the DM content is often found to be within a range of 30- 35% (Berglund & Börjesson, 2003; Carlsson & Uldal, 2009; Lyng et al., 2011).

Other aspects with sorted food waste from households are that it will always need some kind of pretreatment and hygienisation. Normally there will be a share of the food waste that is sorted wrongly. This needs to be removed before AD to give the best end-products, secure operation and cost efficient operation. In Norway substrates used for biogas production are regulated by ”Forskrift om animalske biprodukter som ikke er beregnet på konsum” (Nærings- og fiskeridepartementet, 2007) to ensure no spreading of deceases to human and animals related to the value chain of biogas production. This regulation divides animal waste into three categories. Food waste belongs to category III which is waste that had the purpose to be food, but ended in the waste anyway. Byproducts belonging to this category can be used for animal feed, technical purposes, manure and soil improvements. Category III wastes can be used as substrate when heated to minimum 70˚ C for 1 hour and the particle length is less than 12 mm to ensure security (Mattilsynet, 2007).

2.2 Anaerobic digestion

The process where organic material is degraded without access to oxygen in a controlled engineered system is called anaerobic digestion (Angelidaki & Batstone, 2012, p.583). Several process factors play important roles of how well the overall performance of the anaerobic digestion process becomes. The most essential factors are nutrients, temperature and inhibitory factors. Nutrient composition of the substrate influences to what extent the microorganisms can degrade it. In the solid waste area it is rare that the nutrition is the limiting factor for the anaerobic digestion. The temperature has a strong influence on phase distribution, mass transfer rates, solubility and microbiological processes. Inhibitory factors are aspects that restrict the biological processes. (Angelidaki & Batstone, 2012, p.595-599)

AD have four key biochemical stages which are hydrolysis, acidogenesis, acetogenesis and methanogenesis. Figure 2-1shows the sequence of the stages. Hydrolysis is the first step with the purpose of dissolving the particulates into molecules since microbes can't accept particles. Carbohydrates, proteins and lipids are the three main components that can be split, and water is used in the process of splitting. From the hydrolysis it is produced simple sugars, amino acids and long-chain fatty acids. (Angelidaki & Batstone, 2012, p.586-587)

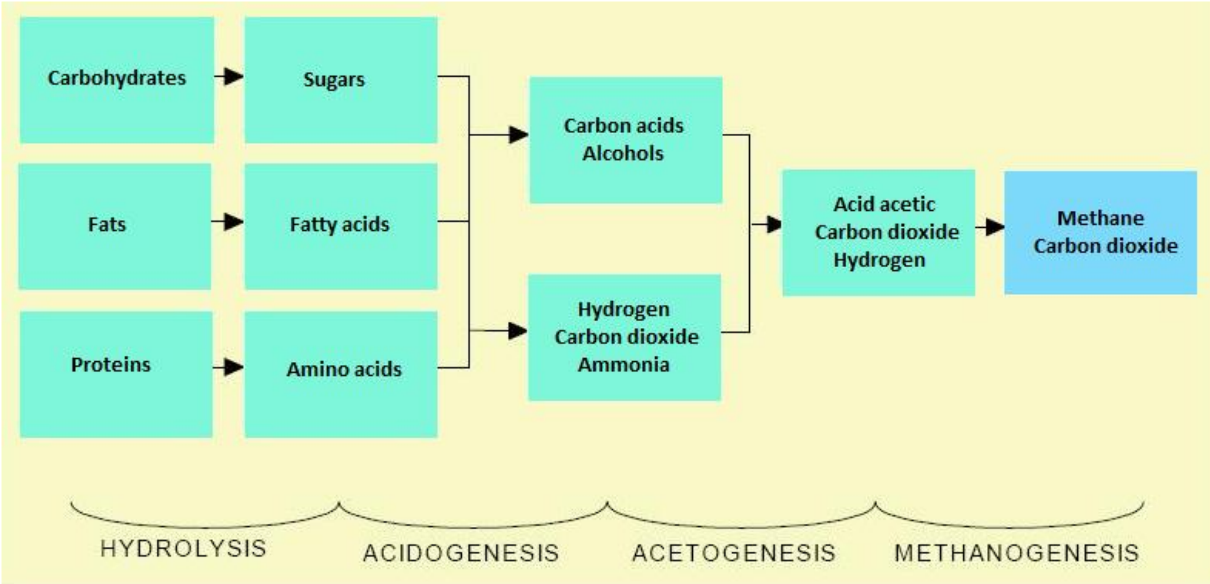

Figure 2-1 The biochemical stages of AD ("Biogas energy overview," 2012)

In the acidogenesis sugars and amino acids are converted into volatile fatty acids (VFA), alcohols, hydrogen and CO_2. This step has usually a considerable energy yield connected to it under most conditions. The main reason for this is that under stable conditions in the reactor most of the substrates are converted directly without going through reduced products. (Angelidaki & Batstone, 2012, p.587-588)

The acetogenesis process transforms VFA and alcohol into acetate whish further is converted to H_2. Acetate is produced in lower levels than H_2. This process is very sensitive for the H_2 concentration and the transportation of H_2 to the methanogenesis is very important. In the methanogenesis H_2 and acetate are converted to methane by two different pathways; hydrogenotrophic and aceticlastic methanogenesis. The acetogenesis and hydrogenotrophic methanogenesis are in close coexistence due to the importance of H_2 transport. Usually the hydrogenotrophic part contributes to 30-40% of the methane production and the aceticlastic for the rest. The aceticlastic methanogenesis is then the most effective of the two when it comes to methane production, but it is also one of the most sensitive processes in the anaerobic digestion. (Angelidaki & Batstone, 2012, p.589-591)

How the AD is conducted is often divided into four main technologically processes:

- **Dry/ wet digestion:**
  The moisture content in the biological digester decides which process it is. Dry processes have moisture content below 75% and wet above 90%. The choice of process has the substrate's moisture content as a starting point, but there are also other factors that can contribute to the choice (Jansen, 2012)
- **Psychrophilic/mesophilic/thermophilic digestion:**
  At which temperature level the digestion occurs is categorized by this definition. Operation below 20°C in the biogas digester is categorized as psychrophilic, but this temperature level is not often used in biogas digesters (Ward, Hobbs, Holliman, & Jones, 2008). A range of 20-42˚C for mesophilic processes and 45-60˚C for thermophilic processes is found in the literature (Forster-Carneiro, Isaac, Pérez, & Schvartz, 2012, p.8; Jansen, 2012, p.605; Pöschl, Ward, & Owende, 2010; Weiland, 2010), but the most common optimum is at 35˚C for mesophilic and 55˚C for thermophilic (Ward et al., 2008).
- **One-stage/two-stage digestion:**
  Due to different biochemical stages in the AD it can also be favourable to choose a staged process technology. It is most common to operate with two stages where the hydrolysis/acidification processes are separated from the acetogenesis/methanogenesis processes due to different optimum conditions. In many cases a multi-staged process will be more stable and results in a higher performance. The building and maintenance cost is though higher for multi-staged digesters. (Ward et al., 2008)
- **One-phase/two-phase digestion:**
  Phased digestion is used in combination with staged processes. The biomass is separated into a solid and a liquid phase after the acidification. The solid phase is treated further in the acidification stage and the liquid is passed through to the methanogenic stage. This enables a much higher methanogenic rate (Jansen, 2012, p.606). Control of the operation and process parameters of two-phased digestion is difficult. If the hydrolysis stage malfunctions, this can result in energy losses and hydrolysis gas released to the atmosphere. (Weiland, 2010)

2.3 Byproducts from AD

When using AD for managing organic wastes the main products will be biogas and digestate. Biogas will mainly consist of CO_2 and CH_4. The energy content of biogas is directly related to the methane content since carbon dioxide has a heating value of zero. Dependent on the substrate the methane content in the raw biogas leaving the reactor can vary, but the normal range is between 60-70 vol % (Swedish Gas Center, 2007).

AD as a treatment method for organic wastes should have as purpose to extract the maximum recovery value from the substrates. When it comes to the digestate this implies that it should have a quality that is acceptable for purposes such as soil amendment and landscaping. The quality of the digestate can be evaluated by three criteria; chemical, biological and physical aspects. Heavy metals and other inorganic contaminants, persistent organic contaminants and nutrients (N-P-K) are aspects that are related to the chemical quality of the digestate. Substrates like household waste can contain persistent contaminants like halogenated hydrocarbons, PCBs and PAHs. The main advantage of digestate is that it has a high content of nutrients. (Monnet, 2003; Lukehurst, Frost & Al Seadi, 2010)

Aspects that define the biological quality are pathogens, seeds and transmissible spongiform encephalopathy (TSE). Dependent on the substrates that are used in the AD the organic waste can contain hazardous matter that can result in spreading of pathogens and diseases between animals, humans and the environment. Biological treatment that ensures safe digestate is therefore essential. (Monnet, 2003)

The most common physical impurities are plastic and rubber, metal, glass and ceramic, sand and stones and cellulosic materials like wood and paper. When having such impurities in the digestate this will affect not only the quality of the digestate but it can also contribute to a lower biogas yield and increase the operational cost. (Lukehurst et al., 2010)

Dependent on the substrate used for AD the contamination will vary. This also affects the extent of the pretreatment and the digestion itself. For MSW it will be more effective to source segregate than having an extensive mechanical pretreatment if it is a mixed collection. This is due to a more effective removing of potential contaminants at source than mechanical pretreatment. (Monnet, 2003)

Use of digestate

In the AD substances like carbon (C), hydrogen (H) and oxygen (O) will be drawn from the substrates, but essential plant nutrients like nitrogen (N), phosphorus (P) and potassium (K) mainly remain in the digestate. Thus the composition of fertilizer agents in the digestate is dependent on the substrate. In the AD the nutrients (N-P-K) are mineralized which improves the plant uptake and make the nutrients in the digestate more available than in untreated organic waste. Consumption of digestate also benefits the humus and is therefore also suited for soil amendment in agriculture or landscaping. In contrast to chemical fertilizers, the use of digestate creates a nutrient cycle and maintains or improves the soil structure due to the application of organic matter. (Monnet, 2003)

In some cases it will be advantageous to treat the digestate further after AD. This is especially common for large commercial AD plants processing MSW. In such cases the posttreatment is done to increase the value of the digestate or to appeal to new markets. Dewatering is common to do as postttreatment. When dewatering the digestate it is separated in two fragments; a liquid and a solid part. The solid part is the fibre which is low in plant nutrients. Due to this the solid part can be used as soil conditioner or as low grade fertilizer. Another option is further treatment like composting. The liquid part has a more beneficial

N-P-K balance when it comes to fertilization. High water content makes the liquid part possible to apply by conventional irrigation methods. (Monnet, 2003)

2.4 Biogas utilization and upgrading

The biogas from the AD can either be used directly or be further treated dependent on the use area. In the following sections different ways of utilizing biogas are presented.

2.4.1 Heat generation

When biogas is used for heat generation the gas is combusted in a boiler. Generated heat can warm up water which can be used for heating of buildings located nearby or delivered to a local district heating network. A boiler used for combustion of biogas functions in the same way as a boiler for solid or liquid fuels, but it has to be specially modified to combust gas. (Swedish Gas Center, 2007)

Heat generation is especially relevant for farm plants and small biogas plants located close to heating plants. Seen in a resource perspective this solution is not optimal since it uses a high-grade energy source for a low grade purpose (Marthinsen, Skogesal, Thobeck, & Briseid, 2008).

2.4.2 Combined heat and power generation

In cogeneration there is no need for carbon dioxide removal. It is more important to lower the water and hydrogen sulphide due to possible corrosion and other damages. The biogas can then be used as fuel in stationary engines or gas turbines. Otto and diesel engines are typically used for this purpose. About 30-40% of the energy in the biogas is converted to electricity and the rest as heat. When the heat is utilized it is possible to retrieve as much as 85% of the energy. (Marthinsen et al., 2008; Swedish Gas Center, 2007)

2.4.3 Biogas upgrading for transport purposes or delivery to gas grids

If the biogas is being used for fuel or to be delivered to a gas grid, the methane content has to be increased by removal of water, hydrogen sulphide and CO_2. The process for increasing the methane content is referred to as biogas upgrading. In today's market it is common to request a methane content of about 97% in upgraded biogas (Hulteberg, Bauer, Persson, & Tamm, 2013).

Biogas used as fuel for vehicles has the same requirement of engine type as those utilizing natural gas. The quality demand for biogas is though strict and needs to be upgraded to obtain:

- A higher calorific value so that the vehicles can operate over longer distances
- A gas quality that is consistent to provide safe driving and engine operation
- No enhancement of corrosion due to high levels of hydrogen sulphide, ammonia and water
- A gas without mechanically particles that can be damaging

Upgraded biogas is considered to be among the cleanest fuels because of its minimal impact on the environment and human health (Monnet, 2003).

Upgrading technologies

Today there are five commercial upgrading technologies. The different technologies are shortly described based on Hulteberg et al. (2013) and for thoroughly descriptions this reference is recommended.

- **Amine scrubbing:**
  There are many variations of the process, but in general the technology consists of an absorber and a stripper. The CO_2 in the biogas is removed by the absorber using amines and the stripper removes the CO_2 from the amine solution.
- **Pressure swing adsorption (PSA):**
  In contrast to scrubbing this is a dry method using physical properties to separate gases. Raw biogas is compressed to a high pressure and fed into an adsorption column. The adsorption column retains the CO_2, but not the methane. When the adsorption material in the column is saturated the CO_2 gets desorbed and led into an off-gas stream by releasing the pressure. If there is a continuous production there will be a need for several columns since they will be opened and closed consecutively.
- **Membrane separation (MB):**
  By using membranes (a dense filter) it is possible to separate components in a gas or liquid down to the molecular level. For biogas upgrading the membranes used are able to retain most of the methane while the majority of the CO_2 penetrates them. Normally the raw biogas is cleaned before compression and removal of CO_2 by membranes. This is done to prevent condensation during compression and since the hydrogen sulphide will not be sufficiently separated by the membranes.
- **Water scrubbing (WS):**
  CO_2 has a much higher solubility than methane in water. By using high pressure the CO_2 is separated from the raw biogas and dissolved into water in the absorption column. The CO_2 is removed from the water by adding air at atmospheric pressure.
- **Organic physical scrubbing:**
  An organic solvent is used as CO_2 absorbent. In design this process is very similar to water scrubbing, but with two main differences; smaller column diameter due to lower requirement for organic solvent flow and need of heating/cooling before desorption/absorption.

Distribution of upgraded biogas

Transportation of biogas can be done in the same manner as natural gas; in pipes or on gas cylinders. Biogas can be transported in a separate gas grid, but if it is to be injected to an existing gas grid it has to be upgraded to natural gas quality (Sletten & Maas, 2013). If there are no existing gas grids located relatively close to the biogas plant, the cost of pipelaying can be quite high. A cost benefit comparison has to be conducted to evaluate if transportation in gas grids is the best option.

When transported in gas cylinders the upgraded gas could either be as compressed biogas (CBG) or liquid biogas (LBG). As liquid biogas the volume will be 1/600 of the original volume (Sund Energy, 2011). Today CBG is the most common method of transport in gas cylinders. The gas cylinders is mounted to the trailer and filled to ca. 300 bar. CBG is though a method more suited for transport over short distanced due to lower filling amount per load than LBG (Sletten & Maas, 2013). When choosing LBG over CBG the need for transport will be reduced by six times (Melby, 2008).

2.5 Performance of organic waste systems for biofuel production

This chapter presents research results related to resource efficiency performance and environmental life cycle impact found in the literature.

2.5.1 Resource efficiency performance results from previous studies

For the material rate of recovery (MRR), defined in chapter 4.1.1, the author has not managed to find any studies measuring this indicator for AD systems. Pöschl et al. (2010) provided some data which could result in a calculated MRR, but this would require assumptions which the author has not enough experience to make.

Studies looking at the nutrient recovery rate (NRR) of an AD system have been difficult to find. In the master thesis of Guochang (2014) nutrient efficiency (defined equal to the NRR) was calculated for different value chains with the EU as a case region utilizing sewage sludge as substrate. One of the scenarios evaluated was the combination of AD, land application and biogas upgrading. For this scenario it was found a nitrogen and phosphorus efficiency of respectively about 40% and 21%.

Pöschl et al. (2010) have evaluated the energy efficiency of various biogas production and utilization pathways for German conditions. To evaluate the process energy efficiency they defined a Primary Energy Input to Output (PEIO) ratio. This PEIO is the inverted of the energy efficiency, η, defined in chapter 4.1.1. Another difference is that the PEIO does not include the energy in the substrates. By evaluating different choices of substrates in co-digestion for large scale plants the PEIO ranged from 34.1 to 55%. How difference in utilization pathways influenced the co-digestion case with the lowest PEIO was also evaluated. By comparing six utilization alternatives the upgrading to fuel was in the mid range with a PEIO of 8.7%. The alternatives exceeding were fuel cell with external heat with a PEIO of 6.1% and CHP in combination with gas grid injection of 1.3%.

Saving of primary input by different biogas utilization pathways is discussed in Pöschl et al. (2010). For large scale biogas systems the production of biomethane as transportation fuel has the largest savings related to it. Usage of biogas as fuel has almost 39% larger savings than the second best alternative which is to upgrade the gas and inject it into a gas grid.

Berglund & Börjesson (2003) studied from a life-cycle perspective the net energy output and energy efficiency in AD of various raw materials for Swedish conditions. They detected that a net energy input required to run a biogas system (i.e. centralised biogas plant) typically was in the range of 20-40% of the energy content in the produced biogas. The operation of the biogas plant was found to be the most energy demanding process corresponding to 40-80% of the net energy input in the system. The analysis included processes as collection, treatment and transport of substrate, operation of the plant as well as transport and spreading of the digestate. In cases with upgrading they detected that the need for PE constituted 11% of the energy content of the biogas. 60% was used for the gas cleaning and 40% for the compression.

2.5.2 Environmental life cycle impact results from previous studies

Life cycle assessments of biofuels used in Sweden was conducted by Börjesson, Tufvesson, & Lantz (2010). Among these biofuels was biogas produced from organic household waste and organic commercial waste. The emissions related to biogas used as fuel depended on the allocation method used. By using the partitioning approch (both physical and economical) and the substitution approach the emissions varied from contributing to emissions to reduction of emissions. Organic household waste contributed to an emission of about 10 g CO2-eq./MJ biofuel when using partitioning approach and a reduction of about 3 g CO2-eq./MJ biofuel when using substitution approach. For organic commercial waste the emissions were respectively a contribution of about 8 g CO2-eq./MJ biofuel and a reduction of about 16 g CO2-eq./MJ biofuel. Comparing the biogas produced by organic household waste with fossile fuels resulted in a reduction of greenhouse gases (GHG) of 88% using the partitioning approach and 103% with the substitution approach. For the organic commercial waste the reduction was respectively 90% and 119%.

Lyng et al. (2011) carried out an analysis of different biogas value chains and concluded that biogas used as fuel in transportation had the best climate effect. In evaluating food waste for a general case they found that the net GHG emissions for production of biogas for fuel and digestate replacing chemical fertilizers had a reduction of almost 200 kg CO_2- equivalents per ton DM food waste. Since this evaluation is done with general values this is more an indication of which range the emissions of such cases will be in. Values used for decision making should be based on analysis where values are adjusted a specific region or plant.

The GHG emissions from various substrate based biogas used as a transportation fuel was compared to other utilization areas in Uusitalo et al. (2014). In all of the cases the use of biogas in transportation sector led to reduction of GHG emissions compared to fossil fuels. The reduction was in the range of 49-85%. Among the three chosen substrates, source separated biowaste, waste water treatment plant sludge and agricultural biomass, the case where biowaste was utilized for production of biogas to fuel was the one with the lowest emissions. Biowaste for transportation fuel had an emission of ca. 220 g CO_2-equivalents per MJ of biogas produced.

Pertl, Mostbauer, & Obersteiner (2010) evaluated the GHG emissions related to systems using different upgrading technologies; PSA, WS, MB and Bottom Ash for Biogas Upgrading (BABIU). Municipal organic waste (separated organic waste from households) and agricultural resources were the two substrates used as substrates in the AD for the different scenarios. In this study the gas was upgraded with the purpose to be fed into a gas grid and converted to energy in a CHP plant. This study did not include treatment and transport of digestate. The scenario using organic waste as substrate and WS for upgrading had GHG emissions of 108.9 kg CO_2-eq./per 100 m^3 upgraded biogas. Compared to the conventional upgrading technologies WS had the lowest emissions, but both scenarios using BABIU had lower emissions. BABIU had emissions of 31.9 and 102.8 kg CO_2-eq./per 100 m^3 upgraded biogas for respectively use of organic waste and agricultural resources.

Starr, Gabarrell, Villalba, Talens, & Lombardi (2012) evaluated three different upgrading technologies by using LCA; high pressure water scrubbing (HPWS), alkaline with regeneration (AwR) and BABIU. The study concluded that BABIU had the lowest overall environmental impact of all the biogas upgrading technologies. Amine scrubbing and HPWS became second in having the best performance compared to other current technologies (PSA, MB, cryogenic, organic physical absorption). Starr et al. (2012) only looked at the upgrading technology itself and did not include other processes in the value chain since these were assumed similar for the different upgrading methods. Although Starr et al. (2012) had other system boundaries than Pertl et al. (2010) both of the studies evaluated the WS technology as one of the leading commercial upgrading technologies when it comes to its environmental impact.

3 Case study – Romerike biogas plant

As a case study Romerike biogas plant (RBA) located at Nes in Romerike, Norway has been evaluated. The value chain corresponding to this biogas plant is shown in Figure 3-1. In the Oslo area paper and HHW are collected at customer. The customer sorts the HHW into three different coloured bags that are thrown in one bin. Green bags are for food waste, blue for plastic and ordinary plastic bags for residual waste. The HHW gets collected by collection lorries driven on biogas and transported to the energy recovery plants at Haraldrud and Klemetsrud. Here the waste is sorted using the Optibag technology. Optibag by Envac is one example of a fully automatic optical sorting waste management system. Camera technology will recognise the colour of the bag and the different bags will be pushed off the conveyor belt and directed for the appropriate container. This system requires less space for waste storage and all waste bags can be collected in the same waste chute or bin (Envac, 2013). The food waste gets transported to the biogas plant at Nes.

Operation of RBA was started 20.12.2012 and the plant is now in a run-up period. RBA is designed to handle 50 000 ton organic wastes per year. At full capacity it is estimated that about 60% of the incoming substrates are food waste from Oslo that have been optical sorted. The remaining organic substrates delivered to RBA are food waste from other municipalities, commercial food waste and liquid food waste. Future distribution between the different substrates is not decided, and will be affected by research and experience.

At RBA the substrates are used to produce biogas and digestate. The biogas is upgraded and liquefied to be used as fuel in buses and waste collection lorries in Oslo. As for the digestate it can be transformed into three agricultural products; liquid digestate, solid biofertilizer and concentrated liquid biofertilizer. Digestate from the digesters goes either through posttreatment and ends up as liquid digestate ready for use or is sent to dewatering and water treatment. After dewatering and water treatment the two remaining products are completed.

In the period that RBA has been in operation it has not been produced any LBG. Until now they have produced CBG and some of this amount has been sold to customers. The digestate has been transformed to liquid digestate and solid biofertilizer. None of the centrate has been used to produce concentrated liquid biofertilizer. The produced fertilizer products have till now been delivered for experiments and to local farmers for testing. Long-term contracts will be signed in 2015 where RBA will claim payment for the fertilizer value itself (personal communication, N.F. Lumholdt, 30 June, 2014).

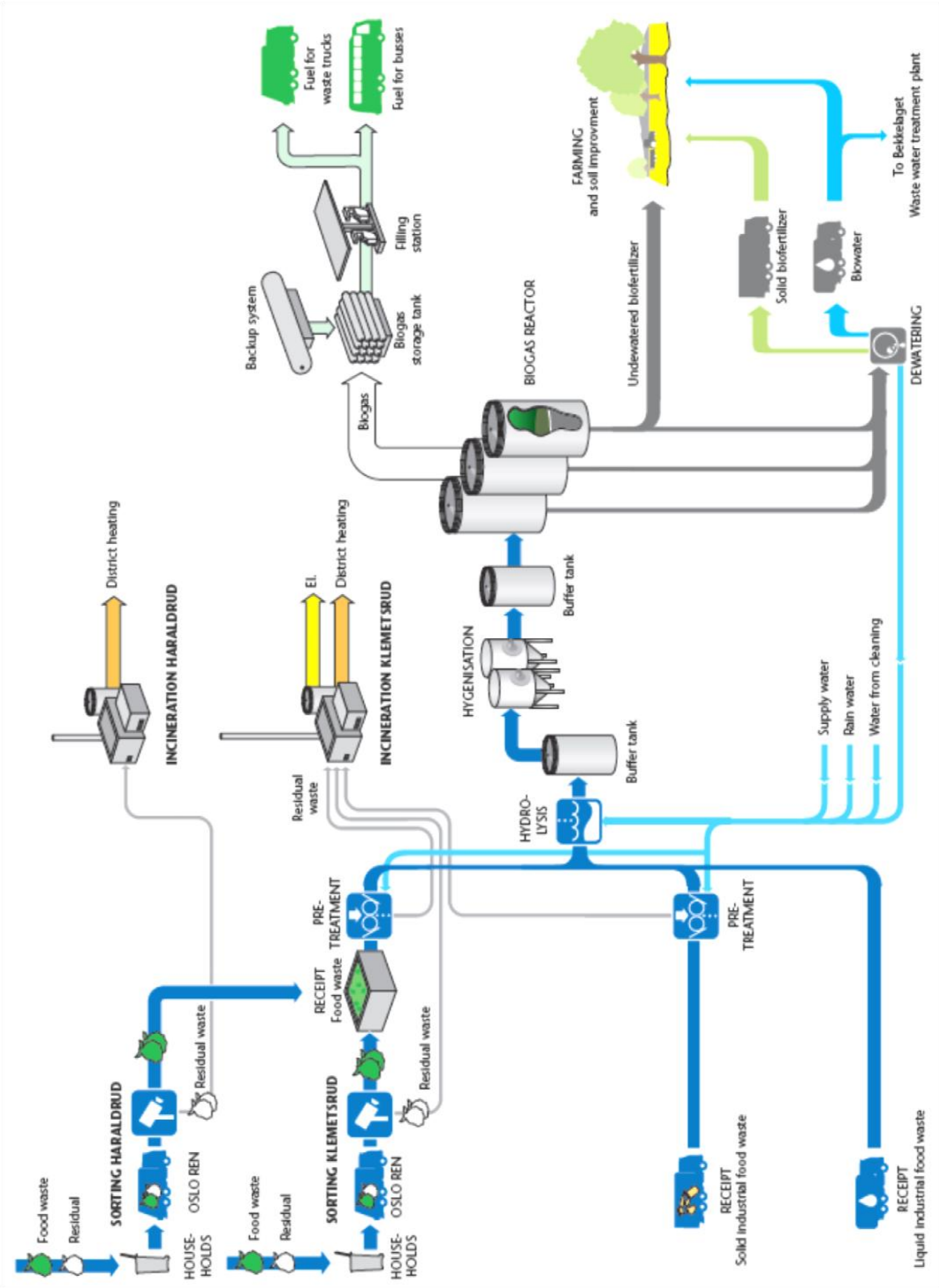

Figure 3-1 Value chain for biogas production at RBA (Oslo kommune EGE, 2013)

3.1 Pretreatment

At RBA the waste enters the plant through one of the three reception halls where the truck can tip the waste in a bunker. Two of the halls are also enable to receive liquid waste through a pump system that delivers the liquid waste to one of three buffer tanks. The green bags are transported from the bunker to one of the pretreatment lines with a crane with a grab. At RBA they have installed two separate identical pretreatment lines to ensure high flexibility and secure operation. Only one line is operated at a time. First the bags are opened using a grinder. Then the waste is transported through four stages of mechanical pretreatment which all utilize the separation technique. The first stage is metal separation using an electromagnet. Collected metal is delivered to Norsk Gjenvining for recycling (E. Govasmark, personal communication, 28 April, 2014). Afterwards water is added to the substrate mix to reduce the DM content to make it suitable for the next separation stage performed by the Biosep technology.

The Biosep technology is a Norwegian developed technology by Norsk Biogass AS for separation of organic material from plastics and other packaging materials in waste streams. The biomass from this process will be virtually plastic free. Today Norsk Biogass AS delivers whole pretreatment systems for food waste where the Biosep is the core component (Norsk Biogass AS, 2013). The Biosep can consist of two stages. Both stages have the same four operation modes:

- Feeding: a spiral conveyor feeds the Biosep continuously with food waste. If the moisture content is too low, water is added to the unit. A rotor pulls the material through a sieve and the soft digestible fractions go to further processing.
- Reject cleaning: the material that did not pass the sieve is tossed around in the machine as clean water or process liquid is added. In this way a minimum amount of digestible material is lost by clinging on to the plastic and packaging material.
- Reject drying: the reject is dried to avoid large pockets of liquid on the reject which can contain digestible material.
- Reject discharge: after the previous modes the reject is discharges into a spiral conveyor for further transportation to a container.

The difference of the two stages is that the second stage has a finer masking of the sieve (BioPrePlant). At RBA Biosep only has one step in the pretreatment for removal of plastics, textiles, twiggs etc bigger than 25 mm.

Stage three is for removal of material larger than 10 mm. For this purpose a strainpress is installed. The strainpress by Huber Technology Inc. is a horizontal pipe-shaped separator as shown in Figure 3-2. It consists of an inlet and screening zone, press zone and a discharge section. The liquid is pressed through the screening zone and to further processes by a pump. The material left on the screen surface is stripped off by a coaxial screw and then pushed through the press zone. In the press zone the material is dewatered and compacted. Afterwards the material is pressed through a gap around a hydraulically operated pressure cone. This clog up part of the pipe end and a counterpressure builds up. The reject from this process can get filtered and dewatered to approximate 45% DM (Huber Technology Inc., 2012).

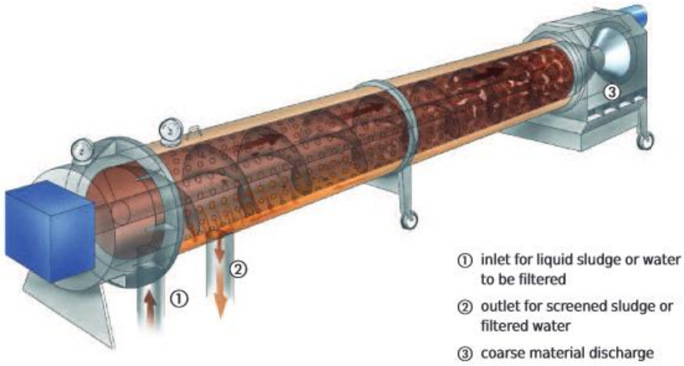

Figure 3-2 Strainpress by Huber Technology Inc. (Huber Technology Inc., 2012)

The last stage of the mechanical pretreatment at RBA is hydrocyclones installed in the circulation circuits to the pulper, flash tank and each of the digesters. These hydrocyclones remove and wash grit and sediments smaller than 10 mm. (E. Govasmark, 28 April, 2014)

Removed plastic and twiggs from the pretreatment are transported to be incinerated for energy recovery elsewhere (E. Govasmark, personal communication, 28 April, 2014).

The food waste is now liquid with a particle size of maximum 10 mm. It is then transferred to temporal storage in one of the three buffer tanks. As mentioned the liquid food waste gets pumped directly to the buffer tanks and should not have a particle size exceeding the pretreated food waste. Due to the continuous operation of the pretreatment the buffer tanks are installed to ensure even distribution of the waste independent on quality of delivery and irregularities in the pretreatment.

3.2 Anaerobic digestion

At RBA the pretreated substrate will be exposed to Cambi's Thermal Hydrolysis Process (THP), Figure 3-3. This technology will expose the substrate for a thermal pretreatment, hygienisation as well as hydrolysis before entering the digester. Most of the conventional biogas technologies operate at temperatures around 70°C, but the THP can treat the organic material at 165-170°C (Sargalski, Solheim, & Fjordside). The pretreated material is pumped batch-wise into the pulper. At RBA the material in the pulper gets preheated to 80-100°C by receiving steam from the reactor/flash tank when the flashing between reactor and the flash tank occurs. The increase in temperature decreases the viscosity of the material and enables it to get mixed by pumping in circulation. Foul gases produced in the pulper are removed by an odour removal system. The foul gases are pumped by ejector compressor pumps from the pulper to the digester(s) where they are decomposed. (Sargalski, Solheim, & Fjordside)

After being preheated the material is pumped to the reactor. Here steam is injected into the reactor until the desired operation temperature and pressure is reached. At RBA the operation temperature is above 130°C at a pressure of 4-5 bar for about 30 minutes. The steam is provided from a boiler driven by landfill gas from the local landfill. Due to the high temperature in the reactor the material gets hygienisated as well as hydrolyzed in this step. After the hydrolysis is complete, a pressure driven valve on the reactor will be opened to reduce the pressure and temperature (Sargalski et al.). The material is then flashed from the reactor to the flash tank. When entering the flash tank a steam explosion will occur (Cambi AS). Steam explosion can be seen as a pretreatment method that makes the material more digestible when entering the digester. After being through the flash tank the pressure and temperature are still too high to enter the digester. Therefore a heat exchanger is installed after the flash tank to reduce the temperature to the conditions in the digester (Sargalski et al.). At RBA they operate under mesophilic conditions with a digester temperature of 38-39°C and a retention time of about 24 days (N.F. Lumholdt, personal communication, 24 September, 2013). The recovered heat is used for preheating of the water that is supplied to the boiler.

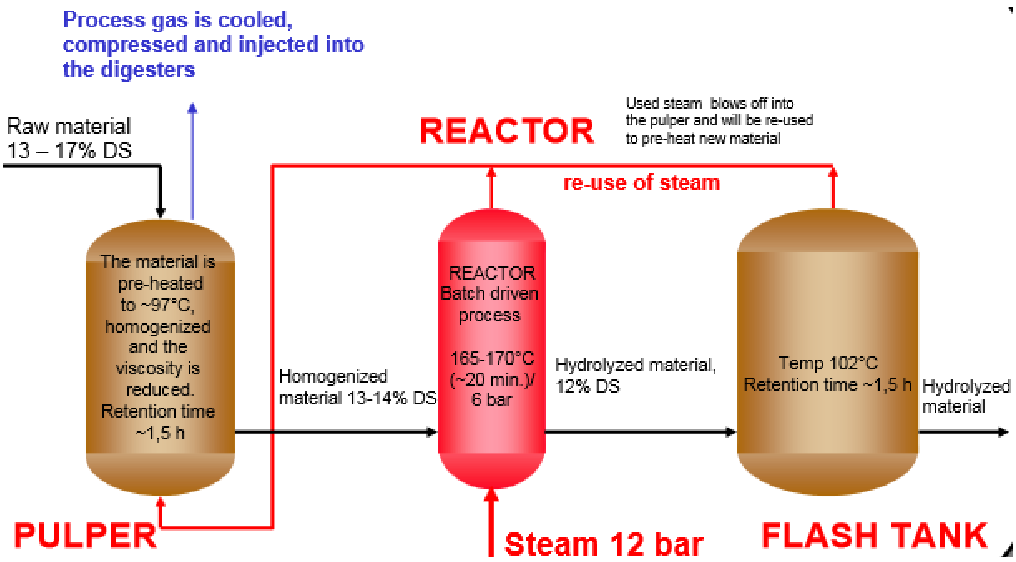

Figure 3-3 Principal sketch of THP (Sargalski et al.)

The digestate from the digester is then posttreated by entering a strainpress to ensure that there are no unwanted items that will affect the quality of the end product. This strainpress is the same kind as the one mentioned under chapter 3.1, but with the intention to remove objects larger than 5 mm. In the nearest future this strainpress will be improved so that it will remove items above 2 mm (E. Govasmark, personal communication, 28 April, 2014). The liquid digestate leaving the strainpress is an adequate fertilizer product. Used in agriculture the liquid digestate will have a N-P-K factor corresponding to chemical fertilizer. In the future it will be beneficial to transport the liquid digestate in pipes to storage tanks where farmers can collect the digestate. Today the liquid digestate is sent to a storage tank located at the premises where lorries can pump the digestate on board and transport it to use areas. In periods where the fertilizer cannot be spread on land or there are excess of fertilizer, RBA has to have another option. Then it is possible to dewater the liquid digestate. This is a method also used to save transport. The dewatering occurs by first polymerize (thickening) the digestate and then separation by a decanter centrifuge. This results in solid biofertilizer and centrate. The centrate goes through a reject water treatment where acid is added, it is evaporated and the DM content is increased. The flows leaving the water treatment is concentrated liquid biofertilizer and cleaned effluent water that either is used in internal processes or delivered to the sewer system. Today all the fertilizer products produced at RBA has to be transported by lorries for usage in agriculture.

3.3 Biogas upgrading and transformation to liquefied biogas

The upgrading process at RBA starts with a cleaning/separator stage to remove unwanted liquid/condensate. To get the wanted temperature and pressure for the gas entering the upgrading method it is sent through a two-staged compressor with an intercooler and an aftercooler. At RBA the upgrading method used is a pressurized water scrubber for removal of CO_2, SO_2 etc. Figure 3-4 shows a schematic illustration of a water scrubber. In the absorption column the CO_2 is separated from the raw biogas and dissolved into water by using high pressure usually in the range of 6-10 bar. The CO_2 is then removed from the water in a desorption column by adding of air at atmospheric pressure (Hulteberg et al., 2013). At RBA the scrubber operates at a pressure of 10 bar. The gas fed into the scrubber consists of approximately 60% methane and is upgraded to 97-98% methane in the water scrubber (Lumholdt, 2013). At RBA the methane concentration is estimated to vary between 57-65% depending on the waste characteristics of the substrates fed into the plant (Cambi AS, 2011).

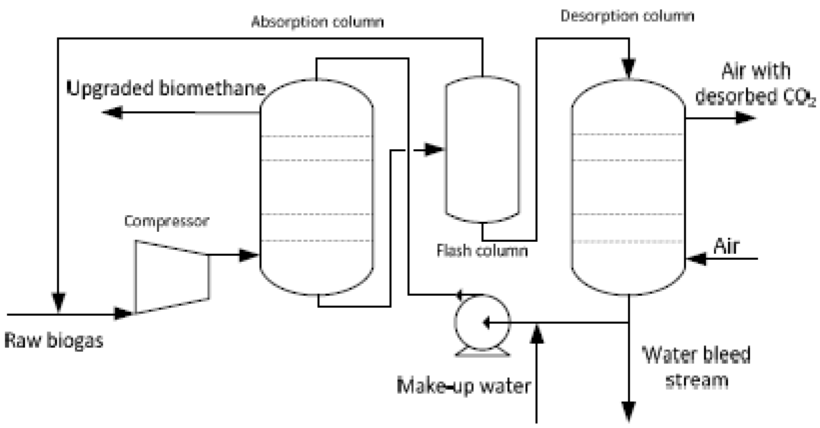

Figure 3-4 Schematic illustration of a water scrubber (Hulteberg et al., 2013)

The CO_2 removed from the biogas upgrading is further cleaned for methane by a regenerative thermal oxidation (RTO) process. This process oxidizes unwanted climate gases to CO_2 at 1000 °C. Afterward the methane content shall be under 0.2% before the CO_2 is released through the stack. (E. Govasmark, personal communication, 28 April, 2014; Lumholdt, 2013)

Removal of water happens in two absorption drier towers in alternating operation. In the bottom of the towers there are carbon filters for removal of oil from the compressor.

Since there are no gas grids located at Nes the biogas must either be compressed or liquefied to be able to transport. Liquefied biogas will require less volume and hence the need for transportation will be reduced. At Nes the upgraded biogas gets liquefied. The upgraded biogas gets compressed to 30 bar. To ensure the wanted methane content of 99.7% (E. Govasmark, personal communication, 28 April, 2014), more CO_2 is removed by CO_2 polishing. The CO_2 polishing happens in molsieve adsorption towers. After this treatment the CO_2 concentration can maximum be 50 ppm. For the gas to become liquid the gas has to be cooled down. At Nes the gas cooling occurs by cryogenic cooling in a Mixed Refrigerant process which cools the gas down to about 160°C (Lumholdt, 2013).

To minimize methane released to the atmosphere RBA has as mentioned a RTO installed. This is to prevent among others methane emissions through the stack. In situations where there are too much biogas produced compared to the capacity of the upgrading it has been installed a flare. The flare will burn the methane content in the biogas and transform these emissions into CO_2 which has a lower GWP than CH_4.

4 Methodology

An overview over the most important aspects of MFA and LCA, the general procedures and the procedure conducted for the RBA case are presented in this chapter.

4.1 Material flow analysis

4.1.1 Concept

MFA is a method that can be a suited tool in for instance waste management. This method is a systematic assessment of flows and stocks of materials within a defined system confined in space and time. By using the law of conservation of matter it is possible to control the results from a MFA. The interaction between the sources, the pathways, and the intermediate and final sinks of a material makes it possible to put up a material balance comparing all inputs, stocks and outputs of a process. (Brunner & Rechberger, 2003a)

As shown in Figure 4-1 the MFA procedure consists of four main stages; problem definition, system definition, determination of flows and stocks and illustration and interpretation. In the general MFA procedure it is common to start with the definition of the problem and the goals. Further the system is defined by choosing relevant substances, system boundaries, processes and goods. Interaction between the different processes is decided in step three. Here mass flows of goods and their substance concentrations are estimated. Flows and stocks of substances are calculated by using the law of conservation of matter and uncertainties associated are considered. The last stage is to illustrate the results in a proper way to be able to visualize the conclusions and to ease implementation of decisions related to the goal. (Brunner & Rechberger, 2003b)

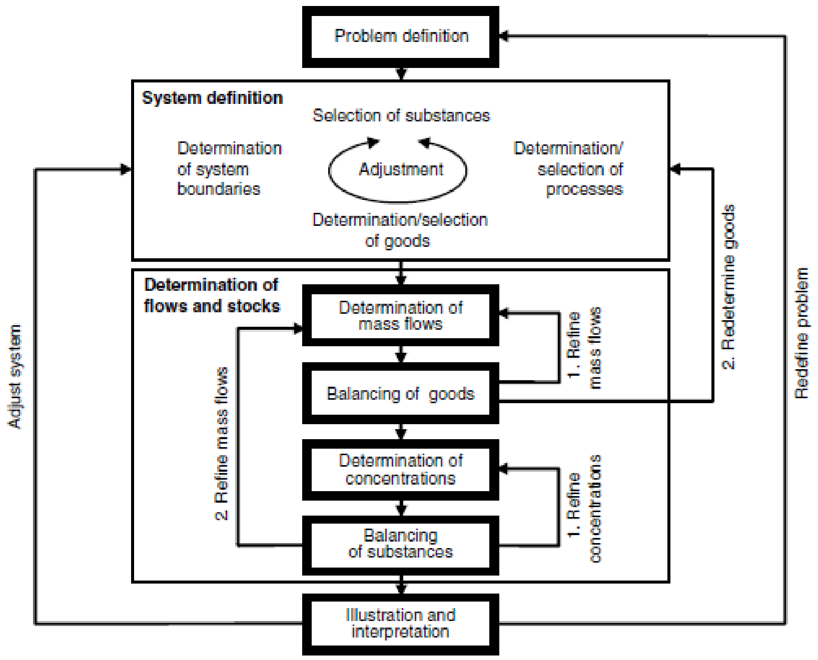

Figure 4-1 Procedures for MFA (Brunner & Rechberger, 2003b)

In Figure 4-1 there are several arrows pointing back to earlier stages. This illustrate that an good MFA is developed by iteratively optimizing the stages. Therefore it is best to start with rough estimations and provisional data and then make improvements to the system and data.

The MFA will in this study be used to detect the resource efficiency performance for the RBA value chain. In the work with the pre-thesis project a general system for utilization of biogas was developed, Figure 4-2. This gives a simplified overview of the main processes and flows for such value chains. Not all processes and flows will be relevant for different value chains. Modifications when dealing with specific cases will be necessary.

In the general system the dotted lines are pure energy flows and the solid lines are material flows. The system definition in Figure 4-2 includes transportation of the substrates, waste from different processes as well as the biosolid product. In a more correct system also different biofertilizer product should be included as well as transportation of these flows and in some cases also the fuel that is produced. Dependent on the substrate and/or the intended quality of the end products the need for different processes will vary. Five main processes, A-E, were defined:

- A: sorting
- B: pretreatment
- C: anaerobic digestion
- D: bioresidual treatment
- E: biogas utilization and upgrading

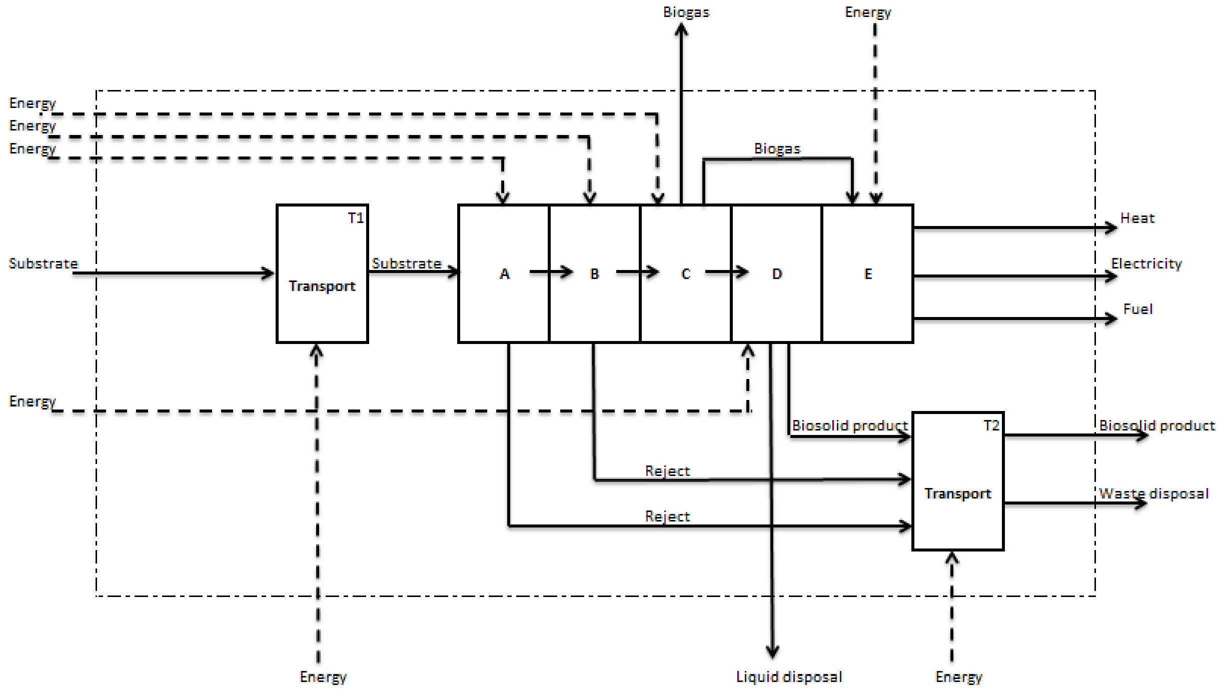

Figure 4-2 General value chain for biogas utilization

The general system gave the basis for the development of the indicators shown in equation (1), (2) and (3) which is used to detect the resource efficiency performance for the case studied.

Equation (1) shows the general formula for the energy efficiency. Dependent on the studied value chain the indicator value could contain some or all of the energy flows included in the equation. The numerator includes all the energy flows for energy produced in the system. Energy consumed in the system is in the denominator.

$$\eta = \frac{E_{fuel} + E_{heat} + E_{el}}{\sum E_{substrate} + \sum E_{t,i} + \sum E_{p,j}} \qquad (1)$$

MRR has been defined in equation (2). Here the numerator expresses the DM content in digestate products used in agriculture. The numerator can therefore consist of more than one DM flow dependent on which digestate products that are produced in chosen value chains.

$$MRR = \frac{DM_{digestate}}{DM_{substrate}} \qquad (2)$$

NRR is defined by equation (3). NP and NS are nutrients in respectively the products used for agricultural purposes and in the substrates entering the system. N and P are two of the essential plant nutrients and therefore these are chosen as indicators for NRR.

$$NRR = \frac{NP}{NS} \qquad (3)$$

4.1.2 Problem definition

The problem of this study is to analyse the specific RBA value chain producing biogas from organic waste and where the biogas is upgraded and used as fuel. Calculation of the system's resource efficiency performance and evaluation of the models sensitivity will be the goal of the MFA. The resource efficiency performance of the system is measured through the definition of three different indicators; energy efficiency, material rate of recovery (MRR) and nutrients rate of recovery (NRR).

4.1.3 System definition

The spatial system boundary is the geographic boundary for the necessary processes related to the production of LBG and biofertilizer products at RBA. The technical system starts with the optical sorting of the HHW that is delivered to RBA and ends at the application area of the products. Due to data for RBA were provided for the period of October 2013 to May 2014, this has been chosen to constitute the temporal boundary of the MFA.

Originally it was planned to build up the MFA model with basis in flows with DM content to be able to provide the resource efficiency performance of RBA. This had simplified the system to only include flows and processes that involve DM in some way. Total waste flows relevant for energy calculations of the DM flows would have been used, but the MFA principle of mass balance would not hold for the total waste flows. It is only the organic DM content in the substrate that can be transformed into biogas. The DM content is also linked to the nutrients in the biofertilizer products.

According to original desired level of detail for the evaluation of the RBA value chain the system shown in Figure 5-1 to Figure 5-4 was developed. It was desirable to detect the mass flows relevant for transportation, DM flows through the system and relevant energy flows. Data on in- and outflows of mass (found in Appendix D) were provided. If fractions at designed conditions (at full capacity, 50000 ton/year) had been used to find the flows through the processes happening at RBA, named "Biogas plant processes" in Figure 5-1 and Figure 5-3, there would be no correlation between the calculated flows leaving RBA and the ones provided. The system boundaries provided in Figure 5-1 to Figure 5-4 will be used for calculation of efficiencies, but mass balances (on DM basis) for all the processes and the system as a total will not be valid.

For the calculations done in the MFA the assumptions/data regarding transport distances, load capacity and type of fuel are the same as the ones mentioned in chapter 5.2.1 under the different processes.

4.2 Life cycle assessment

4.2.1 Concept

According to ISO 14040 LCA is defined as "compilation and evaluation of the inputs, outputs and potential environmental impacts of a product system throughout its life cycle". The product system is defined as the total system of unit processes in the life cycle of the product. LCA can then be used as a tool to analyse the environmental burden of products through the different stages within their lifetime. In LCA the expression "from the cradle to the grave is used to express that all stages in the products life cycle are included;

- extraction of resources
- production of materials, product parts and the product itself
- the use phase of the product
- management after discarding (reuse, recycling or final disposal)

(Guinée et al., 2002, p.5-6)

LCA is a tool that tries to tackle the challenge of having a holistic view when evaluating environmental impacts. A holistic perspective will give the most correct picture of the burdens connected to a product or service delivered from a system. The choice of which life cycle phases as well as upstream processes in the economy that should be included is important to ensure a holistic perspective. This makes LCA an important tool to reveal issues of problem shifting. Problem shifting can be of two types:

- solving one problem by shifting it to another place in the value chain that is excluded by the investigated system border
- solving one type of environmental problem generates another in the process

A consistent system description with clearly stated system boundaries is therefore crucial to ensure a holistic perspective that avoids problem shifting. (Strømman, 2010)

Based on a number of ISO standards a world-wide consensus for a framework of the working method for LCA has been structured. The entire LCA procedure is divided into four phases within this framework. These four phases are shown in Figure 4-3 and described in chapter 4.2.2-4.2.5. (Heijungs & Guinée, 2012, p.17-29)

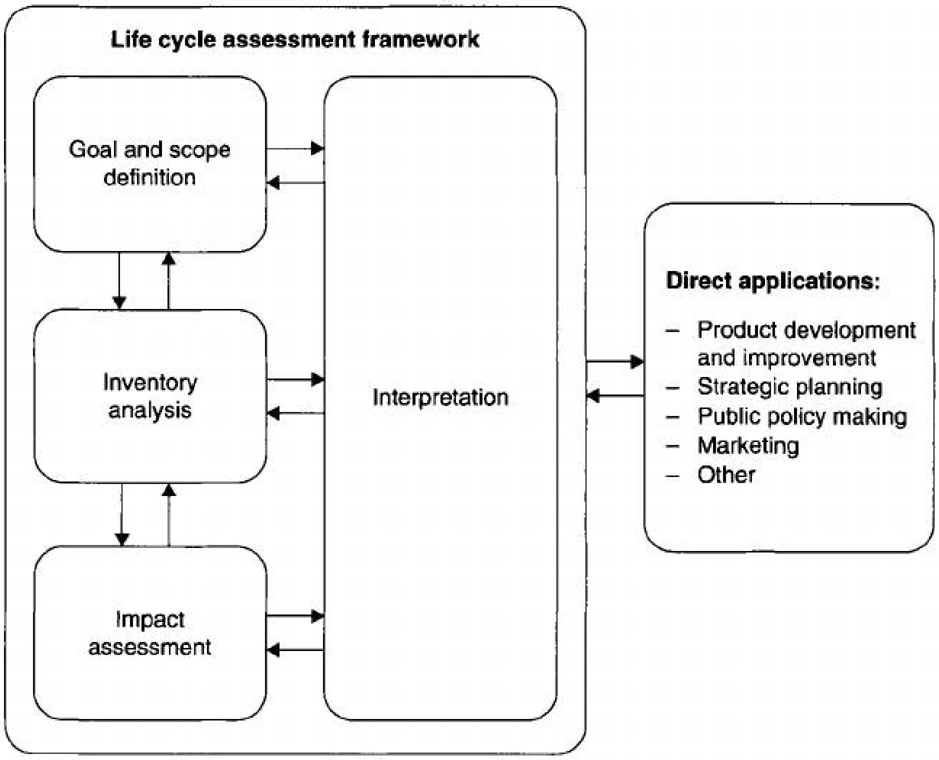

Figure 4-3 General framework for LCA (Heijungs & Guinée, 2012, p.16)

4.2.2 Goal and scope definition

In this phase the plan of the LCA study gets defined as clearly as possible. The goal of the study should include the intended application and the reason for conducting the LCA, the intended audience and whether the result is to be disclosed (Pålsson & Riise, 2011a).

The primary goal of utilizing LCA on the RBA value chain is to detect the environmental life cycle impacts of managing wet organic waste as it is done in this case.

A secondary goal is to conduct a sensitivity analysis to identify how "sensitive" the model is for changes of parameter values and the structure of the model. Further explanations on how this is conducted for the investigated case are found in chapter 4.3.2.

In the scope the detail and depth of the study are described. This involves making a number of decisions. In the scope the following aspects should be considered and outlined (Pålsson & Riise, 2011a):

- The product system
- The function of the system and the functional unit
- System boundary
- Allocation procedures
- Environmental impact assessment methodology and types of impact
- Data requirement and quality
- Assumptions and limitations

The scope of the RBA value chain is established by the following assumptions:

- The construction of the sorting and biogas production facility (RBA), including machinery and electric installation will not be included. It is only the operation stage that will be accounted for in this analysis.
- Production of plastic bags for HHW sorting of food waste and plastic will not be included in this study. According to Kirkeby, Birgirsdottir, Hansen, & Christensen (2006) the use of plastic bags for collection of organic waste have an influence on energy use and emissions. The plastic bags used for collection in the Oslo area are produced for the purpose of waste sorting and should optimally been included if a more comprehensive study was done.
- Transportation of different waste/reject flows from RBA will not be included in the model.
- Use of landfill gas in operation of RBA will not be included since data has not been received within the time limit. If data were received the landfill gas would not be considered as an avoided burden although it is located on the premises of RBA. This gas would have been treated with another method if not used at RBA. Not including the landfill gas in the biogas plant would result in a lower biogas output from the plant due to the use of produced biogas for internal processes. Due to this the landfill gas had been treated as an input parameter if biogenic emissions were included.
- CH_4 and CO_2 released in the foreground system from the upgrading and liquefaction stage at RBA and from use of the byproducts will be excluded in the LCA. These emissions have been neglected since these are biogenic emissions. Systems based on biomass are often described as carbon neutral since the CO_2 released from combustion of biomass approximately equals the amount of sequestered by biomass re-growth. This ignores the fact that the CO_2 remains in the atmosphere for a period and in this period it contributes to climate change. The time perspective of the study then affects

the contributions of the biogenic emissions. (Cherubini, Peters, Berntsen, Strømman & Hertwich, 2010)

- Transport or other handling of centrate for the evaluated period will not be included in this analysis. In the evaluated period none of the centrate has been processed in the water treatment and resulted in concentrated liquid fertilizer. This could not be sent directly to the sewer system and would have need of some kind of handling or transported to other sites for treatment.

Functional unit

What kind of function or service the product system delivers should be described by the FU. The main purpose of a FU is to have a reference to which the inputs and outputs are related (Sauer, 2012, p.45). Therefore the FU itself has to be measurable. The FU as a reference is necessary to ensure comparability of results from similar LCA studies (Sauer, 2012, p.45). It is however important to keep in mind that the system description can vary among the different studies.

The function of RBA is to treat wet organic waste by AD to produce biogas and fertilizer products. The chosen FU is:
1 ton DM mixed organic waste entering RBA

The definition of entering RBA means the substrate mix that is delivered to the premises of RBA at Nes. Different substrate mixes will affect among others the extent of the pretreatment, the retention time in the digester and the biogas yield. In this study the system is analysed with the present substrate mix, but the FU is chosen so that the system also can be valid for future situations.

System boundaries

Data that are gathered specifically for a given study are generally referred to as foreground processes. All the foreground processes constitute the foreground system that is the system that the one conducting the LCA needs to model and investigate in detail. The value chains upstream of the foreground system are modelled using generic data from databases. These processes are called background processes and constitute the background system. (Strømman, 2010)

The person conducting the LCA needs to collect the foreground data on inputs and emissions, as well as the inputs from the background system to the foreground system. Databases will provide data on inputs and emissions from the background system, and data collection from background processes will therefore not be necessary. Foreground systems are typically unidirectional, while the background system will contain loops between processes since they generally represent a larger part of the whole economy. The interface between the background and foreground system is called the system boundary. The system boundary decides to which extent the collection of specific data is necessary before it is valid to use generic data. (Strømman, 2010)

In this LCA study the production of LBG and biofertilizer products from different types of food waste at RBA is evaluated. System boundaries that are clearly stated are important in order to know which processes to include in the foreground system. To conduct a good LCA where uncertainties are minimized the foreground processes should be based on specific data and generic data will be sufficient for the background processes.

Foreground system

The foreground system will be defined in four different ways in the study of the RBA value chain. By evaluating these cases it will be possible to localize the avoided burdens by utilizing products from RBA in contrast to more ordinary applications. The four cases are different in the following way:

- **Case A:** This case illustrates the value chain of RBA, much like the one defined for the MFA, but processes regarding the use of the products are included. This involves the use of the amount of LBG produced at RBA as fuel in buses and the liquid digestate and solid biofertilizer as fertilizer. Emissions directly linked to the use of these products will not be included in this study since they are accounted as biogenic emissions.
- **Case B:** This case symbolizes the alternative where diesel had been used as fuel instead of LBG produced at RBA. The amount of diesel used in this case corresponds to the amount needed to travel the same distance as for the produced amount LBG.
- **Case C:** For this case the amount chemical fertilizer that accounts for the N content in the liquid digestate is modelled.
- **Case D:** The amount chemical fertilizer that is necessary to account for the N content in the solid biofertilizer produced at RBA is modelled in this case.

Figure 4-4 shows a sketch were the four cases are illustrated. Case A is all the processes linked with gray arrows included the use processes linked with green arrows. Each of the use processes linked to with red arrows illustrate case B-D. Green and red arrows leaving the same process goes to different uses. The red arrow illustrates the alternative used if the respective product at RBA had not been produced.

Due to late reception of data related to RBA it has not been possible to detect direct stressor emissions related to the foreground processes. The foreground processes will therefore be linked to data from the ecoinvent database.

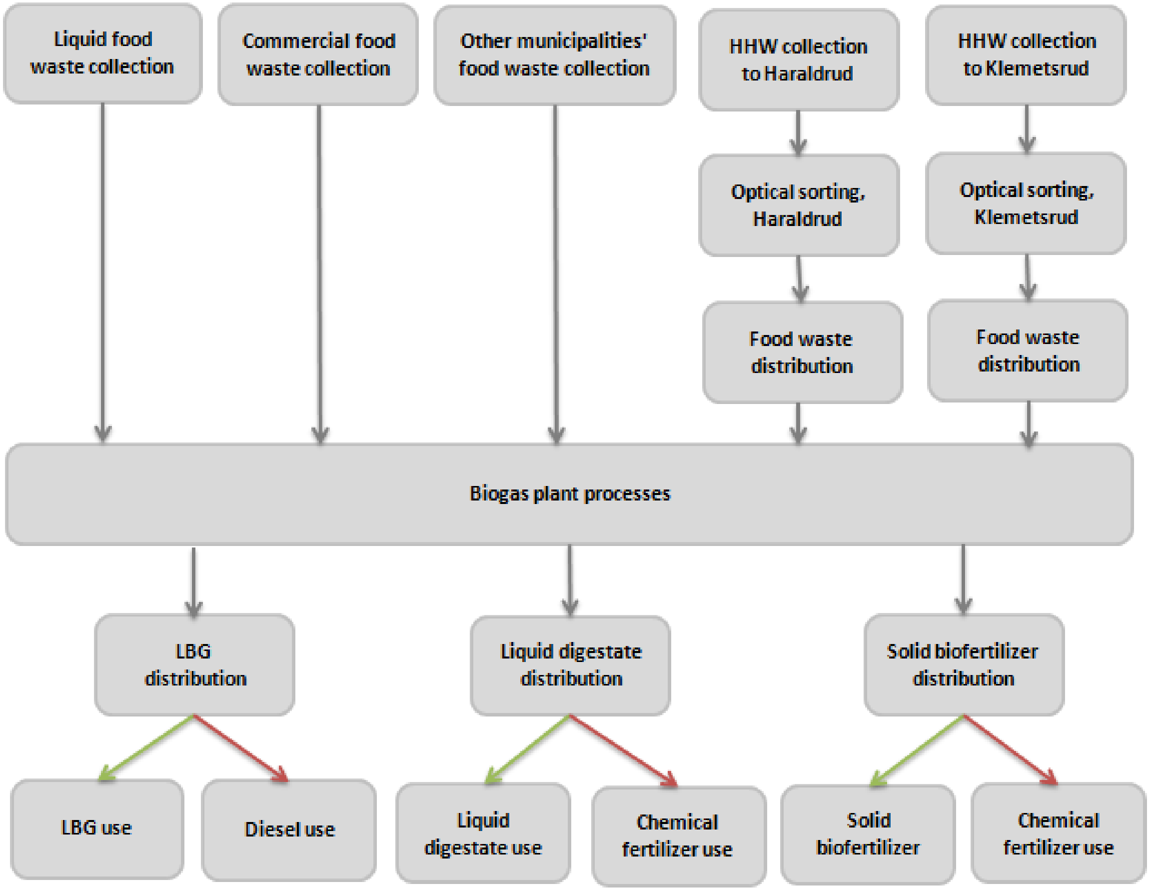

Figure 4-4 Sketch of the foreground system

Background system

The background data will be provided from the Swiss life cycle inventory (LCI) database called ecoinvent (version 2.2). Ecoinvent is a comprehensive database with several thousands of LCI datasets in different process areas. Data provided in ecoinvent are based on industrial data and internationally renowned research institutes and LCA consultants are responsible for compiling them (ecoinvent Centre).

Allocation

Many processes generate multiple outputs. Such processes can be distinguished by what type of by-product they produce (Strømman, 2010):

- **Exclusive byproducts:** products that cannot be produced separately elsewhere
- **Ordinary byproducts:** products are linked together in the process and it is not possible to produce one without producing the other. Each product can though be produced separately elsewhere.
- **Joint products:** products from processes where the process is designed to have multiple outputs

Allocation methods are used to assign the environmental burdens from the process to each of the products. It is also possible to use allocation on processes with multiple inputs. There are three main types of allocation approaches (Strømman, 2010; Sauer, 2012, p.57):

- **The disaggregation approach:** By collecting more detailed inventory for a process it can be possible to create separate inventory model for the different products. In practice the process is further divided into subprocesses until each process only has one product.
- **The substitution approach:** Also known as avoided product method or system expansion method. When using this approach the system boundaries are expanded by including more than one production technology. The part of the original technology producing the by-product(s) is substituted by one (or more) of the byproducts produced by an alternative technology. This product will then be credited with the avoided production of the other by-product(s) from the chosen alternative technology. When applying this approach caution must be taken since the choice of alternative technologies can have different effects on the results. It is then smart to conduct a sensitivity analysis with respect to the various technology alternatives.
- **The partitioning approach:** By choosing a chosen property a share of the environmental impacts is assigned to the different products. This property can be mass, exergy, energy or price dependent on the driving force of the multiple production. The chosen partitioning variable will be between zero and one.

According to the ISO 14044 the partitioning approach should be avoided if possible to use either the disaggregation or substitution approach. If it is not possible to avoid partitioning, the inputs and outputs should be allocated based on physical relationships. Usage of economical values is not desirable due to fluctuations in price of byproducts can change the results and conclusions of a study. (Sauer, 2012, p.57)

At RBA the electricity consumption for the optical sorting has to be allocated to the food waste. From Optibag there will be three outflows; plastic waste, food waste and residual waste. If Optibag had not been installed in the value chain, all the HHW would have been sent to incineration as is the case for the residual waste today. The allocation factor will be based on plastic and food waste flows since the purpose of Optibag is to sort out these flows. Impacts related to the electricity consumption of Optibag will then be allocated to the food waste by using the partitioning approach with mass as the chosen property (calculations for the allocation factor is found in Appendix A).

Avoided burdens

Calculation of climate impact from biogas production is of interest to evaluate to what extent the produced products, in this case biogas and organic biofertilizer products, replace other products. Therefore four cases, as mentioned under "System boundaries" in chapter 4.2.2, have been developed to differentiate the impacts. By evaluating case A towards the combination of case B-D it is possible to see the impacts related to the different use.

Differences in case A and the combination of case B-D will show the avoided burdens of the RBA value chain. At RBA the LBG will be used as fuel and will replace a share of the diesel consumption by buses and waste collection lorries in the Oslo area. The biofertilizer products will be used in agriculture and replace chemical fertilizer.

The avoided burden related to use of LBG as vehicle fuel contra diesel will be based on the distance possible to drive with the amount LBG produced at RBA. Data regarding transport of buses have been used to calculate the distance. For the biofertilizer products the avoided burden will be compared to chemical fertilizers. The amount of N in the products from RBA will give the need for chemical fertilizer.

Characterization method and impact categories

In this study the climate change impact category will have a focus.

The ReCiPe method will be used since this is based upon ISO 14040 and 14044. ReCiPe transforms the LCI results into a limited number of indicators scores which is helpful regarding the interpretation. The indicator scores give the relative severity on an environmental impact category. In ReCiPe the indicators are determined at two levels; midpoint and endpoint categories. The midpoint perspective has eighteen categories and the endpoint has three. Midpoint categories have lower uncertainties associated with them, but can be harder to interpret (ReCiPe). The midpoint categories are listed below in Table 4-1 together with their belonging characterization factor. In this study the midpoint categories will be used due to lower uncertainties as well as it gives a more complete picture of the environmental impacts from the system.

ReCiPe has three possible cultural perspectives; individualist, hierarchist and egalitarian. The individualist has a short term perspective with an optimistic view that technology can avoid many future problems. Heierarchist has the view of todays’ decision makers and can therefore be referred as a consensus model. The hierarchistic view is therefore often encountered in scientific models and used as a default model. A long term view with precautionary principle thinking is the principle of the egalitarian (ReCiPe). In this study the hierarchist point of view has been chosen.

Table 4-1 Midpoint categories in the ReCiPe characterization model (Goedkoop et al.,2013)

Impact category	Characterization factors	Abbreviation	Unit
Climate change	Global warming potential	GWP	kg CO2 eq
Ozone depletion	Ozone depletion potential	ODP	kg CFC-11 eq
Terrestrial acidification	Terrestrial acidification potential	TAP	kg SO2 eq
Freshwater eutrophication	Freshwater eutrophication potential	FEP	kg P eq
Marine eutrophication	Marine eutrophication potential	MEP	kg N eq
Human toxicity	Human toxicity potential	HTP	kg 1,4-DB eq
Photochemical oxidant formation	Photochemical oxidant formation potential	POFP	kg NMVOC
Particulate matter formation	Particulate matter formation potential	PMFP	kg PM10 eq
Terrestrial ecotoxicity	Terrestrial ecotoxicity potential	TETP	kg 1,4-DB eq
Freshwater ecotoxicity	Freshwater ecotoxicity potential	FETP	kg 1,4-DB eq
Marine ecotoxicity	Marine ecotoxicity potential	METP	kg 1,4-DB eq
Ionising radiation	Ionising radiation potential	IRP	kg U235 eq
Agricultural land occupation	Agricultural land occupation potential	ALOP	m2a
Urban land occupation	Urban land occupation potential	ULOP	m2a
Natural land transformation	Natural land transformation potential	NLTP	m2
Water depletion	Water depletion potential	WDP	m3
Metal depletion	Metal depletion potential	MDP	kg Fe eq
Fossil depletion	Fossil depletion potential	FDP	kg oil eq

Data requirements and quality

Data for the foreground processes are collected from the specific actors. Mass flows related to the Optibag plants at Haraldrud and Klemetsrud are provided from Oslo EGE for year 2013 and scaled to correlate to flows entering RBA. Data related to estimation of electricity consumption for Optibag are based on one of the lines at Klemetsrud in September 2013. The lines at Haraldrud and Klemetsrud are identical and the estimation of electricity consumption should therefore be valid for both of the plants.

Plant specific data for RBA have mainly been provided by Oslo EGE and collected for the period of October 2013 to May 2014. The plant has still some start-up problems and hence this period gave the best data regarding the desired operation of the plant. Previous data would not give any indications on how the plant is intended to operate. Since it was not possible to find the electricity demand for the different installations at RBA it was used electricity bills for the last quarter of 2013 and the first quarter of 2014 to estimate the total electricity consumption for the investigated period. The bills for April and May are not available jet. Therefore the consumption in the two quarters was divided by the number of days in the quarters and multiplied by the number of days in October to May. Estimation on electricity consumption regarding the liquefaction plant at RBA was provided by the supplier, Wärtsilä Oil & Gas, since this part has not been in operation jet.

Norsk Gjenvinning AS and RenoNorden Norge have provided the data related to transportation of HHW in the Oslo area. AGA AS is responsible for the distribution and sale of LBG and has provided data for transportation of LBG.

4.2.3 Inventory analysis

The inventory analysis is carried out through collection of data and calculations. Quantification of inputs, outputs and emissions for relevant activities within the system is carried out in this phase (Pålsson & Riise, 2011b). The data that are collected can be divided into two groups: foreground data and background data. The foreground data describe the part of the data that need high resolution and detailed data. In many cases this will include specific data from production processes from the owner or supplier. Dependent on the goal of the study the data can be collected from different data sources. The background data are connected to upstream processes in the value chain and less detail is required. Generic data in databases are often used for the background data.

4.2.4 Life cycle impact assessment

The purpose of this phase is to understand and evaluate the magnitude and significance of the potential environmental impact from the results in the inventory analysis (Heijungs, 2012, p.22). According to ISO the life cycle impact assessment (LCIA) is structured into a number of steps. In the following sections these steps are presented. To conduct a LCA in compliance with the ISO standard the three first stages are mandatory. There are although few LCA studies reporting the classification step. (Heijungs, 2012, p.26)

Selection of impact categories, category indicators and characterization models

As a first step of the LCIA the selection of the impact categories, corresponding indicators and characterization model are presented in connection with the definition of the study's goal and scope (Margni & Curran, 2012, p.70). The choice of characterization model will normally decide which impact categories that are chosen, since the characterization model often includes predefined selection and set-up of impact categories (Pålsson & Mattsson, 2011).

Classification

In the classification step the inventory data are assigned to the different impact categories. According to the environmental impact the inventory items have the potential to cause, they are assigned to the relevant category. Each entry of the LCI can belong to more than one impact category, and then each of these categories are assigned in its entirety (this is valid if it is not partitioned or allocated). (Margni & Curran, 2012, p.71)

Characterization

In this step the results for the category indicators are calculated by using the input and output flows from the inventory. By running every substance through a model its potential impact in the assigned impact category (categories) is calculated. A substance's potential impact is given relative to a dominant factor in the category. For Climate Change potential this factor is based on 1 kg of CO_2 emissions reported in units of CO_2-equivalents. To find the contribution from the emission of a specific substance to an impact category, the emission from the substrate is multiplied by a characterization factor. The total impact for the system in one category is found by adding up the contribution from each emission. (Margni & Curran, 2012, p.72)

Normalization

Sometimes the results from the inventory and impact categories can be difficult to interpret due to different units and magnitudes. By calculation of the magnitude of category indicator results relative to reference information the results get normalized. This contributes to a better understanding of the results. Normalization helps to analyse the relevance of individual contributions but also by relating them to different parts of the process. (Pålsson & Mattson, 2011)

Grouping

Grouping involves dividing the results from the characterization step into different categories or groups. This may give a clearer overview of the environmental impact. After being grouped the emissions are sorted on a normal basis (input vs. output, global vs. local) and can also be ranked by a given hierarchy according to priority. It is important to remember that the ranking is based on value choices and may therefore result in different ranking results for studies based on the same indicator results. (Pålsson & Mattson, 2011)

Weighting

Weighting is done by conversion and possibly aggregation of indicator results across impact categories by using numerical factors. These factors are based on value choices and data prior to weighting should remain available (Margni & Curran, 2012, p.73). Since these factors are not scientifically based and the weighting method only describe an answer based on the method's assumptions and system boundaries this step will introduce a lot of uncertainties. Weighting should therefore only be used when it is necessary for the interpretation of the inventory data. (Pålsson & Mattsson, 2011)

4.2.5 Interpretation

As a last step of a LCA the findings of the inventory analysis or the impact assessment, or both, are evaluated towards the goal and scope to be able to draw conclusions and recommendations. Identification of the most important environmental issues and alternatives of how to possible reduce the impacts investigated should be included in the interpretation. To ensure good results it can be beneficial to conduct an uncertainty or sensitivity analysis on the data. (Heijungs, 2012, p. 27-28)

4.3 Sensitivity analysis

A sensitivity analysis has the purpose to investigate how assumptions and input values of model variables and parameters will change the results and affect the conclusions of the study. In the sensitivity analysis changes in process data, model choices and other variables are deliberately changed in order to determine the robustness of the results.

One common method of doing sensitivity analysis is by using model variation where an input value of a parameter is changed one at a time. Each time an input value is changed the others are fixed. Model variation will be used for both the MFA and LCA models.

4.3.1 MFA model

For the investigation of the sensitivity of the MFA model it has been decided to choose only some of the parameters in the model. Many parameters as lower heating values (LHV), PE content, fuel consumption etc. are more or less decided for the given case. Values that have been changed are DM contents, transport distances and volume and mass of LBG. DM contents were changed by +/- 15% and distances were increased by 50%. Due to uncertainties in the actual volume of CBG produced at RBA the sold volume of CBG has been treated as it was LBG. Sold amount is not equal as the produced amount and therefore it was of interest to change this parameter. The transformation from gas volume to mass was calculated using ideal gas law. Due to uncertainties by using this method for calculation of mass it was of interest to investigate the impact of this parameter. These parameters were changed by +/- 15%.

4.3.2 LCA model

The sensitivity analysis of the LCA method was conducted to only investigate parameters related to transport distances and how they affect GWP. GWP was chosen to be investigated since it was the category with the highest impact as well as it is a topic of high current interest. The LCA method was built up by processes were the main demand connected to ecoinvent data were transport related. Data provided for distances were rough estimates and hence of interest to be investigated. Parameters investigated were only relevant for the RBA value chain, case A.

5 Results

This chapter presents the results found from the MFA and LCA model.

5.1 MFA modelling

5.1.1 Quantification of flows

As a third stage in the MFA the determination of all the flows and stocks in the system is found through mass balance and model approach equations. This is not done for the system defined here due to the lack of detailed information. Dependent on the complexity the processes that are defined are dependent on the goals of the study. Each process can be subdivided into subprocesses or merged into a single process. An example of subdividing is process 6 in Figure 5-1 and Figure 5-3 which was planned to have eight subprocesses to illustrate the main processes at RBA. Subprocess 6.1 in Figure 5-2 and Figure 5-4 is only one of several processes where processes belonging to this process is merged together to simplify the system.

Figure 5-1 to Figure 5-4 show the planned MFA system with the processes and flows that were wanted to be found.

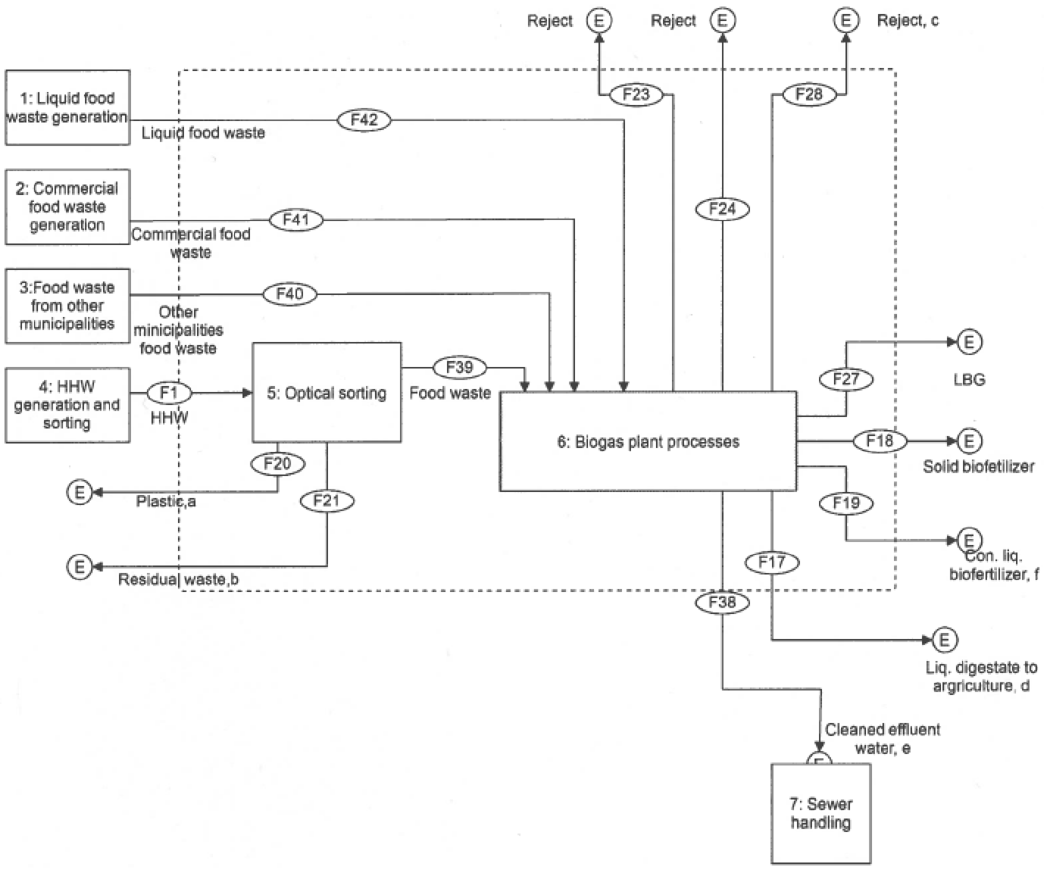

Figure 5-1 RBA system with DM flows

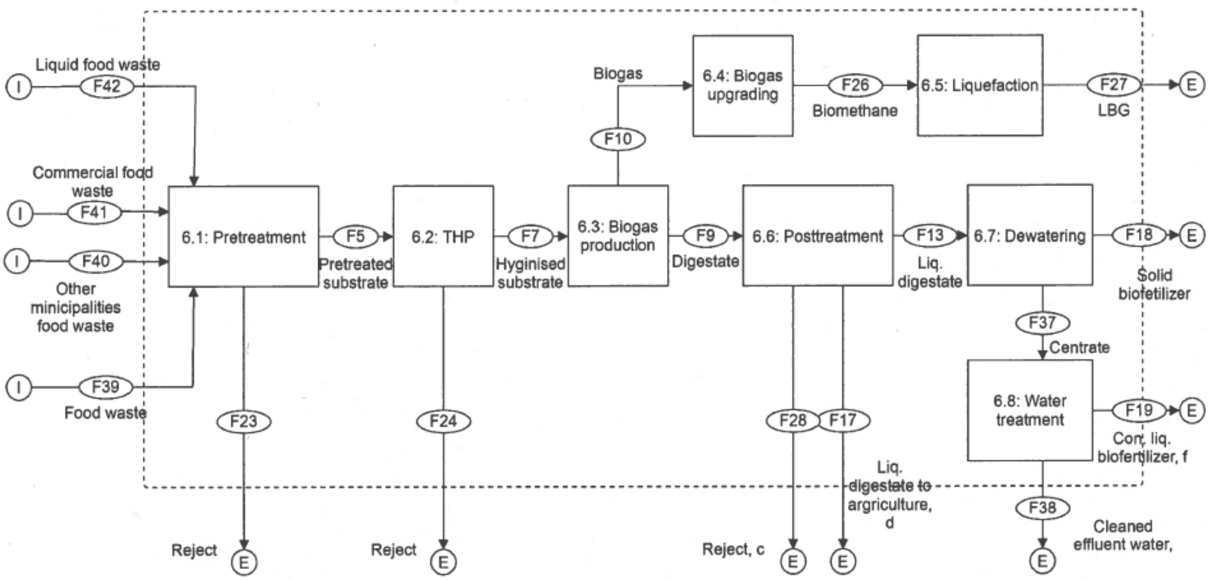

Figure 5-2 RBA subsystem with DM flows

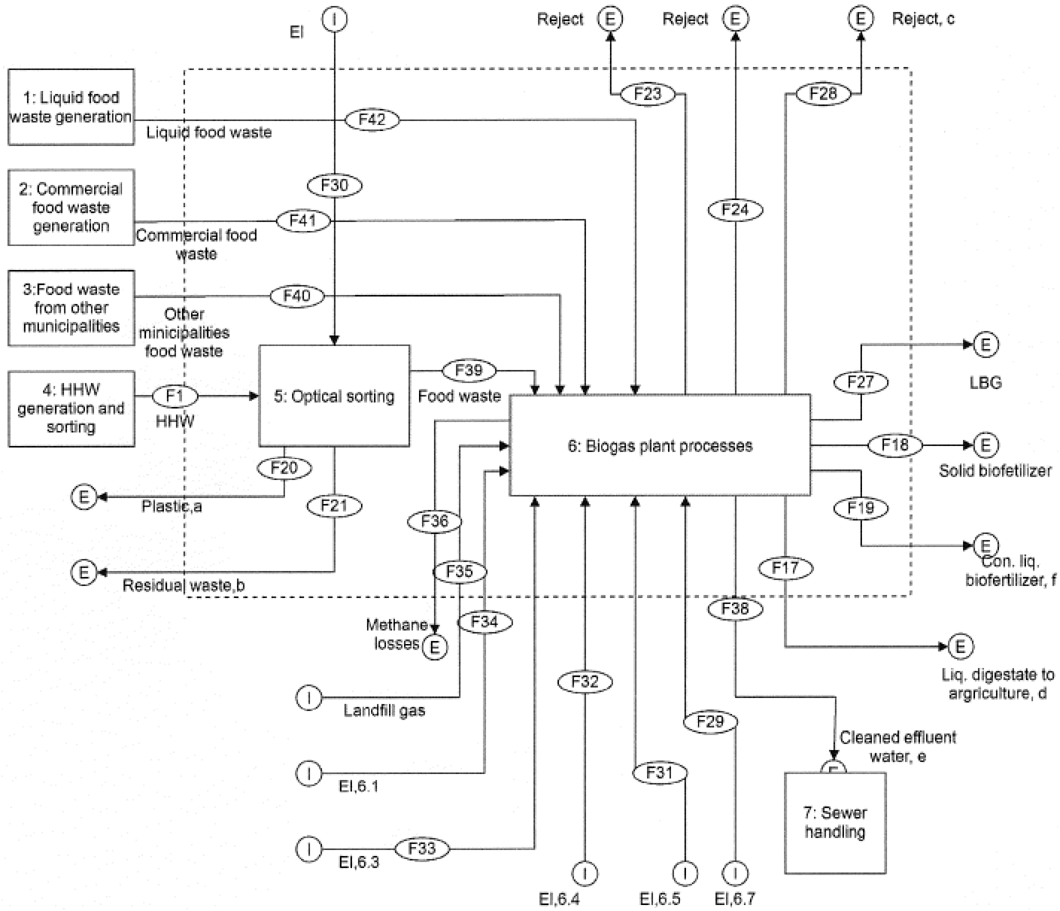

Figure 5-3 RBA system with energy flows

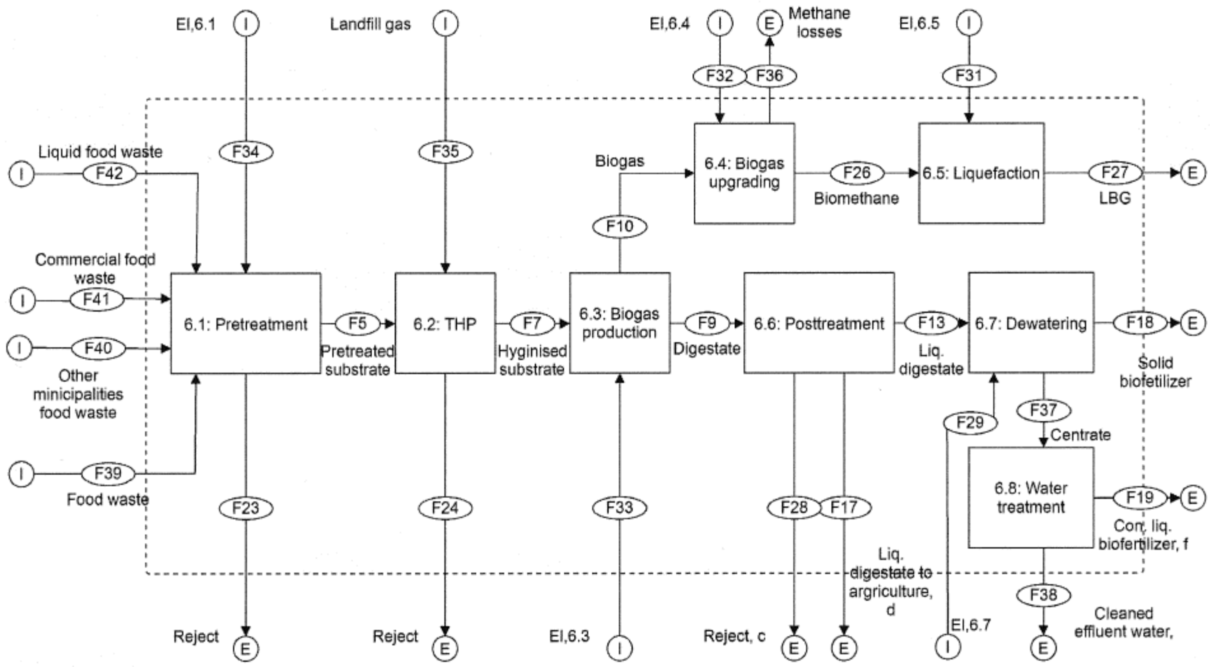

Figure 5-4 RBA subsystem with energy flows

Table 5-1 shows the quantified mass and DM flows necessary for finding the resource efficiency of the RBA value chain. Data and calculations for these flows are found in Appendix A.

Table 5-1 Mass and DM flows

Flow description	Mass flow	Value (ton/period)	DM flow	Value (ton DM/period)
Liquid food waste	X_1,6.1	147	DM_1,6.1	22
Commercial food waste	X_2,6.1	422	DM_2,6.1	127
Other municipalities food waste	X_3,6.1	390	DM_3,6.1	117
Household waste from Oslo area	X_4,5	83 640	DM_4,5	10 689
Plastic	X_5,0a	1 778	DM_5,0a	-
Residual waste	X_5,0b	73 038	DM_5,0b	8 042
Food waste	X_5,6.1	8 824	DM_5,6.1	2 647
LBG	X_6.5,0	85	DM_6.5,0	
Liquid digestate to agriculture	X_6.6,0d	120	DM_6.6,0d	3,2
Solid biofertilizer	X_6.7,0	1 519	DM_6.7,0	380

The table above, Table 5-1, shows that the second largest mass and DM flow within the system exits the system as residual waste. This flow is sent to incineration for energy recovery. Seen from this systems point of view the DM flow is a loss of material that could be used to produce biogas and biofertilizer products.

To quantify the N and P flows the N and P content in the DM flows have to be known. Table 5-2 gives the data used to calculate the N and P flows.

Table 5-2 N and P content in substrate and products

Item	Waste flows [1]	Liquid digestate to agriculture [2]	Solid biofertilizer [2]
Total N [mg/kg DM]	8 933	105 000	66 300
Total P [% of DM]	0.52	0.979	1.16

[1] Analysis evidence, food waste March 2013, received from K.A Sølvernes (8 December, 2013)
[2] Analysis evidence from November 2014 received from E. Govasmark (13 June, 2014)

Data provided in Table 5-2 and calculations found in Appendix A resulted in the N and P flows presented in Table 5-3.

Table 5-3 N and P flows

Flow description	N flow	Value (ton N/period)	P flow	Value (ton P/period)
Liquid food waste	N_1,6.1	0.196	P_1,6.1	0.114
Commercial food waste	N_2,6.1	1.131	P_2,6.1	0.658
Other municipalities' food waste	N_3,6.1	1.045	P_3,6.1	0.608
Household waste from Oslo area	N_4,5	95	P_4,5	55.58
Food waste	N_5,6.1	24	P_5,6.1	13.77
Liquid digestate to agriculture	N_6.6,0d	0.34	P_6.6,0d	0.032
Solid biofertilizer	N_6.7,0	25.18	P_6.7,0	4.4

As seen in Table 5-3 the largest N and P flows correspond to the largest mass flow in the system, the HHW flow. The second and third largest flows are related to the food waste and the solid biofertilizer. Both of these flows have high DM content as well as they are the second and third largest flows not leaving the system if not as a product.

Energy content in the flows and energy needed for the operation of processes are presented in respectively Table 5-4 and Table 5-5.

Table 5-4 Values for LHV and PE used for calculations

Parameter		Value	Unit
LHV food waste	[1]	13.8	MJ/kg DM
LHV LBG	[2]	9.97	kWh/Nm3
PE for biogas consumed	[3]	1.8	MJ/tkm
PE per diesel consumed	[4]	4.785	MJ/l
PE for electricity consumed	[4]	4.5	MJ/kWh el

[1] Value based on Hung & Solli (2011)
[2] Value based on Swedish Gas Center (2007)
[3] Ordinary energy consumption for transport work from the ecoinvent database provided Norwegian electricity mix
[4] Value from the ecoinvent database provided Norwegian electricity mix

Table 5-5 Operation energy for processes

Process		Value	Unit
Optical sorting	[1]	9.34	kWh/ton
Electricity for biogas plant without liquefaction	[2]	2 767 028	kWh/period
Liquefaction	[3]	0.95	kWh/kg LBG

[1] Value based on electricity for process as well as ventilation, lighting etc. with a load factor of 0.5. Estimation provided by P. Thorbeck (19 June, 2014)
[2] Estimate based on electricity bills from RBA for the last and first quarter of respectively 2013 and 2014
[3] Electricity demand for the total liquefaction plant. Data provided by A. Jakobsen (personal communication, 25 April, 2014)

The quantified energy flows are shown in Table 5-6. Calculations are found in Appendix A.

Table 5-6 Energy flows

Flow description	Energy flow	Tot PE (MJ/period)
Liquid food waste	E_1,6.1	303 545
Commercial food waste	E_2,6.1	1 747 080
Other municipalities food waste	E_3,6.1	1 614 103
Household waste from Oslo area	E_4,5	147 505 136
LBG	E_6.5,0	4 228 078
Transport of liquid food waste	E_t-1,6.1	947
Transport of commercial food waste	E_t-2.6.1	2 726
Transport of others municipalities food waste	E_t-3.6.2	8 395
Transport of household waste from Oslo area	E_t-4,5	4 516 581
Transport of food waste from Haraldrud	E_t-5,6.1 (H)	31 367
Transport of food waste from Klemetsrud	E_t-5,6.1 (K)	19 361
Transport of LBG	E_t-6.5,0	498
Transport of liquid digestate to agriculture	E_t-6.6,0d	452
Transport of solid biofertilizer	E_t-6.7,0	5 723
Electricity for optical sorting	E_p5,el	2 928 941
Electricity for the RBA plant	E_p6,el	12 461 588
Electricity for upgrading at RBA	E_p6.5,el	362 581

As seen in Table 5-6 the majority of the energy inputs to the value chain are from substrates. The substrates stands for about 88% of the PE put into the value chain. If the energy in the substrates are disregarded, the largest energy inputs are electricity for the RBA plant, electricity for optical sorting and as fuel for transport of HHW. When not including the substrate energy the electricity to RBA stands for about 61% of the energy input to the value chain. Transport of HHW and electricity to optical sorting stands for respectively about 22% and 14%. Both of these energy flows are linked to the biggest mass flow within the system.

5.1.2 Quantification of the resource efficiency performance

Based on the flows presented in Table 5-1, Table 5-3 and Table 5-6 and calculations found in Appendix A the resource efficiency performance of the system was found by detecting the indicator values. Table 5-7 gives the indicator values for the resource efficiency performance for the RBA value chain.

Table 5-7 Resource efficiency performances

Item	MRR	NRR		η		
		NR	PR	sold	estimated	scaled
Efficiency (%)	3.6	26.1	7.8	2.5	26.1	18.3

For the energy efficiency it was decided to calculate thee different indicator values. This was done since it was made aware of that the sold amount of upgraded gas from RBA, which was received data for, was not equal to the amount produced. Therefore it was calculated values responding to the biogas yield found in literature for the amount entering RBA in the period (denoted “estimated” in Table 2-1) and where the biogas produces at full capacity was scaled down to the present amount of waste entering RBA (denoted “scaled” in Table 5-7). These efficiencies were found by using the same equations as for the sold amount, but by changing the parameter to respectively estimated and scaled volumes. For equations and calculations of these gas volumes the reader is referred to Appendix A.

5.2 LCA modelling

5.2.1 Inventory analysis

For the LCA study four cases have been evaluated. In Table 5-8 the LCI for the defined processes are presented and in the following sections the processes within the different cases are described.

Table 5-8 Overview of the LCI data for the defined processes

Case	Process	Value	Unit	ecoinvent data
A	Liquid food waste collection	8 798	tkm	Transport, lorry 16-32t, EURO5/RER U
	Commercial food waste collection	25 320	tkm	Transport, lorry 16-32t, EURO5/RER U
	Other minicipalities' food waste collection	27 292	tkm	Transport, lorry 7.5-16t, EURO5/RER U
	Household waste collection to Haraldrud	1 626 124	tkm	Transport, lorry 3.5-7.5t, EURO5/RER U
	Household waste collection to Klemetsrud	883 088	tkm	Transport, lorry 3.5-7.5t, EURO5/RER U
	Optical sorting, Haraldrud	421 470	MJ	Electricity, high voltage, production NO, at grid/NO U
	Optical sorting, Klemetsrud	228 885	MJ	Electricity, high voltage, production NO, at grid/NO U
	Food waste distriibution from Haraldrud	291 350	tkm	Transport, lorry 16-32t, EURO5/RER U
	Food waste distribution from Klemetsrud	179 833	tkm	Transport, lorry 16-32t, EURO5/RER U
	Biogas plant processes	10 251 134	MJ	Electricity, high voltage, production NO, at grid/NO U
	LBG distribution	5 085	tkm	Transport, lorry 16-32t, EURO5/RER U
	Liquid digestate distribution	4 200	tkm	Transport, lorry 16-32t, EURO5/RER U
	Solid biofertilizer distribution	53 160	tkm	Transport, lorry 16-32t, EURO5/RER U
B	Diesel use	18 639 241	pkm	Transport, regular bus/CH U
C	Chemical fertilizer use (replacing liquid digestate)	340	kg N	Ammonium nitrate phosphate, as N, at regional storehouse/RER U
		142	tkm	Transport, lorry 3.5-7.5t, EURO5/RER U
D	Chemical fertilizer use (replacing solid biofertilizer)	25 175	kg N	Ammonium nitrate phosphate, as N, at regional storehouse/RER U
		10 490	tkm	Transport, lorry 16-32t, EURO5/RER U

Values provided in Table 5-8 are based on calculations done by using equations found in Appendix B.2 (excluding the emissions factors from the equations).

Case A

Liquid food waste collection

The main share of liquid food waste is collected by tankers using diesel in the Oslo area and transported to RBA. A distance of 60 km is assumed. Transportation data used from the ecoinvent database have been chosen to best correspond to the load assumed in the MFA model.

Commercial food waste collection

As for the liquid food waste also the main share of the commercial food waste will be collected in the Oslo area. Hence the same transport distance and transportation data from ecoinvent as for the liquid waste collection have been chosen for this process.

Other municipalities' food waste collection

For this process it has not been received special information for the actual areas of collection, hence a distance of 70 km has been chosen. Due to information received for the HHW collection in the Oslo area it is reasonable to assume that collection in others municipalities has similar loads of their lorries. Since the majority of the lorries in Oslo have loads of 9.2 ton it has been assumed a load in the range of 7.5-16 ton for this process.

Household waste collection

In Oslo there are two companies responsible for the collection of HHW, Norsk Gjenvinning AS and RenoNorden Norge. Both companies use biomethane as fuel in their collection vehicles. When contacting these companies it was made apparent that there were lacks regarding the data collection of the consumption of biogas used for transportation. RenoNorden did not have any satisfactory method to calculate the fuel consumption on their vehicles at present. They are now working on finding a method that will provide them with more accurate data for fuel consumption (B.E. Bakken, personal communication, 19 December, 2013). A number of different collection vehicles are used by the two companies. They vary in load and function, which will affect the fuel consumption. Norsk Gjenvinning AS reported that they had vehicles with loads of 6.2 ton, 6.8 ton and 9.2 ton. At present there is no documentation on how much the different vehicles are used during a year. 15 of 25 of their vehicles had a loading capacity of 9.2 ton (S.E. Johnsen, personal communication, 19 December, 2013). Therefore a mean transport distance for the collection routes of 30 km per load has been chosen based on the provided information from the two companies.

To have as close a compliance with the actual situation and the data provided in ecoinvent it has been chosen to use Euro 5 diesel for lorry with a load of 3.5-7.5 ton. There are no available data for transportation using biomethane in ecoinvent. Euro 5 has therefore been selected since this is evaluated as the cleanest of the diesel fuels available in ecoinvent. A load range that lies under the majority of lorries used by Norsk Gjennvinning AS has been chosen to contribute to a lower fuel consumption and hence compensates for that a more pollutant fuel is used in the analysis.

Optical sorting

Optibag plants are installed to sort the HHW at the waste-to-energy facilities at Haraldrud and Klemetsrud. Heat and detergents used at the facilities are not relevant for the chosen value chain since these would be needed regardless of the Optibag plants. The only relevant consumptions are electricity and oil for motors running Optibag. Due to difficulty in estimating oil consumption and assumed to have little influence in the overall picture this is neglected.

For estimation of specific electricity consumption for Optibag one line at Klemetsrud for September 2013 was used for calculations. Since the lines at Klemetsrud and Haraldsrud are identical this estimation will apply for both of the plants. Valid assumptions regarding the electricity consumption for the process itself and electricity for ventilation, lighting and other electricity for the building were provided by Petter Thorbeck from Mepex Consult AS serving as a project leader at EGE (personal communication, 19 June, 2014). Operational data at Klemetsrud were provided by Knut Erik Ramstad, operation manager at Haraldrud and Klemetsrud in Oslo EGE (personal communication, 13 January, 2014). Data and calculation are found in Appendix A. The electricity demand has been allocated to the food waste by applying the same allocation factor as used in the MFA (Appendix A). In addition to the electricity demand for the process itself, it has been chosen to include ventilation, lighting and other electricity for the building. This is done to correspond to the data received for electricity consumption at RBA.

Food waste distribution, Haraldrud and Klemetsrud

Transportation lengths of food waste from Haraldrud and Klemetsrud to RBA are estimated to be respectively 50 km and 60 km (estimated from gulesider.no). The lorries in operation are using diesel as fuel and are transporting containers with a load of approximately 20 tons (personal communication, K.A Sølvernes, 11 December, 2013).

Biogas plant processes

Due to not have received adequate operational data from RBA within the time limit it was not possible to estimate the electricity consumption for the different parts of the plant. Therefore the total electricity consumption of the plant for the period has been used and the estimated electricity for liquefying the period’s biogas has been added. It was desirable to open the “black box” of biogas plant processes and define eight processes within the process “Biogas plant processes”, as illustrated in Figure 5-1 and Figure 5-2. Appendix D shows the received operational data from RBA and Appendix C shows the estimated electricity consumption for the different installations at full capacity. Data in Appendix C were estimated by Knut Johnson working at RBA when the author visited the plant. Many of these installations were estimated to run continuously throughout the year. Then these data could be used to find the effect for different parts of the plant. The effect multiplied by actual operational time would then estimate the electricity demand for the different parts of the plant.

In the following bullet points the desired subprocesses of the biogas plant are described:

- **Pretreatment:**
  The pretreatment process would consist of several steps as described in chapter 3.1. Electricity and oil for motors would have been the demand for this process. The oil consumption would have been neglected based on the same assumptions mentioned in this chapter under "Optical sorting". Installations that would have been included in the calculation of the total electricity demand for this process are found in Appendix C.
- **THP:**
  The THP process defined for the purpose of this study would have included what Cambi refers to as the "boiler supplier scope". The "boiler supplier scope" includes water softening, feed water preheating tank, burner, boiler and boiler feedwater tank. By including the "boiler supplier scope" in the THP process it would have simplified the system. The "boiler supplier scope" is mainly used to create steam from landfill gas used in the THP. Some of the steam is also used in the dewatering process. This process would have a demand for landfill gas, softening agents and ion exchangers for desalination. At RBA they have a low consumption of softening agents and ion exchangers (personal communication, E. Govasmark, 28. April, 2014) and hence this demand would probably be neglected if proven that the type of agents had low environmental impacts.
- **Biogas production:**
  Mechanisms that involve the digesters would be included in this process. This involves among others cooling and filtration systems for the digesters. Appendix C provides an overview of installations that would be included in the electricity consumption for this process. To avoid/limit foaming in the digesters a defoamer is consumed. The consumption of defoamer is used by necessity and it has been shown difficult to give a good estimate on the consumption. The type(s) of defoamer agent(s) was not provided. Since both the defoamer agent and the consumption were unknown this demand would have been neglected.
- **Biogas upgrading:**
  The water scrubber technology, described in chapter 3.3, would be included in this process. Due to poor operational data from RBA on this part of the plant the electricity consumption would have to be estimated by data found in the literature at the current situation. Emissions related to this process are the CO_2 removed and methane slip from the water scrubber. The methane slip is estimated to be below 1% of the methane content of the gas going through the upgrading technology.
- **Liquefaction:**
  Liquefaction would include the mechanisms which result in a CH_4 concentration of 99.7% and that the gas is in a liquid form. This implies among others the gas polishing

and the cryogenic cooling. An estimate of 0.95 kWh/kg LBG provided from supplier Wärtsilä Oli & Gas would be used for the electricity consumption in this process (A. Jakobsen, personal communication, 25 April, 2014). The value is an estimate on the entire plant delivered by Wärtsilä. This implies the gas polishing, the cryogenic cooling as well as electricity for pumps, fans etc.

Other consumptions in this process are oils for motors and refrigerants for the gas cooling. These consumptions would be neglected in this study due to difficulty in data collection and estimated low consumption from the supplier. Wärtsilä has so far not recorded any leakages on their plants (A. Jakobsen, personal communication, 25 April, 2014). This implies no need for refilling of refrigerant and hence the assumption of a low consumption.

Emissions from this process will be CO_2 removed by the CO_2 polishing. No methane is assumed to be lost in this process (A. Jakobsen, personal communication, April 25, 2014).

- **Posttreatment**
  Posttreatment would include mechanisms that involve the liquid digestate. Appendix C views what the total electricity demand for this process would be composed of.
- **Dewatering:**
  As mentioned in chapter 3.2 the dewatering process occurs by first polymerize the digestate and then separation by a decanter centrifuge. This provides a need for electricity and polymers. Appendix C shows what would be included in the electricity demand. Common polymer consumption is between 7-12 kg/ton DM. At RBA they have managed to lower this consumption, but it has not been clarified which polymers agents they are using and the consumption.
- **Water treatment:**
  This process involves the reject water treatment where acid is added as well as the evaporator used to increase the DM content. Which installations that would be included for the estimation of the electricity demand of this process is found in Appendix C.

LBG distribution

LBG produced at RBA will be transported to gas stations in the Oslo area. A transport route of 60 km has been estimated based on the distance from RBA to the city centre of Oslo (Aker Brygge used for distance estimation in gulesider.no). Lorries with a load of 22 ton, driven on Euro 6 diesel with a consumption of about 0.45 l/km is used for transportation of LBG. (J. Melby, personal communication, 17 December, 2013). Due to lack of time demands in the foreground system has had to be directly linked to the ecoinvent database.

Liquid digestate distribution

Distribution of liquid digestate is done by tankers driven on diesel. Customers within a distance of 25-50 km from RBA are desired. At the present situation this ambition is reached (personal communication, E. Govasmark, 28 April, 2014). For the calculations it has been used a distance of 35 km.

Solid biofertilizer distribution

Transportation of solid biofertilizer is done by lorries transporting containers. The lorries use diesel as fuel and have a load of approximately 20 tons (personal communication, K.A Sølvernes, 11 December, 2013). Customers are wanted within a 25-50 km radius. In this study a distance of 35 km has been chosen.

LBG use

To be able to relate environmental impacts to diesel as fuel compared to LBG it was necessary to find out how far it is possible to drive on the amount sold form RBA in the given period. Hetland & Bjørlykke (2012) assumed a gas consumption of 0.6 Sm^3/km in buses. The total distance possible to drive with the produced amount from RBA was found to be about 207 103 km (see Appendix B.2 for calculations).

Emissions related to use of LBG as vehicle fuel will not be included in this study since biogenic emissions have been excluded. Due to this there are no calculations for emissions of this process.

Liquid digestate use

The total N in this product gives the basis of how much liquid digestate that can replace chemical fertilizer products. Based on calculations done in the MFA (Appendix A) it was found that an amount of 340 kg N came from this product. Emissions to the use of this product have been excluded since it is biogenic.

Solid biofertilizer use

To be able to look at the avoided burden from this product it has been assumed that it replaces chemical fertilizer as well. From the MFA it was found that 25.18 ton N had to be replaced with chemical fertilizer. As for the other products produced at RBA the emission related to the use is considered as biogenic and hence excluded.

Case B

Diesel use

The diesel consumption in this case is the amount needed to travel the same distance, about 207 103 km, possible on the sold amount LBG from RBA. For the LCI it has been used a capacity of 90 persons in buses retrieved from Unibuss (2014). Then it is assumed that the bus is full.

Case C

Chemical fertilizer use (replacing liquid digestate)

Data for ammonium nitrate phosphate in ecoinvent are used as chemical fertilizer for this study. This fertilizer was just encountered to regional storage so the need of transport of the chemical fertilizer to where it is used had to be included. For the fertilizer it was reported an N content of 8.4% used to find the necessary amount of 4.05 ton of fertilizer to be transported (calculations found in Appendix B.2). It was assumed a transport distance of 35 km since this is the transport distance used for the biofertilizer products from RBA. Due to the low quantum needed to be transported for this case, a lorry with load of 3.5-7.5 ton was assumed.

Case D

Chemical fertilizer use (replacing solid biofertilizer)

It was used the same chemical fertilizer and transport distance as case C. For this case an amount of 299.76 ton of chemical fertilizer had to be transported (calculations found in Appendix B.2)

5.2.2 Life cycle impact assessment

The software Arda, developed at the Norwegian University of Science and technology (NTNU), was intended to be used to conduct the LCA part of this study. In Arda the collected life cycle inventory is plotted into a template. By uploading the template to the software the inventory is linked to the ecoinvent database and the ReCiPe Hierarchy method. Results are produced according to choices made by the analyst.

The model that was defined for case A in Arda created results that were way too large. The error in the model was not detected and the author had to do the calculations manually. Emission factors and equations for calculations are found in Appendix B.1 and B.2.

In Figure 5-5 the respective contributions to the different impact categories from the different processes in case A are shown.

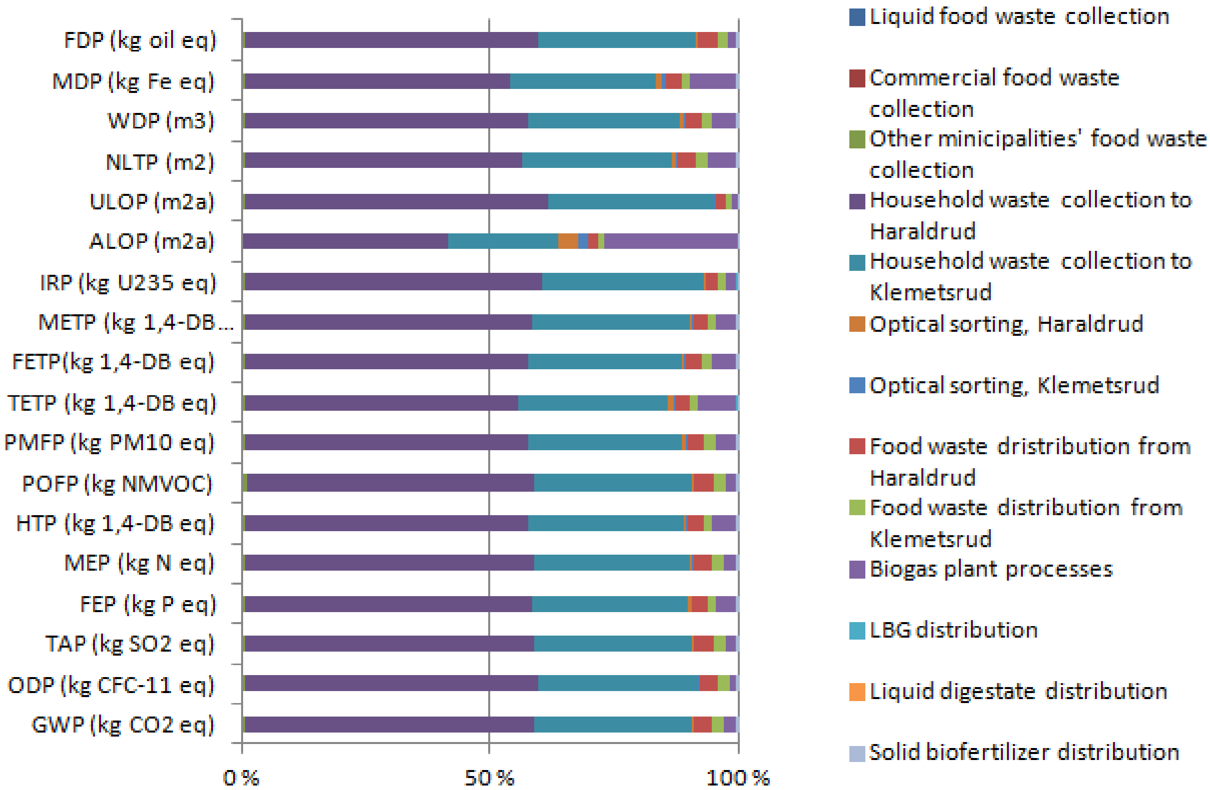

Figure 5-5 Contributions from the processes in case A to the different impact categories

As illustrated in Figure 5-5 the collection of HHW to Haraldrud and Klemetsrud contributes the most to all of the impact categories. In all of the impact categories, except ALOP, these two processes constitute to over 80% of the total impacts.

The total impacts for case A-D are shown in Table 5-9. GWP, FDP and HTP are the categories with the highest impacts for all of the cases. By not being able to conduct a structural path analysis in Arda it has not been detected the factors that are significant for this outcome. Due to the limitations of this model it has been chosen to emphasize on GWP in this study.

Table 5-9 Total impacts for case A-D when using the volume for sold amount of biogas

Impact	Case A	Case B	Case C	Case D
GWP (kg CO2 eq)	1 325 994	1 937 218	1 858	134 314
ODP (kg CFC-11 eq)	0.20	0.33	0.00	0.02
TAP (kg SO2 eq)	3 813	12 457	14	998
FEP (kg P eq)	149	113	0,6	42
MEP (kg N eq)	195.1	777.2	0,8	59.2
HTP (kg 1,4-DB eq)	198 606	151 984	641	46 896
POFP (kg NMVOC)	5 535	22 010	17	1 249
PMFP (kg PM10 eq)	1 862	5 483	6	442
TETP (kg 1,4-DB eq)	330	215	0,2	15
FETP(kg 1,4-DB eq)	4 023	3 307	11	811
METP (kg 1,4-DB eq)	5 379	3 692	13	940
IRP (kg U235 eq)	194 437	185 155	354	25 613
ALOP (m2a)	9 448	3 427	35	2 567
ULOP (m2a)	28 358	16 024	10	679
NLTP (m2)	497	701	1	41
WDP (m3)	5 539	6 019	7	473
MDP (kg Fe eq)	75 977	51 985	161	11 722
FDP (kg oil eq)	450 587	654 323	700	50 683

To evaluate the benefits of the RBA value chain compared to the alternatives the impacts from case A has to be compared to the sum of cases B-D. If RBA had not been producing their products, the impacts found from cases B-D would have been the reality. In Figure 5-6 the GWP impacts from the two applications options are presented.

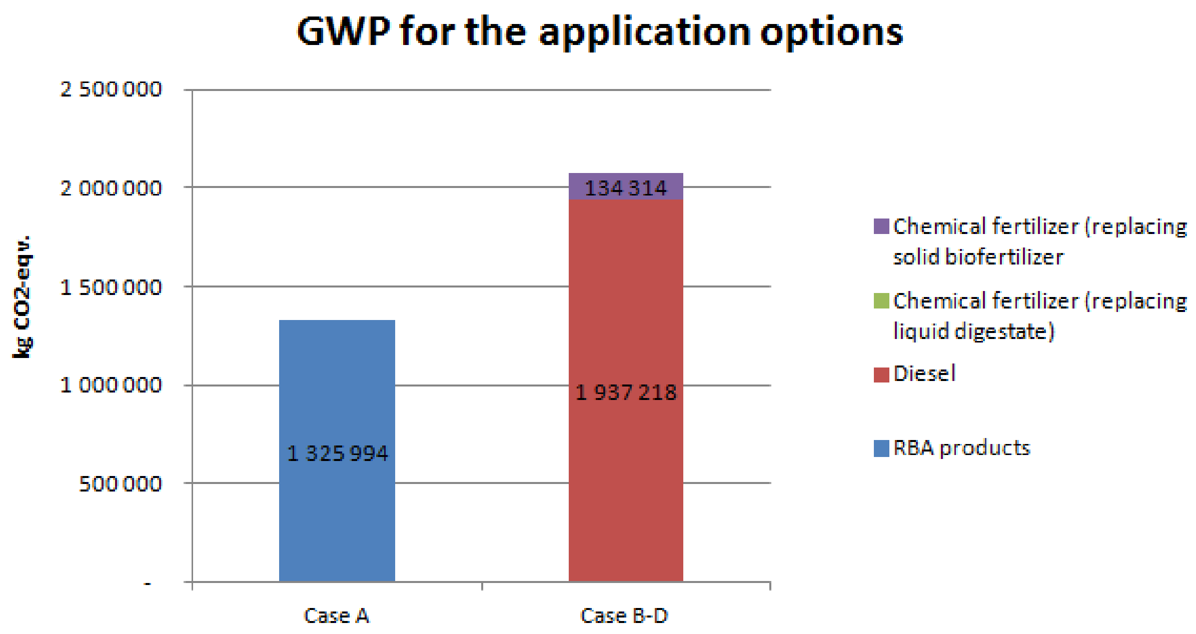

Figure 5-6 Impact of GWP for the two application options

The difference between the two bars in Figure 5-6 illustrates the avoided burdens by introducing the RBA value chain. The avoided burden was found to be about 747 396 kg CO_2-eq.

The results presented above are based on calculations done with the sold amount of CBG for the period. Since it was stated that the produced amount was larger than the sold amount, the impacts related to an estimated volume (found by using V_e in the calculations) was found to provide a better basis for comparison with results found in the literature. Table 5-10 shows the impact results when calculations are done with the estimated volume.

Table 5-10 Total impacts for case A-D when using the estimated biogas volume

Impact	Case A	Case B	Case C	Case D
GWP (kg CO2 eq)	1 343 041	20 913 979	1 858	134 314
ODP (kg CFC-11 eq)	0,20	3,56	0,00	0,02
TAP (kg SO2 eq)	3 859	134 484	14	998
FEP (kg P eq)	151	1 224	0,6	42
MEP (kg N eq)	197,6	8 390,8	0,8	59,2
HTP (kg 1,4-DB eq)	202 266	1 640 799	641	46 896
POFP (kg NMVOC)	5 599	237 621	17	1 249
PMFP (kg PM10 eq)	1 894	59 198	6	442
TETP (kg 1,4-DB eq)	339	2 324	0,2	15
FETP(kg 1,4-DB eq)	4 100	35 706	11	811
METP (kg 1,4-DB eq)	5 464	39 854	13	940
IRP (kg U235 eq)	196 441	1 998 910	354	25 613
ALOP (m2a)	10 175	36 996	35	2 567
ULOP (m2a)	28 543	172 995	10	679
NLTP (m2)	507	7 564	1	41
WDP (m3)	5 642	64 983	7	473
MDP (kg Fe eq)	78 287	561 221	161	11 722
FDP (kg oil eq)	455 163	7 063 997	700	50 683

By comparing the GWP values provided for case A in Table 5-9 with Table 5-10 the impact increased by about 1.3% when using estimated volume instead of sold volume. Estimated gas volume was almost 23.5 times larger than the sold amount. For case B the impact increased with almost 9.8% when the volume was increased.

5.3 Sensitivity analysis

The results of the sensitivity analysis of the MFA and LCA model are presented in this chapter.

5.3.1 MFA model

In Table 5-11 the sensitivity analysis of the MFA model is shown. As mentioned in chapter 4.3.1 not all the parameters were evaluated in the sensitivity analysis.

Table 5-11 Sensitivity analysis of the MFA model

Input variables	Unit	Initial value	% change initial value	% change in result			
				MRR	NR	PR	η
DM in liquid food waste	-	15 %	15 %	-0,030 %	-0,030 %	-0,030 %	-0,027 %
	-	15 %	-15 %	0,030 %	0,030 %	0,030 %	0,027 %
DM in commercial food waste	-	30 %	15 %	-0,173 %	-0,173 %	-0,173 %	-0,153 %
	-	30 %	-15 %	0,173 %	0,173 %	0,173 %	0,153 %
DM in other municipalities' food waste	-	30 %	15 %	-0,160 %	-0,160 %	-0,160 %	-0,141 %
	-	30 %	-15 %	0,160 %	0,160 %	0,160 %	0,141 %
Share of food waste in Oslo residual waste	-	36,7 %	15 %	-9,919 %	-9,919 %	-9,919 %	-8,847 %
	-	36,7 %	-15 %	12,347 %	12,347 %	12,347 %	10,749 %
DM in food waste	-	30 %	15 %	-3,498 %	-3,498 %	-3,498 %	-3,096 %
	-	30 %	-15 %	3,761 %	3,761 %	3,761 %	3,301 %
DM in liq. dig. to agriculture	-	2,7 %	15 %	0,127 %	0,200 %	0,107 %	-
	-	2,7 %	-15 %	-0,127 %	-0,200 %	-0,107 %	-
DM in solid biofertilizer	-	25 %	15 %	14,873 %	14,800 %	14,893 %	-
	-	25 %	-15 %	-14,873 %	-14,800 %	-14,893 %	-
Route distance, liquid organic waste	km	60	50 %	-	-	-	-0,00029 %
Route distance, commercial food waste	km	60	50 %	-	-	-	-0,00081 %
Route distance, other municipalities' food waste	km	70	50 %	-	-	-	-0,00246 %
Distance for transportation of HHW	km	30	50 %	-	-	-	-1,300 %
Route distance,food waste from Haraldrud	km	50	50 %	-	-	-	-0,009 %
Route distance,food waste from Klemetsrud	km	60	50 %	-	-	-	-0,006 %
Route distance, LBG	km	60	50 %	-	-	-	-0,0002 %
Route distance, liquid digestate	km	35	50 %	-	-	-	-0,0001 %
Route distance, solid biofertilizer	km	35	50 %	-	-	-	-0,002 %
Volume of the LBG	Nm3	117800	15 %	-	-	-	14,963 %
	Nm3	117800	-15 %	-	-	-	-14,973 %
Mass of LBG	ton/period	85	15 %	-	-	-	-0,032 %
	ton/period	85	-15 %	-	-	-	0,032 %

As seen in Table 5-11 there were four parameters that stood out among the parameters investigated; share of food waste in the residual waste, DM in food waste, DM in solid biofertilizer and the volume of the LBG. The share of food waste in the residual waste had a big impact on all of the indicator values. Also the DM content in the food waste had an impact on all of the indicator values, but to a lesser extent than the food waste share in residual waste. DM content in the solid biofertilizer had a big impact on the MRR, NR and PR. When it comes to the volume of LBG it has a big impact on the energy efficiency of the system. Due to their impacts on the results it is important to find values as good and exact as possible for these parameters to minimize the uncertainties of the model. For the energy efficiency the result is almost changed as much as the change in the parameter. The fact that the volume of the gas had an impact on the energy efficiency was also shown in chapter 5.1.2 where energy efficiencies based on an estimated value and a scaled value were found. This parameter is hence very important to detect accurate values to minimize the uncertainty in the calculation of the energy efficiency of the system.

5.3.2 LCA model

Table 5-12 shows the results from the sensitivity analysis conducted on the LCA model. In chapter 4.3.2 the reason for the choice of parameters is explained.

Table 5-12 Sensitivity analysis of the LCA model

Input variables	Unit	Initial value	% change initial value	% change in result
				GWP
Route distance, liquid organic waste	km	60	50 %	0.056 %
Route distance, commercial food waste	km	60	50 %	0.160 %
Route distance, other municipalities' food waste	km	70	50 %	0.231 %
Distance for transportation of HHW	km	30	50 %	44.728 %
Route distance,food waste from Haraldrud	km	50	50 %	1.840 %
Route distance,food waste from Klemetsrud	km	60	50 %	1.136 %
Route distance, LBG	km	60	50 %	0.032 %
Route distance, liquid digestate	km	35	50 %	0.027 %
Route distance, solid biofertilizer	km	35	50 %	0.336 %

As seen in Table 5-12 the distance for transportation stands out from the rest of the parameters. By increasing this parameter by 50% the GWP increased with about 45%. To minimize the uncertainties of the model it is of interest to strive for as accurate values as possible for this parameter.

6 Discussion

6.1 Main finding

In the study of the RBA value chain it was found smaller MRR and NRR values than would have been the case if all of the biofertilizer products had been produced in the period investigated. For the investigated period it was found an MRR of 3.6%, NR of 26.1% and PR of 7.8%. All of these flows are related to the DM content in the products. Since RBA is in a run-up period none of the centrate has been transformed to concentrated liquid digestate. This indicates a loss of DM which affects the efficiencies. Due to data related to the centrate flow have not been received, it has not been possible to evaluate to what extent this would have affected the results.

From the sensitivity analysis it was found that the DM content in solid biofertilizer had a large impact on the MRR and NRR. When changing this parameter by 15% it resulted in an almost as large change in the efficiencies. This implies that good data related to this parameter are important when evaluating the resource efficiency of the system. Another parameter worth mentioned is the food waste share in the residual waste. By reducing this share by 15% the MRR and NRR were increased by about 12.3% and the energy efficiency by 10.8%. This states the importance of information regarding sorting. If the knowledge of correct sorting increases among people it can result in a great effect on the resource efficiency of the value chain.

The energy efficiency was found to be very low, 2.5%. This is mainly due to the biogas volume used for calculations. Since RBA is in a run-up period it was only received data for the amount of biogas sold. It was informed that this value has large deviations from the actual amount produced. Therefore it was of interest to see how sensitive the model was for changes in this parameter. By changing the volume by +/- 15% the efficiency was found to almost change with the same share. To find estimates that were more representative for the actual case at RBA, two efficiencies using an estimated and a scaled volume were calculated. The estimated and scaled values were found to be respectively 26.1% and 18.3%. Although RBA is in a run-up period these values give more realistic indications of the energy efficiency according to the produced volume.

According to the DM results found in the MFA and the impact results in the LCA a total GWP was found to be about 455 kg CO_2-eq./FU (calculations found in Appendix B.2) for the RBA value chain. In evaluating this case it was detected that the processes for collection of HHW constituted to over 80% in all the impact categories except one. These processes are related to transport of large amounts of waste and hence it is reasonable that they will be responsible for a large share of the impacts, but it is considered that the share is lower in reality. The HHW collection processes are modelled as they were driven on Euro 5 diesel, but this is not the case. In Oslo the HHW is collected by lorries using biomethane as fuel. Oslo municipality has hence done measures to lower the impact related to these processes. Correct modelling data would then result in lower impacts. How sensitive the model is for changes of transportation distances were evaluated and also here it was made clear that correct data for the processes regarding HHW collection is of great importance. It was found that an increase of the distance by 50% resulted in an increase of about 44.7%.

The avoided GWP was found to be about 747 396 kg CO_2-eq when utilizing products from RBA in comparison to the alternatives. Impacts were also calculated using an estimated gas volume to give better indications related to the actual biogas produced. Then it was found that by increasing the volume to the estimated value the GWP for case A increased by about 1.3% but for case B there was an increase of 9.8%. The impact of using the correct gas volume hence has an impact of detecting the correct avoided burdens of the RBA value chain.

6.2 Comparison with literature

6.2.1 Resource efficiency performance

Regarding MRR it was not found any record of investigation of this indicator in the literature. Comparison of the MRR found for the RBA value chain and studies in literature is therefore not possible.

Guochang (2014) investigated the NRR for a system combining AD, land application and upgrading and found indicators defined equal as NR and PR of respectively 40% and 21%. These results are much larger than the ones found in this study, 26.1% and 7.8%. Part of the reason for these differences is due to the definition of the two systems. Guochang investigated a general system with the EU as a case region. The study was then based on more general values within the EU and not for a specific plant where specific technologies and values were provided. At the same time the two studies have different substrates entering the AD. The study of Guochang investigates sewage sludge as substrate in contrast to different types of food wastes. This will affect among others the need for pretreatment, biogas yield and the extent of the posttreatment to ensure safe products. Another aspect is that RBA is still under a run-up period. This implies that the system is not operated under desired conditions. Aspects affecting the NR and PR at present operation are how the biofertilizer products are handled. For the period evaluated liquid digestate and solid biofertilizer are the only products from RBA. The centrate from the dewatering has not been transformed to concentrated liquid biofertilizer and this can be seen as a loss of DM and hence a lower NR and PR than the intended purpose. Another aspect that could have had an impact on the NRR is the DM content of the liquid digestate. At the present it is about 2.7%, but it is desired to be 4.5%. By conducting the sensitivity analysis it was shown that change in this parameter had little impact on the NRR. If this had been the desired 4.5% it would still change the NR and PR with less than 1%.

The PEIO ratio reported by Pöschl et al. (2010) ranged from 34.1% to 55% for various biogas production and upgrading pathways are not comparable to the defined energy efficiency in this study. Pöschl's definition of PEIO is the inverted of the defined energy efficiency, but it does not include the energy in the substrates.

Berglund & Börjesson (2003) detected that the net energy input (excluding substrate energy) required to run a biogas system was about 20-40% of the energy content in the produced biogas. This is not the case for the system modelled in this study. Due to calculations using sold amount of biogas this constitutes to a very low energy output. By running the MFA model with the scaled and estimated gas volumes found in Appendix A it was found that the energy input to the system, not including substrate energy, constituted to respectively about 71% and 52%. The energy flows found for these cases will not be shown in this report, but the share of energy input of the energy in the produced biogas was found by (E_tot,t + E_tot,p)/E_6.5,0 (data found in Appendix A). Though there are many assumptions and hence uncertainties related to the estimated and scaled biogas volumes, this could be an indication of a higher energy input to the RBA value chain than results found in the literature.

According to Berglund & Börjesson (2003) the operation of the biogas plant was found to be the most energy demanding process corresponding to 40-80% of the net energy input to the system. The net energy input did not include the substrate energy for their study. By excluding the substrate energy in the study of the RBA value chain it was found that the electricity consumption at RBA was the most energy demanding. The electricity consumption for the biogas plant constituted 61% of the energy input to the value chain. Energy input for operation of RBA was hence in correlation with what Berglund & Börjesson concluded. One important aspect to mention for the model of RBA is that the need for landfill gas has been excluded. This implies that the share of energy input is actually larger than calculated. Since the demand for landfill gas is unknown it is difficult to estimate to what extent this would affect the energy needed for operation of RBA.

6.2.2 Environmental life cycle impact

Results related to the calculation with use of estimated biogas volumes will give basis for the comparison between the results found in the literature. This is done since many of the studies relate the impact to a FU considering the produced biogas, hence the results from the sold amount would indicate much higher impacts related to RBA than is the actual case.

Börjesson et al. (2010) reported an emission of 10 g CO2-eq./MJ biofuel when using partitioning approach and 3 g CO2-eq./MJ biofuel when using substitution approach. Based on the MFA and LCA results in this study it was found an impact of about 13.7 g CO2-eq./MJ biofuel for the RBA value chain. The value for RBA is higher than it would be since the total impacts at RBA have not been allocated to the LBG. Hence the impact used in the comparison here is for all the products from RBA and is therefore not directly comparable to the results found by Börjesson et al. If the emissions at RBA had been allocated to the LBG this would most likely result in lower emissions which would lead to results more simular to the ones found using the partitioning approach in Börjesson et al.

The reduction by utilizing biomethane as fuel contra fossil fuels was investigated by Börjesson et al. (2010) and Lyng et al. (2011). Since the impacts have not been allocated to the LBG in this study, such a comparison will not be valid to conduct for RBA.

As Börjesson et al. (2010) also Uusitalo et al. (2014) reported their results related to the energy content in biogas. Uusitalo et al. reported though a much larger value, 220 g CO_2-eq. per MJ of biogas produced. The reason for this could for instance be due to different characteristics of the substrates or differences in the system boundary.

Emissions related to gas upgrading for grid injection was evaluated by Pertl et al. (2010). For a scenario using organic waste as substrate and WS for upgrading it was found GHG emissions of 108.9 kg CO_2-eq./per 100 m^3 upgraded biogas. In comparison RBA had an emission of about 49.3 kg CO_2-eq./per 100 Nm^3. Pertl et al. did not include treatment and transport of digestate and had anyway higher emissions as well as it is not necessary to liquefy the gas when delivered to the grid. These values have also diferent units for the gas volume, and since the pressure and temperature in Pertl et al. are not given it is difficult to know if the same volume is used.

Due to the assumptions done and the uncertainties related to this study it is difficult to do good comparisons with results found in the literature. It is not stated if the results found in the literature included biogenic emissions. If this is the case this results in larger values than if biogenic emissions are excluded.

6.3 Strength and weakness

Performing both a MFA and a LCA on the value chain of RBA can contribute to a more robust analysis. The flows quantified in the MFA can contribute to the inventory data in the LCA. Results from the MFA can be used in the inventory of the LCA if there is lack of information or unmeasured data. In cases where there are available data the data could be checked by comparing it with the MFA results. If there are large deviations between the values this indicates that there could be errors in the model or in the data and there will be need for a revision.

Flows found to detect the efficiencies in the MFA also contributed to find how much of the products from RBA that could replace other products as diesel and chemical fertilizer.

When conducting both a MFA and a LCA it is possible to both detect the resource efficiency performance of the value chain as well as the environmental life cycle impact.

Common weaknesses of the modelling

Both of the two models have become much less detailed than what was intended. This implies that there have been used much less specific data which impose larger uncertainties in the model. Factors that have imposed uncertainties in both of the models are:

- Exclusion of transport of reject flows and products needed in the operation of RBA:
  As for the products from RBA many of the reject flows are transported to other premises where they are decomposed or entering other processes. To be consistent with the practice used for the substrate inflows and products from RBA also the transport of these flows should be included. Optionally some of the transport could be allocated to this system and some to the process where it enters.
- Neglecting of the landfill gas consumed in the operation:
  By neglecting the use of landfill gas to the operation of RBA the overall energy input to the system gets lowered to what is the actual case which results in a higher energy efficiency than is the case. If the LCA had included biogenic emissions the neglecting of landfill gas would result in lower impacts than actually is the case.
- Poor data regarding the produced amount LBG:
  The use of sold amount results in lower energy efficiency as well as the avoided burdens gets reduced. As shown in chapter 5.2.2 the impact increased by 1.3% for case A when increasing the volume to the estimated value, but for case B this resulted in an increase of 9.8%. When the produced biogas actually is larger this implies that also the avoided burdens related to case A are larger than the value found.
- CBG has been used as it was LBG:
  The amount CBG from RBA has been used in calculations as it was LBG. This could have affected for instance the required transportation. CBG has higher volume than LBG and hence more transportation is needed to transport the same energy content. When treated CBG as LBG the transport related to the distribution of the gas produced may have been reduced compared to the actual case.
- Estimation of electricity consumption at RBA:
  Electricity bills for two quarters in the evaluated period were provided from RBA. To estimate the consumption for the entire period the provided data were divided by the number of days in the two quarters and then multiplied by the number of days in the eight months evaluated. This can have resulted in a higher consumption than the actual case due to the fact that the remaining months were spring months (higher electricity demand in winter) as well as the plant could have been operated differently.

Weaknesses of the MFA model

To conduct a more thorough investigation of RBA it would be profitable to detect the flows through the system as well as the energy needed in the different processes. This could provide better inventory data to the LCA as well as it would be easier to detect where potential losses of DM happened. In general it would give a better insight of the system where it would be easier to suggest specific measures for improvement.

Weaknesses of the LCA model

By using ecoinvent data for the foreground processes larger uncertainties in the model are imposed. When using data from the ecoinvent database it is also difficult to find data that match the actual situation. Examples of this are the use of Euro 5 diesel for the HHW collection processes and the distribution of LBG which in reality use respectively biomethane and Euro 6 diesel.

For case C and D emissions related to use should ideally been included since these emissions had not been biogenic emissions. Such data were not available within the deadline and therefore this could have resulted in larger impacts for these cases than the ones found.

Biogenic emissions should have been included in the study to be able to locate the all the emissions in the system. Although the emissions are biogenic this does not imply that the impact is zero within the time frame of the evaluated system.

6.4 Further work

In a further work of this assignment it would be beneficial to define a system with more processes to achieve a system more equal to the reality. By including more processes and receiving more accurate inputs and outputs for them it would result in a system with much lesser uncertainty. This would probably be easier doing when RBA has completed the run-up period and started the production of LBG and when the biofertilizer products are not produced for research purposes.

If such models are defined they will be able to provide more reliable results regarding the resource recovery efficiency and environmental life cycle impact for the RBA value chain. Then it would be easier to compare the value chain with similar studies found in the literature as well as more detailed measures regarding improvements in the system could be proposed.

7 Conclusion

While evaluating the resource recovery efficiencies of RBA it was found that they were poorer than would have been the case if RBA had been operated in a manner more similar to the original idea of the thesis. Due to RBA is in a run-up period the dewatering process is tested and this has resulted in that the concentrated liquid digestate has not been produced from the centrate in the evaluated period. This resulted in a lower total DM content from the products which imply lower MRR and NRR. It was found an MRR of 3.6%, NR of 26.1% and PR of 7.8%.

When evaluating how sensitive the MFA was it was found that the DM content in solid biofertilizer had a great impact on the indicator values. Hence it is important to have low uncertainties in this factor for having a good representation of the efficiencies of the system. It was also found that reduction of incorrect sorting regarding food waste was very important for the indicator values.

The energy efficiency of the system was found to be very low, 2.5%. This was due to that the sold amount of biogas was used instead of the actual produced amount. The gas volume had a large effect on this indicator and hence the efficiency was calculated by using an estimated volume as well. Then the energy efficiency was found to be 26.1%.

When evaluating the environmental life cycle impact of the RBA value chain it was found a total GWP impact of 455 kg CO_2-eq./FU. Of the defined processes the processes related to HHW collection had the biggest impacts, with a combined impact of over 80% in almost all of the categories. Due to the data used in the modelling the impacts were evaluated as higher than what is the actual case, though it was shown that the model was very sensitive for changes in the related collection distance.

By calculating the emissions related to RBA compared to what the alternative option (diesel and chemical fertilizer) had been it was found an avoided burden of 747 396 kg CO_2-eq by implementing the value chain.

There are large uncertainties related to the modelling done in this study. These results should not be used as actual facts, but they can contribute to indicate where in the value chain there are places for improvements. Therefore it is recommended that the modelling performed in this thesis should be improved to give better results.

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Appendices

Appendix A – MFA calculations and quantifications

Appendix B – Data and calculations for the LCA

Appendix C – Electricity demand for installations at RBA

Appendix D – Operational data from RBA

Appendix A – MFA calculations and quantifications

Parameters

	Short name	Value	Unit
Volume	V	117 800	Nm3/period
Absolute pressure	P	101 325	Pa
Absolute temperature	T	273.15	K
Molar mass CH4	M_CH4	16.04	g/mol
Molar mass CO2	M_CO2	44.01	g/mol
Share of CH4	p_CH4	99.70 %	
Share of CO2	p_CO2	0.30 %	
Ideal gas constant	R	8.314	J/(K*mol)
Allocation factor	α	83 %	
Correction factor	c_flows	69.7 %	
Installed effect Klemetsrud processing plant	I_pro,optibag	230	kW
Postinstalled effect for blue bags at Klemetsrud	I_p.pro,optibag	15	kW
Load factor	L	0.5	/h
Operation time	t_optibag	188	h/month
Monthly amount of HHW	x_hhw	3698	ton/month
Spesific el demand processing plant	e_pro,optibag	6.23	kWh/ton
Electricity share of e_pro,optibag for ventilation, lighting etc.	p_el,optibag	50 %	
Specific el demand for Optibag	e_optibag	9.34	kWh/ton
Share of food waste in Oslo residual waste	p_fw,res	36.7 %	
Specific el demand for liquefaction	e_liq.lbg	0.95	kWh/kg LBG
DM in liquid food waste	dm_1,6.1	15 %	
DM in commercial food waste	dm_2,6.1	30 %	
DM in other municipalities food waste	dm_3,6.1	30 %	
DM in food waste	dm_5,6.1	30 %	
DM in liquid digestate to agriculture, d	dm_6.6,0d	2.7 %	
DM in solid biofertilizer	dm_6.7,0	25 %	
N in liquid food waste	n_1,6.1	0.0089	ton N/ton DM
N in commercial food waste	n_2,6.1	0.0089	ton N/ton DM
N in other municipalities food waste	n_3,6.1	0.0089	ton N/ton DM
N in household waste	n_4,5	0.0089	ton N/ton DM
N in food waste	n_5,6.1	0.0089	ton N/ton DM
N in liquid digestate to agriculture, d	n_6.6,0d	0.105	ton N/ton DM
N in solid biofertilizer	n_6.7,0	0.0663	ton N/ton DM
P in liquid food waste	p_1,6.1	0.52 %	
P in commercial food waste	p_2,6.1	0.52 %	
P in other municipalities food waste	p_3,6.1	0.52 %	
P in household waste	p_4,5	0.52 %	
P in food waste	p_5,6.1	0.52 %	
P in liquid digestate to agriculture, d	p_6.6,0d	0.98 %	

P in solid biofertilizer	p_6.7,0	1.16 %	
Lower heating value organic HHW	lhv_org	13800	MJ/ton DM
Lower heating value upgraded biogas	lhv_up.bio	35.9	MJ/Nm3
PE for ordinary transport work	pe_ord	1.8	MJ/tkm
PE for diesel consumed	pe_diesel	4.785	MJ/l
PE for Norwegian electricity mix	pe_el	1.251	MJ/MJ el
Distance of transportation of HHW	d_4,5	30	km
Truck load for the remaining vehicles	tl_other	20	ton/load
Truck load other municipalities' food waste	tl_3,6.1	7	ton/load
Truck load for LBG	tl_6.5,0	22	ton/load
Route distance, liquid organic waste	rd_1,6.1	60	km/load
Route distance, commercial food waste	rd_2,6.1	60	km/load
Route distance, other municipalities' food waste	rd_3,6.1	70	km/load
Route distance, food waste from Haraldrud	rd_5,6.1,h	50	km/load
Route distance, food waste from Klemetsrud	rd_5,6.1,k	60	km/load
Route distance, LBG	rd_6.5,0	60	km/load
Route distance, liquid digestate	rd_6.6,0d	35	km/load
Route distance, solid biofertilizer	rd_6.7,0	35	km/load
Fuel use by diesel vehicles	f_diesel	0.45	l/km
Biogas yield for municipal organic waste	b	130	Nm3/ton

Equations for parameters:

$$\alpha = \frac{X\_5,6.1}{X\_5,6.1 + X\_5,0a}$$

$$e\_optibag = (1 + p\_el,optibag) * \frac{(((I\_pro,optibag + I\_p.pro,optibag) * L) * t\_optibag)}{x\_hhw}$$

$$c\_flows = \frac{X\_5,6.1}{X\_5,6.1\ (K) + X\_5,6.1\ (H)}$$

Flows used for calculations

	Short name	Value	Unit
Actual amount org. waste from Klemetsrud	X_5,6.1 (K)	4 302	ton/year
Actual amount org. waste from Haraldrud	X_5,6.1 (H)	8 364	ton/year
Actual amount HHW to Klemetsrud	X_4,5 (K)	42 254	ton/year
Actual amount HHW to Haraldrud	X_4,5 (H)	77 807	ton/year
Actual amount plastic from Klemetsrud	X_5,0a (K)	939	ton/year
Actual amount plastic from Haraldsrud	X_5,0a (H)	1 613	ton/year
Volume upgraded biogas, sold from RBA	V	117 800	Nm3/period
Electricity for the biogas plant	E_plant,el	2 767 028	kWh/period
Volume upgraded biogas, estimated from literature	V_e	1 271 755	Nm3/period
Volume upgraded biogas, estimated full capacity RBA	V_f	4 536 000	Nm3/year
Total incoming waste flow to RBA, full capacity	X_tot	50 000	ton/year
Volume upgraded biogas, scaled	V_s	887 489	Nm3/period

Equations

$$V\_e = b * (X\_1,6.1 + X\_2,6.1 + X\_3,6.1 + X\_5,6.1)$$

$$V\_s = (V\_f/X\_tot) * (X\_1,6.1 + X\_2,6.1 + X\_3,6.1 + X\_5,6.1)$$

Mass flow results

Flow	Value (ton/period)	
X_1,6.1	147	
X_2,6.1	422	
X_3,6.1	390	
X_4,5	83 640	
X_5,0a	1 778	
X_5,0b	73 038	
X_5,6.1	8 824	
X_6.5,0	85	[1]
X_6.6,0d	120	
X_6.7,0	1 519	

[1] Found by using the ideal gas law. See equation for formula

Equations for mass flows

X_4,5 = c_flows *(X_4,5 (K) + X_4,5 (H))

X_5,0a = c_flows * (X_5,0a (K) + X_5,0a (H))

X_5,0b = X_4,5 - X_5,0a - X_5,6.1

X_5,6.1 = c_flows * (X_5,6.1 (K) + X_5,6.1 (H))

$$X\_6.5,0 = \frac{P*V*(M\_CH4*p\_CH4 + M\_CO2*p\_CO2)*10^6}{R*T}$$

DM flow results

Flow	Value (ton DM/ period)	
DM_1,6.1	22	
DM_2,6.1	127	
DM_3,6.1	117	
DM_4,5	10 689	
DM_5,0a	-	[1]
DM_5,0b	8 042	
DM_5,6.1	2 647	
DM_6.6,0d	3,2	
DM_6.7,0	380	

[1] Assumed no DM in the plastic flow, X_5,0a, hence no N and P

Equations for DM flows

DM_1,6.1 = dm_1,6.1 * X_1,6.1

DM_2,6.1 = dm_2,6.1 * X_2,6.1

DM_3,6.1 = dm_3,6.1 * X_3,6.1

DM_4,5 = DM_5,0a + DM_5,0b + DM_5,6.1

DM_5,0b = p_fw,res * dm_5,6.1 * X_5,0b

DM_5,6.1 = dm_5,6.1 * X_5,6.1

DM_6.6,0d = dm_6.6,0d * X_6.6,0d

DM_6.7,0 = dm_6.7,0 * X_6.7,0

N flow results

Flow	Value (ton N/ period)
N_1,6.1	0.196
N_2,6.1	1.131
N_3,6.1	1.045
N_4,5	95
N_5,6.1	24
N_6.6,0d	0.34
N_6.7,0	25.18

Equations for N flows

N_1,6.1 = n_1,6.1 * DM_1,6.1
N_2,6.1 = n_2,6.1 * DM_2,6.1
N_3,6.1 = n_3,6.1 * DM_3,6.2
N_4,5 = n_4,5 * DM_4,5
N_5,6.1 = n_5,6.1 * DM_5,6.1
N_6.6,0d = n_6.6,0d * DM_6.6,0d
N_6.7,0 = n_6.7,0 * DM_6.7,0

P flow results

Flow	Value (ton P/ period)
P_1,6.1 =	0.114
P_2,6.1 =	0.658
P_3,6.1 =	0.608
P_4,5 =	55.58
P_5,6.1 =	13.77
P_6.6,0d =	0.032
P_6.7,0 =	4.4

Equations for P flows

P_1,6.1 = p_1,6.1 * DM_1,6.1
P_2,6.1 = p_2,6.1 * DM_2,6.1
P_3,6.1 = p_3,6.1 * DM_3,6.2
P_4,5 = p_4,5 * DM_4,5
P_5,6.1 = p_5,6.1 * DM_5,6.1
P_6.6,0d = p_6.6,0d * DM_6.6,0d
P_6.7,0 = p_6.7,0 * DM_6.7,0

Energy flow results

Flow	Value (MJ/ period)
E_1,6.1	303 545
E_2,6.1	1 747 080
E_3,6.1	1 614 103
E_4,5	147 505 136
E_6.5,0	4 228 078
E_t-1,6.1	947
E_t-2.6.1	2 726
E_t-3.6.1	8 395
E_t-4,5	4 516 581
E_t-5,6.1 (H)	31 367
E_t-5,6.1 (K)	19 361
E_t-6.5,0	498
E_t-6.6,0d	452
E_t-6.7,0	5 723
E_p5,el	2 928 941
E_p6,el	12 461 588
E_p6.5,el	362 581

Equations for energy flows

E_1,6.1 = lhv_org * DM_1,6.1
E_2,6.1 = lhv_org * DM_2,6.1
E_3,6.1 = lhv_org * DM_3,6.1
E_4,5 = lhv_org * DM_4,5
E_6.5,0 = lhv_up.bio * V
E_t-1,6.1 = pe_diesel * f_diesel * rd_1,6.1 * (X_1,6.1/tl_other)
E_t-2.6.1 = pe_diesel * f_diesel * rd_2,6.1 * (X_2,6.1/tl_other)
E_t-3.6.1 = pe_diesel * f_diesel * rd_3,6.1 * (X_3,6.1/tl_3,6.1)
E_t-4,5 = pe_ord * d_4,5 * X_4,5
E_t-5,6.1 (H) = pe_diesel * f_diesel * rd_5,6.1,h * ((c_flows * X_5,6.1 (H))/tl_other)
E_t-5,6.1 (K) = pe_diesel * f_diesel * rd_5,6.1,k * ((c_flows * X_5,6.1 (K))/tl_other)
E_t-6.5,0 = pe_diesel * f_diesel * rd_6.5,0 * (X_6.5,0/tl_6.5,0)
E_t-6.6,0d = pe_diesel * f_diesel * rd_6,6,0d * (X_6.6,0d/tl_other)
E_t-6.7,0 = pe_diesel * f_diesel * rd_6,7,0 * (X_6.7,0/tl_other)
E_p5,el = α * pe_el * e_optibag * 3,6 * X_4,5
E_p6,el = pe_el * 3,6 * E_plant,el
E_p6.5,el = pe_el * e_liq.lbg * 3,6 * 1000 * X_6.5,0
E_tot,sub = E_1,6.1 + E_2,6.1+ E_3,6.1 + E_4,5
E_tot,t = E_t-1,6.1 + E_t-2,6.1+ E_t-3,6.1 + E_t-4,5 + E_t-5,6.1(H) + E_t-5,6.1(K) + E_t-6.5,0 + E_t-6.6,0d + E_t-6.7,0
E_tot,p = E_p5,el + E_p6,el + E_p6.5,el

Efficiency results

Flow name	Short name	Value
Material rate of recovery	RR	3.5 %
Nitrogen rate of recovery	NR	26.1 %
Phosphorus rate of recovery	PR	7.8 %
Energy efficiency	η	2.5 %

Equations for the efficiencies

$$RR = \frac{DM\_6.6,0d + DM\_6.7}{DM\_1,6.1 + DM\_2,6.1 + DM\_3,6.1 + DM\_4,5}$$

$$NR = \frac{N\_6.6,0d + N\_6.7}{N\_1,6.1 + N\_2,6.1 + N\_3,6.1 + N\_4,5}$$

$$PR = \frac{P\_6.6,0d + P\_6.7}{P\_1,6.1 + P\_2,6.1 + P\_3,6.1 + P\_4,5}$$

$$\eta = \frac{E\_6.5,0}{E\_tot,sub + E\_tot,t + E\_tot,p}$$

Appendix B – Data and calculation for the LCA

B.1 Emission factors

Impact category	Unit	ef_t,16-32 (lorry 16-32t) /tkm	ef_t,7.5-16 (lorry 7.5-16t) /tkm	ef_t,3.5-7.5 (lorry 3.5-7.5) /tkm	ef_el (electricity) /MJ	ef_fertilizer (Ammonium nitrate phosphate) /kg N	ef_bus (regular bus) /pkm
Climate change	kg CO2 eq	1,68E-01	2,24E-01	4,73E-01	3,07E-03	5,27E+00	1,04E-01
Ozone depletion	kg CFC-11 eq	2,65E-08	3,51E-08	7,19E-08	1,94E-10	7,07E-07	1,77E-08
Terrestrial acidification	kg SO2 eq	5,05E-04	6,61E-04	1,36E-03	7,45E-06	3,94E-02	6,68E-04
Freshwater eutrophication	kg P eq	1,49E-05	1,89E-05	5,28E-05	5,74E-07	1,68E-03	6,08E-06
Marine eutrophication	kg N eq	2,61E-05	3,41E-05	6,94E-05	4,06E-07	2,34E-03	4,17E-05
Human toxicity	kg 1,4-DB eq	1,96E-02	2,47E-02	6,97E-02	9,44E-04	1,85E+00	8,15E-03
Photochemical oxidant formation	kg NMVOC	7,73E-04	1,00E-03	1,97E-03	9,07E-06	4,93E-02	1,18E-03
Particulate matter formation	kg PM10 eq	2,23E-04	2,94E-04	6,51E-04	7,35E-06	1,75E-02	2,94E-04
Terrestrial ecotoxicity	kg 1,4-DB eq	2,87E-05	3,98E-05	1,12E-04	2,55E-06	5,91E-04	1,16E-05
Freshwater ecotoxicity	kg 1,4-DB eq	4,21E-04	5,19E-04	1,40E-03	1,96E-05	3,20E-02	1,77E-04
Marine ecotoxicity	kg 1,4-DB eq	5,12E-04	6,78E-04	1,92E-03	2,08E-05	3,71E-02	1,98E-04
Ionising radiation	kg U235 eq	1,59E-02	2,42E-02	7,15E-02	4,28E-04	1,01E+00	9,93E-03
Agricultural land occupation	m2a	6,41E-04	8,16E-04	2,38E-03	2,45E-04	1,02E-01	1,84E-04
Urban land occupation	m2a	2,04E-03	3,38E-03	1,07E-02	2,94E-05	2,61E-02	8,60E-04
Natural land transformation	m2	6,06E-05	8,14E-05	1,70E-04	2,72E-06	1,59E-03	3,76E-05
Water depletion	m3	6,25E-04	8,21E-04	1,93E-03	2,51E-05	1,85E-02	3,23E-04
Metal depletion	kg Fe eq	7,86E-03	8,99E-03	2,50E-02	6,76E-04	4,62E-01	2,79E-03
Fossil depletion	kg oil eq	5,87E-02	7,76E-02	1,63E-01	5,81E-04	1,99E+00	3,51E-02

B.2 Calculations

Calculations done for the LCA are also based on parameters and flows from the MFA found in Appendix A.

Relevant LCA parameters and flows

	Short name	Value	Unit
Biogas consumption in buses	bc	0.6	Sm3/km
Transformation factor from Sm3 to Nm3	β	0.948	Nm3/Sm3
N share in chemical fertilizer	p_n,c.fertilizer	8.4 %	
Distance driven on produced LBG	d_lbg	207 103	km
Number of persons in regular bus	pb	90	p
Chemical fertilizer needed to replace liquid digestate	X_cf,liquid	4.05	ton/period
Chemical fertilizer needed to replace solid fertilizer	X_cf,solid	299.71	ton/period
Transport from regional storage to use area for chemical fertilizer	d_cf	35	km
GWP impact per FU for case A	gwp_a	455	kg CO2-eq/FU
Total GWP impact case A	tot_gwp	1 325 994	kg CO2-eq

Equations for LCA parameters and flows

$$\text{d\_lbg} = \frac{V}{bc * \beta}$$

$$\text{X\_cf,liquid} = \frac{\text{N\_6.6,0d}}{\text{p\_n,c.fertilizer}}$$

$$\text{X\_cf,solid} = \frac{\text{N\_6.7,0}}{\text{p\_n,c.fertilizer}}$$

$$\text{gwp\_a} = \frac{\text{tot\_gwp}}{\text{DM\_1,6.1} + \text{DM\_2,61} + \text{DM\_3,6.1} + \text{DM\_5,6.1}}$$

Equations for the process emissions

Liquid food waste collection	X_1,6.1 * rd_1,6.1 * ef_t,16-32
Commercial food waste collection	X_2,6.1 * rd_2,6.1 * ef_t,16-32
Other minicipalities' food waste collection	X_3,6.1 * rd_3,6.1 * ef_t,7.5-16
Household waste collection to Haraldrud	X_4,5 (H) * c_flows *d_4,5 * ef_t,3.5-7.5
Household waste collection to Klemetsrud	X_4,5 (K) * c_flows * d_4,5 * ef_t,3.5-7.5
Optical sorting, Haraldrud	X_4,5 (H)* c_flows * α *e_optibag * 3,6 * ef_el
Optical sorting, Klemetsrud	X_4,5 (H)* c_flows * α * e_optibag * 3,6 * ef_el
Food waste dristribution from Haraldrud	X_5,6.1 (H) * c_flows * rd_5,6.1,h * ef_t,16-32
Food waste distribution from Klemetsrud	X_5,6.1 (K) * c_flows * rd_5,6.1,k * ef_t,16-32
Biogas plant processes	3,6 * ef_el * (E_plant,el + 1000 * e_liq.lbg * X_6.5,0)
LBG distribution	X_6.5,0 * rd_6.5,0 * ef_t,16-32
Liquid digestate distribution	X_6.6,0d * rd_6.6,0d * ef_t,16-32
Solid biofertilizer distribution	X_6.7,0 * rd_6.7,0 * ef_t,16-32
Diesel use	d_lbg * pb *ef_bus
Chemical fertilizer use (replacing liquid digestate)	N_6.6,0d * 1000 * ef_fertilizer
	X_cf,liquid * d_cf * ef_t,3.5-7.5
Chemical fertilizer use (replacing solid biofertilizer)	N_6.7,0 * 1000 * ef_fertilizer
	X_cf,solid * d_cf * ef_t,16-32

B.3 Emission results

Results for case A using sold gas volume

	Liquid food waste collection	Commercial food waste collection	Other minicipalities ' food waste collection	Household waste collection to Haraldrud	Household waste collection to Klemetsrud	Optical sorting, Haraldrud
GWP (kg CO2 eq)	1473,78564	4241,25435	6118,46868	768 714,51	417 460,75	4 650,98
ODP (kg CFC-11 eq)	0,00023313	0,0006709	0,00095875	0,12	0,06	0,00
TAP (kg SO2 eq)	4,4399355	12,7772285	18,034365	2 212,72	1 201,65	11,30
FEP (kg P eq)	0,1313541	0,37801029	0,51633061	85,85	46,62	0,87
MEP (kg N eq)	0,22989621	0,66159439	0,92941987	112,92	61,32	0,62
HTP (kg 1,4-DB eq)	172,86145	497,459984	674,700593	113 335,57	61 548,41	1 433,00
POFP (kg NMVOC)	6,80468833	19,5825046	27,3435075	3 210,57	1 743,54	13,76
PMFP (kg PM10 eq)	1,96243358	5,64748343	8,02681199	1 059,40	575,32	11,15
TETP (kg 1,4-DB eq)	0,25258424	0,7268859	1,08755625	181,87	98,77	3,86
FETP(kg 1,4-DB eq)	3,70136828	10,6517827	14,1583137	2 283,40	1 240,03	29,74
METP (kg 1,4-DB eq)	4,50675316	12,969516	18,516189	3 115,83	1 692,09	31,55
IRP (kg U235 eq)	139,502937	401,460989	660,12108	116 253,25	63 132,89	649,29
ALOP (m2a)	5,64142676	16,2348751	22,2754198	3 877,01	2 105,46	371,05
ULOP (m2a)	17,957907	51,6791924	92,230942	17 327,12	9 409,73	44,56
NLTP (m2)	0,53322374	1,53450912	2,22253573	275,91	149,84	4,13
WDP (m3)	5,49841911	15,8233283	22,3940288	3 140,45	1 705,46	38,09
MDP (kg Fe eq)	69,154502	199,012547	245,447338	40 671,90	22 087,42	1 025,35
FDP (kg oil eq)	516,804354	1487,25748	2118,16625	264 280,45	143 521,05	881,85

Optical sorting, Klemetsrud	Food waste dristribution from Haraldrud	Food waste distribution from Klemetsrud	Biogas plant processes	LBG distribution	Liquid digestate distribution	Solid biofertilizer distribution	Sum
2 525,78	48 802,91	30 123,05	31422,9261	851,731895	703,525603	8904,69944	1 325 994
0,00	0,01	0,00	0,00198563	0,00013473	0,00011129	0,00140858	0,2
6,14	147,02	90,75	76,3523914	2,56593264	2,11944548	26,8263513	3 813
0,47	4,35	2,68	5,88819396	0,07591231	0,06270313	0,79364918	149
0,33	7,61	4,70	4,16122407	0,13286188	0,10974315	1,38904642	195
778,21	5 724,13	3 533,16	9681,64435	99,9002889	82,517059	1044,43905	198 606
7,48	225,33	139,08	92,9988345	3,93257333	3,24828275	41,1143269	5 535
6,05	64,98	40,11	75,313069	1,13413188	0,93678635	11,857139	1 862
2,10	8,36	5,16	26,1024005	0,14597377	0,12057349	1,52612882	330
16,15	122,57	75,65	200,938315	2,13909903	1,76688339	22,3638848	4 023
17,13	149,24	92,11	213,168963	2,60454798	2,15134152	27,2300675	5 379
352,60	4 619,50	2 851,33	4386,70915	80,6216982	66,593055	842,884945	194 437
201,51	186,81	115,31	2506,90831	3,26029986	2,69298877	34,0858321	9 448
24,20	594,66	367,05	301,028467	10,3782544	8,57237789	108,50273	28 358
2,24	17,66	10,90	27,8705248	0,30816128	0,25453943	3,22176917	497
20,69	182,07	112,38	257,354685	3,17765272	2,62472271	33,2217715	5 539
556,83	2 289,98	1 413,47	6927,46053	39,9658496	33,0115599	417,835566	75 977
478,90	17 113,45	10 563,08	5957,9741	298,672169	246,701478	3122,56229	450 587

Results for case A using estimated volume

	Liquid food waste collection	Commercial food waste collection	Other minicipalities ' food waste collection	Household waste collection to Haraldrud	Household waste collection to Klemetsrud	Optical sorting, Haraldrud
GWP (kg CO2 eq)	1473,78564	4241,25435	6118,46868	768 714,51	417 460,75	4 650,98
ODP (kg CFC-11 eq)	0,00023313	0,0006709	0,00095875	0,12	0,06	0,00
TAP (kg SO2 eq)	4,4399355	12,7772285	18,034365	2 212,72	1 201,65	11,30
FEP (kg P eq)	0,1313541	0,37801029	0,51633061	85,85	46,62	0,87
MEP (kg N eq)	0,22989621	0,66159439	0,92941987	112,92	61,32	0,62
HTP (kg 1,4-DB eq)	172,86145	497,459984	674,700593	113 335,57	61 548,41	1 433,00
POFP (kg NMVOC)	6,80468833	19,5825046	27,3435075	3 210,57	1 743,54	13,76
PMFP (kg PM10 eq)	1,96243358	5,64748343	8,02681199	1 059,40	575,32	11,15
TETP (kg 1,4-DB eq)	0,25258424	0,7268859	1,08755625	181,87	98,77	3,86
FETP(kg 1,4-DB eq)	3,70136828	10,6517827	14,1583137	2 283,40	1 240,03	29,74
METP (kg 1,4-DB eq)	4,50675316	12,969516	18,516189	3 115,83	1 692,09	31,55
IRP (kg U235 eq)	139,502937	401,460989	660,12108	116 253,25	63 132,89	649,29
ALOP (m2a)	5,64142676	16,2348751	22,2754198	3 877,01	2 105,46	371,05
ULOP (m2a)	17,957907	51,6791924	92,230942	17 327,12	9 409,73	44,56
NLTP (m2)	0,53322374	1,53450912	2,22253573	275,91	149,84	4,13
WDP (m3)	5,49841911	15,8233283	22,3940288	3 140,45	1 705,46	38,09
MDP (kg Fe eq)	69,154502	199,012547	245,447338	40 671,90	22 087,42	1 025,35
FDP (kg oil eq)	516,804354	1487,25748	2118,16625	264 280,45	143 521,05	881,85

Optical sorting, Klemetsrud	Food waste dristribution from Haraldrud	Food waste distribution from Klemetsrud	Biogas plant processes	LBG distribution	Liquid digestate distribution	Solid biofertilizer distribution	Sum
2 525,78	48 802,91	30 123,05	40125,8549	9195,19703	703,525603	8904,69944	1 343 041
0,00	0,01	0,00	0,00253557	0,00145454	0,00011129	0,00140858	0,2
6,14	147,02	90,75	97,4990351	27,7015061	2,11944548	26,8263513	3 859
0,47	4,35	2,68	7,51899474	0,81954036	0,06270313	0,79364918	151
0,33	7,61	4,70	5,31372134	1,43436122	0,10974315	1,38904642	198
778,21	5 724,13	3 533,16	12363,0834	1078,51173	82,517059	1044,43905	202 266
7,48	225,33	139,08	118,755896	42,4555976	3,24828275	41,1143269	5 599
6,05	64,98	40,11	96,1718609	12,2439539	0,93678635	11,857139	1 894
2,10	8,36	5,16	33,3317505	1,57591564	0,12057349	1,52612882	339
16,15	122,57	75,65	256,590416	23,0934607	1,76688339	22,3638848	4 100
17,13	149,24	92,11	272,208478	28,1183927	2,15134152	27,2300675	5 464
352,60	4 619,50	2 851,33	5601,65702	870,382341	66,593055	842,884945	196 441
201,51	186,81	115,31	3201,22444	35,1978126	2,69298877	34,0858321	10 175
24,20	594,66	367,05	384,401648	112,042409	8,57237789	108,50273	28 543
2,24	17,66	10,90	35,5895765	3,3268728	0,25453943	3,22176917	507
20,69	182,07	112,38	328,631926	34,3055638	2,62472271	33,2217715	5 642
556,83	2 289,98	1 413,47	8846,09774	431,466596	33,0115599	417,835566	78 287
478,90	17 113,45	10 563,08	7608,10127	3224,42949	246,701478	3122,56229	455 163

Results for case B using sold volume

	Diesel use
Climate change (kg CO2 eq)	1 937 218
Ozone depletion (kg CFC-11 eq)	0,3
Terrestrial acidification (kg SO2 eq)	12 457
Freshwater eutrophication (kg P eq)	113
Marine eutrophication (kg N eq)	777
Human toxicity (kg 1,4-DB eq)	151 984
Photochemical oxidant formation (kg NMVOC)	22 010
Particulate matter formation (kg PM10 eq)	5 483
Terrestrial ecotoxicity (kg 1,4-DB eq)	215
Freshwater ecotoxicity (kg 1,4-DB eq)	3 307
Marine ecotoxicity (kg 1,4-DB eq)	3 692
Ionising radiation (kg U235 eq)	185 155
Agricultural land occupation (m2a)	3 427
Urban land occupation (m2a)	16 024
Natural land transformation (m2)	701
Water depletion (m3)	6 019
Metal depletion (kg Fe eq)	51 985
Fossil depletion (kg oil eq)	654 323

Results for case B using estimated volume

	Diesel use
Climate change (kg CO2 eq)	20 913 979
Ozone depletion (kg CFC-11 eq)	3,6
Terrestrial acidification (kg SO2 eq)	134 484
Freshwater eutrophication (kg P eq)	1 224
Marine eutrophication (kg N eq)	8 391
Human toxicity (kg 1,4-DB eq)	1 640 799
Photochemical oxidant formation (kg NMVOC)	237 621
Particulate matter formation (kg PM10 eq)	59 198
Terrestrial ecotoxicity (kg 1,4-DB eq)	2 324
Freshwater ecotoxicity (kg 1,4-DB eq)	35 706
Marine ecotoxicity (kg 1,4-DB eq)	39 854
Ionising radiation (kg U235 eq)	1 998 910
Agricultural land occupation (m2a)	36 996
Urban land occupation (m2a)	172 995
Natural land transformation (m2)	7 564
Water depletion (m3)	64 983
Metal depletion (kg Fe eq)	561 221
Fossil depletion (kg oil eq)	7 063 997

Results for case C

Results for case C will be the same for sold and estimated volume since both of these values are related to the same amount of waste entering RBA.

	Fertilizer use	Transport	Sum
Climate change (kg CO2 eq)	1791,280566	67,0092277	1858,28979
Ozone depletion (kg CFC-11 eq)	0,000240504	1,0189E-05	0,00025069
Terrestrial acidification (kg SO2 eq)	13,41401433	0,1928836	13,6068979
Freshwater eutrophication (kg P eq)	0,571839886	0,00748348	0,57932336
Marine eutrophication (kg N eq)	0,79569473	0,0098429	0,80553763
Human toxicity (kg 1,4-DB eq)	630,9383215	9,8795185	640,81784
Photochemical oxidant formation (kg NMVOC)	16,76202423	0,27986662	17,0418908
Particulate matter formation (kg PM10 eq)	5,938129763	0,09234857	6,03047834
Terrestrial ecotoxicity (kg 1,4-DB eq)	0,200952842	0,01585344	0,21680628
Freshwater ecotoxicity (kg 1,4-DB eq)	10,90012406	0,1990447	11,0991688
Marine ecotoxicity (kg 1,4-DB eq)	12,62793411	0,27160818	12,8995423
Ionising radiation (kg U235 eq)	343,8680509	10,1338537	354,001905
Agricultural land occupation (m2a)	34,59945267	0,33796115	34,9374138
Urban land occupation (m2a)	8,883961294	1,51041395	10,3943752
Natural land transformation (m2)	0,541123358	0,02405104	0,5651744
Water depletion (m3)	6,308436624	0,27375433	6,58219096
Metal depletion (kg Fe eq)	157,2857977	3,54538946	160,831187
Fossil depletion (kg oil eq)	676,5616557	23,0374589	699,599115

Results for case D using sold volume

Results for case C will be the same for sold and estimated volume since both of these values are related to the same amount of waste entering RBA.

	Fertilizer use	Transport	Sum
Climate change (kg CO2 eq)	132 557,24	1 757,09	134 314,33
Ozone depletion (kg CFC-11 eq)	0,02	0,00	0,02
Terrestrial acidification (kg SO2 eq)	992,66	5,29	997,95
Freshwater eutrophication (kg P eq)	42,32	0,16	42,47
Marine eutrophication (kg N eq)	58,88	0,27	59,16
Human toxicity (kg 1,4-DB eq)	46 690,31	206,09	46 896,40
Photochemical oxidant formation (kg NMVOC)	1 240,41	8,11	1 248,53
Particulate matter formation (kg PM10 eq)	439,43	2,34	441,77
Terrestrial ecotoxicity (kg 1,4-DB eq)	14,87	0,30	15,17
Freshwater ecotoxicity (kg 1,4-DB eq)	806,62	4,41	811,04
Marine ecotoxicity (kg 1,4-DB eq)	934,48	5,37	939,86
Ionising radiation (kg U235 eq)	25 446,71	166,32	25 613,03
Agricultural land occupation (m2a)	2 560,41	6,73	2 567,13
Urban land occupation (m2a)	657,43	21,41	678,84
Natural land transformation (m2)	40,04	0,64	40,68
Water depletion (m3)	466,83	6,56	473,39
Metal depletion (kg Fe eq)	11 639,37	82,45	11 721,81
Fossil depletion (kg oil eq)	50 066,50	616,15	50 682,65

Appendix C – Electricity demand for installations at RBA

These demands are estimated by Knut Jönsson (Oslo EGE) provided full capacity. Grouping under processes is done according to the system shown in Figure 5-1 to Figure 5-4.

Reception hall		
High-pressure washers	2 000	kWh/year
Liquid reception, pump	1 200	kWh/year
Liquid reception, grinder	400	kWh/year
Odor treatment		
(unknown installation)	192 192	kWh/year
Scrubber pump	131 040	kWh/year
Assistance fan	48 048	kWh/year
6.1 Pretreatment		
Grinder (to open bags)	768 768	kWh/year
Screw conveyor/conveyor belt	13 104	
	13 104	
	26 208	
	76 877	
	69 888	
	26 208	
	13 104	
	69 888	
	13 104	
	13 104	
	6 552	
	10 000	
	10 000	
	361 141	kWh/year
Biosep (2 per line)	960 960	kWh/year
Auxiliary systems, air compressor (Biosep)	96 096	kWh/year
Submergion pump/pumping tank	192 192	kWh/year
Strainpress	26 208	kWh/year
Strainpress pump (to buffer tank)	192 192	kWh/year
6.2 THP		
Stirring of the 3 buffer tanks	196 560	kWh/year
Circulation/feed pump pulper	576 576	kWh/year
Circulation pumps for pulper	192 192	kWh/year
Feed pump, reactor	192 192	kWh/year
Feed pump, flash tank	192 192	kWh/year
Circulation pump, flash tank	192 192	kWh/year
Feed pump, digester	65 520	kWh/year
Instrument air, air compressor (THP)	96 096	kWh/year

6.3 Biogas production

Circulation, digester A and B	1 153 152	kWh/year
Auxiliary compressor, digester A and B	314 496	kWh/year
Circulation pump, digester A (heat exchanger)	192 192	kWh/year
Circulation pump, digester B (heat exchanger)	192 192	kWh/year
Feed pump, strainpress (biofertilizer)	528	kWh/day
Circulation pump, digester A (refrigerant)	96 096	kWh/year
Circulation pump, digester B (refrigerant)	96 096	kWh/year
Cooler water circulation pump	131 040	kWh/year

6.6 Posttreatment

Stirring of pumping tank, liquid digestate	96	kWh/day
Circulation pump pumping tank, liquid digestate	528	kWh/day
Liquid digestate pump	360	kWh/day
Strainpress, liquid digestate	72	kWh/day

6.7 Dewatering

Feed pump, decanter centrifuge	180	kWh/day
Decanter centrifuge	528	kWh/day

6.8 Water treatment

Pump, concentrated liquid biofertilizer	396	kWh/dag
Feed pump, reject water	83	kWh/dag
Pump, reject water	528	kWh/dag
Circulation pump, process water	34 944	kWh/year
Booster pump, technical water	65 520	kWh/year
Hydropneumatic pump	65 520	kWh/year

Installations not categorised under a process

Stirring in storage tanks for reject water, concentrated biofertilzer, liquid digestate	196 560	kWh/year
Screws for content distribution in containers	211 411	kWh/year
Stirring storage tank 2 (concrete)	144 144	kWh/year

Appendix D – Operational data from RBA

D.1 Received inflows

	Tømming bil			Flytende avfall	Levering fra kran	
	Fast matavfall Oslo	Fast matavfall andre kommuner	Fast matavfall industri	Mengde	Linje A	Linje B
Dato	tonn	tonn	tonn	m3	tonn	tonn
01.10.2013	71,56	24,54	0	0	0	27,32
02.10.2013	74,4	0	0	0	0	27,96
03.10.2013	49,46	25	0	0	0	36,12
04.10.2013	23,52	0	0	0	0	29,13
05.10.2013	0	0	0	0	0	33,86
06.10.2013	0	0	0	0	0	24,31
07.10.2013	23,78	0	0	0	0	0
08.10.2013	47,92	25,22	0	0	0	13,04
09.10.2013	49,62	0	0	0	0	36,16
10.10.2013	47,04	0	0	0	0	35,26
11.10.2013	-	-	-	0	0	4,61
12.10.2013	-	-	-	0	5,08	0
13.10.2013	-	-	-	0	35,16	0
14.10.2013	73,06	-	-	0	0	0
15.10.2013	74,26	0	0	0	7,58	0
16.10.2013	71,76	0	0	0	7,05	0
17.10.2013	48,3	0	0	0	36,24	0
18.10.2013	0	0	0	0	40,23	0
19.10.2013	0	0	0	0	18,36	0
20.10.2013	0	0	0	0	17,32	0
21.10.2013	72,52	0	0	0	72,54	0
22.10.2013	71,56	0	0	0	50,57	0
23.10.2013	25,1	0	0	0	24,73	0
24.10.2013	97,64	0	0	0	44,83	0
25.10.2013	0	0	0	0	9,2	0
26.10.2013	0	0	0	0	32,88	0
27.10.2013	0	0	0	0	24,59	0
28.10.2013	72,6	24,48	0	0	13,36	0
29.10.2013	24,16	23,4	0	0	34,12	0
30.10.2013	74,68	0	20	0	50	5,49
31.10.2013	24,82	24,22	0	0	40,04	12,75
01.11.2013	26,26	0	0	0	40,2	0
02.11.2013	0	0	0	0	47,16	0
03.11.2013	0	0	0	0	45,5	0
04.11.2013	49,8	0	0	0	42,93	0
05.11.2013	71,64	0	0	0	34,04	0
06.11.2013	69,78	0	0	0	37,26	0
07.11.2013	40,44	0	0	0	58,78	0
08.11.2013	24,6	0	0	0	34,62	0
09.11.2013	0	0	0	0	23,66	0
10.11.2013	0	0	0	0	31,84	0
11.11.2013	48,56	23,88	0	0	43,67	0
12.11.2013	73,88	0	0	0	58,54	0
13.11.2013	47,62	23,9	0	0	65,64	0
14.11.2013	48,98	0	0	0	31,62	0

15.11.2013	23,62	0	0	0	30,87	0
16.11.2013	0	0	0	0	49,29	0
17.11.2013	0	0	0	0	44,23	0
18.11.2013	49,64	0	0	0	24,61	0
19.11.2013	75,24	0	0	0	37,81	0
20.11.2013	72,66	0	0	0	18,53	41,7
21.11.2013	73,96	0	0	0	0	66,97
22.11.2013	0	0	0	0	0	22,63
23.11.2013	0	0	0	0	24,71	28,76
24.11.2013	0	0	0	0	15,95	0
25.11.2013	72,64	0	0	0	1,21	24,62
26.11.2013	74,26	0	0	0	0	82,12
27.11.2013	76,54	0	0	0	0	33,55
28.11.2013	53,82	0	0	0	0	16,75
29.11.2013	28,36	0	0	0	0	87,96
30.11.2013	0	0	0	0	0	52,86
01.12.2013	0	0	0	0	0	20,27
02.12.2013	77,04	0	0	0	0	28,31
03.12.2013	102,22	0	0	0	0	68,48
04.12.2013	74,5	0	0	0	0	48,61
05.12.2013	54,26	0	0	0	0	50,05
06.12.2013	23,52	0	0	0	0	45,62
07.12.2013	0	0	0	0	0	19,98
08.12.2013	0	0	0	0	0	19,41
09.12.2013	48,72	0	0	0	15,87	15,43
10.12.2013	99,96	0	0	0	35,57	0
11.12.2013	50,08	0	0	0	40,57	0
12.12.2013	72,66	0	0	0	15,62	0
13.12.2013	0	0	0	0	0	0
14.12.2013	0	0	0	0	0	0
15.12.2013	0	0	0	0	0	0
16.12.2013	49,78	25,44	0	0	35,03	0
17.12.2013	49,9	22,48	0	0	54,52	0
18.12.2013	50,22	23,94	0	0	41,24	0
19.12.2013	76,2	0	0	0	0	0
20.12.2013	25,16	0	0	0	0	40,44
21.12.2013	0	0	0	0	0	80,69
22.12.2013	0	0	0	0	0	40,6
23.12.2013	72,2	0	0	0	0	58,93
24.12.2013	24,92	0	0	0	0	23,33
25.12.2013	0	0	0	0	0	52,27
26.12.2013	0	0	0	0	0	46,77
27.12.2013	76,24	0	0	0	0	26,14
28.12.2013	23,58	0	0	0	0	45,86
29.12.2013	0	0	0	0	0	41,03
30.12.2013	81,04	0	0	0	0	33,11
31.12.2013	0	0	0	0	0	55,15
01.01.2014	0	0	0	0	0	40,42
02.01.2014	102,84	25,44	0	0	0	66,49
03.01.2014	23,44	0	0	0	0	62,44
04.01.2014	0	0	0	0	0	59,82
05.01.2014	0	0	0	0	0	10,92
06.01.2014	78,56	0	0	0	0	54,9
07.01.2014	125,5	0	0	0	0	92,14
08.01.2014	75,56	0	0	0	0	25,59
09.01.2014	74,84	0	0	0	0	0
10.01.2014	73	0	0	0	0	0
11.01.2014	0	0	0	0	0	0
12.01.2014	0	0	0	0	0	0

13.01.2014	49,33	0	0	0	0	0
14.01.2014	0	0	0	0	0	22,63
15.01.2014	50,18	0	0	0	0	44,48
16.01.2014	0	0	0	0	0	56,26
17.01.2014	0	0	0	0	0	48,27
18.01.2014	0	0	0	0	0	41,41
19.01.2014	0	0	0	0	0	8,5
20.01.2014	73,24	0	0	0	0	12,25
21.01.2014	53,36	0	0	0	0	28,63
22.01.2014	98,76	0	0	0	0	27,04
23.01.2014	101,06	0	0	0	0	12,77
24.01.2014	25,12	0	0	0	0	10,56
25.01.2014	0	0	0	0	0	4,98
26.01.2014	0	0	0	0	0	21,02
27.01.2014	0	0	0	0	0	15,24
28.01.2014	0	0	0	0	0	27,56
29.01.2014	0	0	0	0	0	29,57
30.01.2014	0	0	0	0	0	28,18
31.01.2014	51,28	0	0	0	0	53,71
01.02.2014	0	0	0	0	5,36	29,61
02.02.2014	0	0	0	0	0	49,2
03.02.2014	24,9	0	0	0	0	51,41
04.02.2014	52,74	0	0	0	0	48,01
05.02.2014	75,3	0	0	0	0	36,13
06.02.2014	50,5	0	0	0	0	14,01
07.02.2014	0	0	0	0	0	38,13
08.02.2014	0	0	0	0	0	28,37
09.02.2014	0	0	0	0	0	14,83
10.02.2014	74,86	0	0	0	0	69,91
11.02.2014	127,28	0	0	0	0	28,76
12.02.2014	49,84	0	0	0	0	4,51
13.02.2014	77,18	0	0	0	0	46,71
14.02.2014	26,96	0	0	0	0	39,58
15.02.2014	0	0	0	0	0	10,8
16.02.2014	0	0	0	0	0	2,55
17.02.2014	77,86	0	0	0	2,55	0
18.02.2014	82,32	0	0	0	87,28	2,53
19.02.2014	77,02	0	0	0	81,9	0
20.02.2014	74,02	0	0	0	0	89,54
21.02.2014	28,02	0	0	0	0	43,3
22.02.2014	0	0	0	0	0	30,46
23.02.2014	0	0	0	0	0	37,14
24.02.2014	48,04	23,26	0	0	0	29,79
25.02.2014	97,7	0	0	0	10,88	49,64
26.02.2014	23,76	0	0	0	0	3,91
27.02.2014	95,42	25,92	0	0	0	70,11
28.02.2014	0	0	0	0	0	81,61
01.03.2014	0	0	0	0	0	56,52
02.03.2014	0	0	0	0	0	59,53
03.03.2014	74,16	0	0	0	0	30,21
04.03.2014	74,14	0	0	0	0	55,16
05.03.2014	47,48	24,86	0	0	0	56,36
06.03.2014	101,86	0	0	0	0	36,25
07.03.2014	0	0	0	0	0	67,86
08.03.2014	0	0	0	0	0	36,01
09.03.2014	0	0	0	0	0	19,93
10.03.2014	48,08	0	0	0	0	38,3
11.03.2014	98,16	0	0	0	0	20,65
12.03.2014	27,9	23,9	0	0	0	78,23

13.03.2014	100,82	0	0	0	0	72,07
14.03.2014	0	0	0	0	0	56,18
15.03.2014	0	0	0	0	0	71,93
16.03.2014	0	0	0	0	0	56,07
17.03.2014	75,2	0	0	0	0	27,39
18.03.2014	72,84	0	0	0	0	85,85
19.03.2014	74,6	0	0	0	0	83,35
20.03.2014	72,72	0	0	0	0	85,23
21.03.2014	0	0	0	0	0	73,73
22.03.2014	0	0	0	0	0	75,55
23.03.2014	0	0	0	0	0	53,5
24.03.2014	48,6	0	0	0	0	33,13
25.03.2014	100,48	0	0	0	0	30,72
26.03.2014	73,28	0	0	0	0	17,01
27.03.2014	72	0	0	0	0	12,22
28.03.2014	0	0	0	0	7,45	17,13
29.03.2014	0	0	0	0	127,68	0
30.03.2014	0	0	0	0	23	0
31.03.2014	73,88	0	0	0	56,59	0
01.04.2014	73,68	0	46,02	21,18	67,51	0
02.04.2014	72,36	0	30,18	0	42,17	0
03.04.2014	98,42	0	55,74	0	50,44	0
04.04.2014	0	0	0	0	79,89	0
05.04.2014	0	0	0	0	53,44	0
06.04.2014	0	0	0	0	54,96	1,93
07.04.2014	25,14	0	5,48	0	40,27	0
08.04.2014	98,54	0	41,28	0	62,75	0
09.04.2014	98,12	0	7,4	0	59,8	0
10.04.2014	48,98	0	33,84	0	36,51	0
11.04.2014	24,08	0	26,08	0	47,6	0
12.04.2014	0	0	0	0	55,9	0
13.04.2014	0	0	0	0	19,36	0
14.04.2014	49,9	0	23,8	34,02	8,77	0
15.04.2014	120,66	0	9,24	0	32,67	0
16.04.2014	98,28	0	24,08	33,16	82,01	0
17.04.2014	0	0	0	0	75,93	0
18.04.2014	0	0	0	0	7,59	0
19.04.2014	0	0	0	0	71,29	0
20.04.2014	0	0	0	0	52,89	0
21.04.2014	0	0	0	0	72,73	0
22.04.2014	23,64	0	0	0	80,64	0
23.04.2014	98,84	0	6,72	22,88	70,62	0
24.04.2014	99,56	0	25,46	0	49,06	0
25.04.2014	0	0	39,4	0	28,24	0
26.04.2014	0	0	0	0	37,38	0
27.04.2014	0	0	0	0	11,44	0
28.04.2014	24,8	0	2,82	35,4	23,99	0
29.04.2014	125,42	0	0	0	0	0
30.04.2014	51,42	0	24,46	0	12,65	0
01.05.2014	0	0	0	0	25,59	0
02.05.2014	0	0	0	0	45,45	0
03.05.2014	0	0	0	0	39,99	0
04.05.2014	0	0	0	0	19,36	0
05.05.2014	72	0	0	0	4,05	0
06.05.2014	99,92	0	0	0	37,41	0
07.05.2014	73,38	0	0	0	7,51	0
08.05.2014	72,66	0	0	0	32	-
09.05.2014	0	0	0	0	20,48	0
10.05.2014	0	0	0	0	15,83	0

11.05.2014	0	0	0	0	0	0
12.05.2014	0	0	0	0	0	0
13.05.2014	0	0	0	0	0	0
14.05.2014	47,76	0	0	0	0	0
15.05.2014	23,88	0	0	0	55,98	0
16.05.2014	25,68	0	0	0	85,56	0
17.05.2014	0	0	0	0	60,03	0
18.05.2014	0	0	0	0	9,4	0
19.05.2014	0	0	0	0	49,99	0
20.05.2014	71,72	0	0	0	87,2	0
21.05.2014	73,34	0	0	0	73,59	0
22.05.2014	74,3	0	0	0	60,3	0
23.05.2014	24,9	0	0	0	23,98	0
24.05.2014	0	0	0	0	0	0
25.05.2014	0	0	0	0	0	0
26.05.2014	0	0	0	0	22,03	0
27.05.2014	25,02	0	0	0	64,99	0
28.05.2014	99,56	0	0	0	63,12	0
29.05.2014	0	0	0	0	46,75	0
30.05.2014	0	0	0	0	37,04	0
31.05.2014	0	0	0	0	51,33	0
SUM	8824,21	389,88	422	146,64	4475,12	4868,74
AVG.	36,31	1,6	1,74	0,6	18,42	20,04
MAX	127,28	25,92	55,74	35,4	127,68	92,14
MIN	0	0	0	0	0	0

D.2 Pretreatment line A

	Driftstider					Pumpetank A		Skruepresse A	
	Fra Kvern A	Til Biosep A	Biosep A	Til Biosep B	Biosep B	Temp.	Mengde	Trykk	Mengde
Dato	t	t	t	t	t	C	m3	bar	m3
01.10.2013	0,11	0	0	0	0	52,4	0	0,48	54,99
02.10.2013	0	0	0	0	0	46,51	0	0,12	25,59
03.10.2013	0	0	0	0	0	43,24	0	0,15	99,99
04.10.2013	0	0	0	0	0	40,6	730,82	0,14	60,59
05.10.2013	0	0	0	0	0	38,61	150,89	0,14	103,79
06.10.2013	0	0	0	0	0	37,18	7	0,08	37,89
07.10.2013	0	0	0	0	0	36,27	0	0,02	47,89
08.10.2013	0	0	0	0	0	34,98	0	0,01	23,38
09.10.2013	0	0	0	0	0	28,47	0,1	-0,01	0,5
10.10.2013	0	0	0	0	0	24,63	0	0	0,1
11.10.2013	0	0	0	0	0	22,72	0	-0,05	0
12.10.2013	1,56	0,52	1,34	0,13	0,45	29,17	219,5	-0,03	2,4
13.10.2013	13,39	3,31	11,08	3,39	11,77	57,94	1227,29	0,43	497,79
14.10.2013	9,75	4,03	11,18	3,15	10,59	56,29	547,39	0,29	301,79
15.10.2013	7,66	3,39	9,73	2,84	9,07	55,54	568,09	0,37	299,8
16.10.2013	6,12	2,67	7,5	2,77	8,7	50,76	443	0,27	243,98
17.10.2013	9,43	2,74	8,84	2,32	7,05	52	924,5	0,36	328,6
18.10.2013	9,44	3,05	9,89	2,63	7,55	51,4	1179,19	0,39	378,79
19.10.2013	3,16	1,07	2,86	1,37	3,73	51,13	378,5	0,12	137,18
20.10.2013	3,02	0,71	2,77	0,77	2,75	42,78	289,9	0,11	92,2
21.10.2013	16,39	4,6	14,76	4,57	14,67	55,03	2453,79	0,68	724,69
22.10.2013	9,5	2,04	7,42	2	7,31	51,32	1337,3	0,36	324,09
23.10.2013	6,41	1,63	5,28	1,73	5,19	51,53	1451,62	0,24	242,81
24.10.2013	11,77	2,63	8,57	3,08	8,59	52,3	2598,14	0,42	370,88
25.10.2013	1,19	0,15	0,66	0,18	0,59	42,84	237,71	0	42,5
26.10.2013	6,61	1,17	5,25	1,4	5,04	40,5	998,59	0,16	227,6
27.10.2013	6,78	1,18	4,77	1,39	4,59	52,54	603,8	0,15	199,1
28.10.2013	5,54	0,76	2,84	1,1	3,59	53,35	448,8	0,1	132,4
29.10.2013	7,79	0,78	3,69	1,56	5,96	48,45	1134,68	0,24	209,29
30.10.2013	10,62	2,38	8,32	2,68	8,09	49,19	2098,19	0,5	296,89
31.10.2013	8,44	1,97	6,66	1,49	5,05	48,8	2404,44	0,56	455,48
01.11.2013	9,09	2,37	8,33	1,87	7,08	49,36	1592,1	0,45	360,5
02.11.2013	13	3,03	12,08	2,51	10,01	51,85	1253,81	0,52	407,99
03.11.2013	12,8	2,3	8,92	4,04	12,74	51,88	1297,28	0,5	500,39
04.11.2013	10,53	3,03	10,57	3	10,48	51,56	1094,49	0,46	453,99
05.11.2013	9,19	2,23	9,54	2,57	8,93	49,6	1057,1	0,41	465,88
06.11.2013	9,8	0,67	4,66	2,04	9,61	53,23	501,68	0,51	277,09
07.11.2013	15,85	1,55	13,5	2,11	13	50,39	1553,98	0,63	667,29
08.11.2013	8,99	1,11	9,3	1,19	8,71	50,23	654,09	0,38	418,39
09.11.2013	6,13	0,65	6,11	0,9	6,44	52,85	432,1	0,3	496,99
10.11.2013	8,2	1,33	8,95	0,99	6,53	49,98	757,2	0,41	290,39
11.11.2013	12,2	1,95	13,33	1,48	11,01	50,7	143	0,55	255,59
12.11.2013	15,82	2,22	16,56	2,18	16,26	50,55	9,31	0,68	19,1
13.11.2013	20,02	5,24	20,75	4,94	20,97	52,36	15,91	1,06	30,19
14.11.2013	14,07	2,45	16,7	2,84	17,02	54,71	49,2	0,81	70,79
15.11.2013	6,63	0,9	8,62	1,13	8,27	44,6	93	0,41	106
16.11.2013	18,63	1,6	20,81	1,94	20,95	52,87	268	0,67	233
17.11.2013	15,21	1,87	17,4	1,23	16,88	51,27	267	0,6	248
18.11.2013	9,44	0,84	11,27	0,98	11,22	53,92	190	0,3	124
19.11.2013	12,56	1,24	14,21	1,45	12,8	52,54	188	0,45	113
20.11.2013	8,65	0,93	9,77	1,07	9,49	52,78	84	0,38	89

21.11.2013	0	0	0	0	0	50,47	0	0,07	0
22.11.2013	0	0	0	0	0	48,25	0	0,06	0
23.11.2013	6	2,27	7,55	0,05	0,24	48,18	43	0,24	55
24.11.2013	6,44	2,8	12,57	0	0	55,97	47	0,32	68
25.11.2013	3	1,6	5,31	0	0	53,13	22	0,23	25
26.11.2013	0,21	0,05	0,26	0	0	50,25	0	0,19	1
27.11.2013	0	0	0	0	0	48	0	0,05	0
28.11.2013	0	0	0	0	0	44,79	0	0,05	0
29.11.2013	0	0	0	0	0	42,51	0	0,05	0
30.11.2013	0	0	0	0	0	40,53	0	0,05	0
01.12.2013	0	0	0	0	0	39,38	0	0,04	0
02.12.2013	0	0	0	0	0	37,14	0	0,04	0
03.12.2013	0	0	0	0	0	36,43	0	0,04	0
04.12.2013	0	0,27	0,78	0	0	48,41	10	0,04	0
05.12.2013	0	0	0	0	0	41,45	0	0,04	0
06.12.2013	0	0	0	0	0	33,26	0	0,04	0
07.12.2013	0	0	0	0	0	29,71	0	0,04	0
08.12.2013	0	0	0	0	0	26,25	0	0,04	0
09.12.2013	4,62	0,68	6,06	0	0	28,64	31	0,08	16
10.12.2013	9,72	2,12	12,82	0	0	54,05	108	0,26	89
11.12.2013	13,37	2,33	17,39	0	0	40,91	113	0,44	98
12.12.2013	7,22	0,96	9,26	0	0	37,76	50	0,28	46
13.12.2013	0	0	0	0	0	43,09	0	0,11	0
14.12.2013	0	0	0	0	0	44,31	2	0,06	6
15.12.2013	0	0	0	0	0	42,59	0	0,04	6
16.12.2013	9,55	0,91	11,53	1,19	11,36	48,13	78	0,26	158
17.12.2013	15,76	1,26	19,84	1,45	19,76	51,17	104	0,39	134
18.12.2013	13,2	1,07	17,15	1,35	17,28	50,42	133	0,34	129
19.12.2013	0	0,14	0,86	0,06	0,77	53,19	45	0,02	4
20.12.2013	0	0	0	0	0	45,78	4	0,02	0
21.12.2013	0	0,19	0,85	0,16	0,69	47,41	7	0,02	1
22.12.2013	0	0	0	0	0	48,12	0	0,1	0
23.12.2013	0	0	0	0	0	28,21	1	0,07	0
24.12.2013	0	0	0	0	0	20,7	0	0,06	0
25.12.2013	0	0	0	0	0	20,75	0	0,08	0
26.12.2013	0	0	0	0	0	21,44	0	0,09	0
27.12.2013	0	0	0	0	0	21,05	0	0,1	0
28.12.2013	0	0	0	0	0	20,87	0	0,09	0
29.12.2013	0	0	0	0	0	21,95	443	0,1	0
30.12.2013	0	0	0	0	0	20,47	0	0,1	0
31.12.2013	0	0	0	0	0	21,49	0	0,1	0
01.01.2014	0	0	0	0	0	22,07	0	0,1	0
02.01.2014	0	0	0	0	0	22,48	0	0,1	0
03.01.2014	0	0	0	0	0	21,55	1	0,1	0
04.01.2014	0	0	0	0	0	21,41	2	0,1	0
05.01.2014	0	0	0	0	0	20,71	0	0,1	0
06.01.2014	0	0	0	0	0	19,94	29	0,1	0
07.01.2014	0	0	0	0	0	21,13	0	0,1	0
08.01.2014	0	0	0	0	0	21,2	0	0,09	0
09.01.2014	0,02	0	0	0	0	20,14	6	0,08	0
10.01.2014	0	0	0	0	0	18,76	1	0,08	0
11.01.2014	0	0	0	0	0	16,09	0	0,07	0
12.01.2014	0	0	0	0	0	15,19	0	0,07	0
13.01.2014	0	0	0	0	0	14,67	0	0,07	0
14.01.2014	0	0	0	0	0	14,75	0	0,12	0
15.01.2014	0	0	0	0	0	14,79	0	0,15	0
16.01.2014	0	0	0	0	0	14,88	0	0,18	0
17.01.2014	0	0	0	0	0	15,4	0	0,21	0
18.01.2014	0	0	0	0	0	15,89	0	0,21	0

19.01.2014	0	0	0	0	0	15,82	32	0,18	0
20.01.2014	0	0	0	0	0	16,56	80	0,15	0
21.01.2014	0	0	0	0	0	16,76	40	0,16	0
22.01.2014	0	0	0	0	0	20,31	109	0,18	0
23.01.2014	0	0	0	0	0	20,13	0	0,18	1
24.01.2014	0	0	0	0	0	19,19	0	0,17	0
25.01.2014	0	0	0	0	0	18,53	0	0,18	0
26.01.2014	0	0	0	0	0	18,91	0	0,17	0
27.01.2014	0	0	0	0	0	18,91	0	0,19	0
28.01.2014	0	0	0	0	0	19,67	0	0,19	0
29.01.2014	0	0	0	0	0	20,16	0	0,14	32
30.01.2014	0	0	0	0	0	20,14	0	0,09	11
31.01.2014	0	0	0	0	0	20,01	0	0,1	46
01.02.2014	0,52	0	0	0	0	26,6	9	0,12	36
02.02.2014	0,16	0	0	0	0	35,67	0	0,1	9
03.02.2014	0	0	0	0	0	34,54	0	0,05	0
04.02.2014	0	0	0	0	0	33,63	0	0,05	0
05.02.2014	0	0	0	0	0	32,37	0	0,04	0
06.02.2014	0	0	0	0	0	31,2	0	0,04	0
07.02.2014	0	0	0	0	0	29,83	0	0,04	0
08.02.2014	0	0	0	0	0	29,01	0	0,04	0
09.02.2014	0	0	0	0	0	28,11	0	0,04	0
10.02.2014	0	0	0	0	0	27,43	0	0,04	0
11.02.2014	0	0	0	0	0	26,73	0	0,04	0
12.02.2014	0	0	0	0	0	26,49	0	0,04	0
13.02.2014	0	0	0	0	0	28,66	0	0,04	0
14.02.2014	0	0	0	0	0	28,04	0	0,04	0
15.02.2014	0,67	0	0	0	0	29,9	5	0,08	8
16.02.2014	0,53	0,15	1,25	0,14	1,4	37,85	7	0,05	42
17.02.2014	2,53	0,13	1,38	0,16	1,33	32,32	12	0,06	25
18.02.2014	12,8	2,22	13,18	2,05	12,19	48,08	157	0,2	274
19.02.2014	13,1	2,19	13,51	2,29	13,01	44,77	353	0,43	358
20.02.2014	0	0	0	0	0	48,11	61	0,07	40
21.02.2014	1,05	0,11	1,29	0,07	1,34	48,92	9	0,05	195
22.02.2014	0	0	0	0	0	52,82	0	0,06	180
23.02.2014	0	0	0	0	0	54,61	1	0,05	222
24.02.2014	0	0	0	0	0	55,42	0	0,05	504
25.02.2014	2,08	0,33	2,11	0,31	2,01	50,77	34	0,08	409
26.02.2014	0	0	0	0	0	48,46	7	0,07	568
27.02.2014	0,01	0	0	0	0	47,45	0	0,06	198
28.02.2014	0	0	0	0	0	44,79	0	0,05	171
01.03.2014	0	0	0	0	0	42,78	1	0,11	50
02.03.2014	0	0	0	0	0	41,53	6	0,2	47
03.03.2014	0	0	0	0	0	40,33	6	0,2	93
04.03.2014	0	0	0	0	0	38,96	7	0,2	36
05.03.2014	0	0	0	0	0	37,91	1	0,2	27
06.03.2014	0	0	0	0	0	39,55	0	0,2	15
07.03.2014	0	0	0	0	0	51,56	0	0,2	9
08.03.2014	0	0	0	0	0	54,91	0	0,23	6
09.03.2014	0	0	0	0	0	56,94	0	0,26	15
10.03.2014	0	0	0	0	0	58,77	4	0,22	38
11.03.2014	0	0	0	0	0	53,88	0	0,11	38
12.03.2014	0	0	0	0	0	51,75	0	0,23	95
13.03.2014	0	0	0	0	0	47,41	0	1,09	28
14.03.2014	0	0	0	0	0	45,3	0	1,24	2
15.03.2014	0	0	0	0	0	42,06	0	1,21	1
16.03.2014	0	0	0	0	0	39,51	0	1,21	0
17.03.2014	0	0	0	0	0	37,19	0	1,16	0
18.03.2014	0	0	0	0	0	36,47	0	1,18	1

19.03.2014	0	0	0	0	0	34,51	0	1,19	0
20.03.2014	0	0	0	0	0	32,82	0	1,21	0
21.03.2014	0	0	0	0	0	31,51	0	1,27	1
22.03.2014	0	0	0	0	0	36,24	0	1,16	1
23.03.2014	0	0	0	0	0	41,34	0	1,07	2
24.03.2014	0	0	0	0	0	38,46	0	1,08	1
25.03.2014	0	0	0	0	0	36,55	0	1,1	1
26.03.2014	0	0	0	0	0	34,68	0	1,11	0
27.03.2014	0	0	0	0	0	33,04	0	1,11	3
28.03.2014	0,31	0,08	0,27	0,06	0,14	32,26	1	1,03	30
29.03.2014	17,69	3,01	17,3	2,86	17,18	43,6	470	0,48	350
30.03.2014	4,4	0,84	4,61	0,63	4,18	43,25	227	0,17	101
31.03.2014	10,08	1,35	10,57	1,36	10,35	40,21	291	0,26	112
01.04.2014	11,16	1,87	15,34	1,71	14,46	41,68	154	0,28	316
02.04.2014	6,18	1,2	7,49	1,28	6,9	41,28	96	0,22	200
03.04.2014	10,62	2,11	7,77	2,05	10,82	43,92	135	0,28	192
04.04.2014	14,14	2,25	14,23	2,21	15,82	44,06	177	0,32	216
05.04.2014	10,14	1,32	11,64	1,31	11,62	47,53	137	0,37	241
06.04.2014	9,39	1,31	11,83	1,24	11,74	42,72	147	0,3	267
07.04.2014	6,29	1,01	8,7	0,86	8,4	42,15	76	0,2	239
08.04.2014	13,86	1,68	18,16	1,66	17,89	46,56	143	0,16	314
09.04.2014	10,17	1,52	12,25	1,5	11,5	44,99	129	0,18	213
10.04.2014	9,05	0,77	8,69	1,59	11,78	44,7	103	0,22	167
11.04.2014	6,87	1,03	8,68	1,05	8,31	39,93	82	0,21	176
12.04.2014	10,98	1,6	14,31	1,05	9,96	46,51	114	0,12	319
13.04.2014	4,76	0,55	8,17	0,43	7,63	49,31	149	0,07	222
14.04.2014	2,67	0,19	5,64	0,22	3,93	47,48	30	0,14	252
15.04.2014	6,89	0,93	9,97	0,95	9,07	46,46	94	0,21	373
16.04.2014	13,52	1,89	14,15	2,34	14,22	46,72	447	0,33	312
17.04.2014	11,82	1,69	13,75	2,08	13,73	44,77	663	0,36	319
18.04.2014	1,33	0,21	2,02	0,2	1,91	45,09	173	0,24	100
19.04.2014	12,06	1,77	14,25	1,69	13,44	47,2	784	0,26	235
20.04.2014	8,5	1,24	12,42	1,23	12,62	45,21	371	0,26	195
21.04.2014	11,67	1,73	15,04	1,82	14,83	48,1	388	0,26	302
22.04.2014	11,87	1,99	15,67	1,8	15,15	45,94	475	0,26	288
23.04.2014	12,2	1,94	16,67	1,98	16,47	46,77	440	0,29	276
24.04.2014	8,89	1,2	13,92	1,42	14,38	46,87	158	0,21	548
25.04.2014	4,73	0,64	5,62	0,77	5,5	45,99	80	0,2	244
26.04.2014	7,84	1,03	8,49	1,07	8,34	41,2	118	0,22	189
27.04.2014	10,26	0,23	3,15	0,24	3,11	45,67	32	0,11	87
28.04.2014	4,56	0,57	5,52	0,66	5,16	44,82	62	0,14	212
29.04.2014	0	0	0	0	0	50,01	21	0,15	101
30.04.2014	3,19	0,44	5,81	0,44	5,7	45,31	44	0,11	146
01.05.2014	5,56	0,39	11,53	0,61	13,63	46,35	53	0,11	157
02.05.2014	10	1,05	11,1	1,07	11,86	47,39	133	0,18	177
03.05.2014	9,45	0,72	10,85	1,24	11,3	49,24	112	0,17	177
04.05.2014	4,61	0,49	7,15	0,65	6,98	47,91	94	0,12	74
05.05.2014	0,67	0,08	0,83	0,07	0,78	49,3	130	0,26	198
06.05.2014	8,8	0,91	10,73	0,94	10,57	40,11	105	0,23	406
07.05.2014	2,09	0,25	2,38	0,24	2,27	47	32	0,13	143
08.05.2014	7,3	0,73	7,83	0,88	7,48	45,82	516	0,21	288
09.05.2014	4,75	0,49	4,79	0,45	4,41	47,93	473	0,12	136
10.05.2014	7,58	0,78	7,23	0,75	6,66	48,67	452	0,19	315
11.05.2014	0	0	0	0	0	35,86	0	0,06	46
12.05.2014	0	0	0	0	0	23,42	3	0,09	105
13.05.2014	0	0	0	0	0	31	1	0,06	36
14.05.2014	0	0	0	0	0	32,5	0	0,05	29
15.05.2014	10,71	1,06	10,72	1,21	10,75	39,74	355	0,28	468
16.05.2014	22,61	2,01	23,99	2,24	23,63	49,02	535	0,54	942

17.05.2014	16,07	1,37	16,59	1,41	16,12	46,88	518	0,44	649
18.05.2014	1,77	0,14	2,69	0,19	3,04	46,34	79	0,06	123
19.05.2014	13,61	1,17	16,15	1,4	16,13	46,69	446	0,3	352
20.05.2014	22,18	1,91	23,88	2,21	23,61	49,65	448	0,58	617
21.05.2014	17,1	1,49	18,28	2,01	18,34	50,37	163	0,69	416
22.05.2014	14,5	1,34	16,52	1,52	16,6	49,52	91	0,6	297
23.05.2014	5,6	0,56	7,36	0,57	7,11	51,68	99	0,25	186
24.05.2014	0	0	0	0	0	42,72	10	0,09	132
25.05.2014	0	0	0	0	0	37,42	0	0,09	262
26.05.2014	7,14	0,59	9,41	0,6	9,43	39,36	80	0,24	252
27.05.2014	18,66	1,38	22,98	1,71	23,75	53,75	123	0,58	585
28.05.2014	16,85	1,33	22,11	1,6	21,7	53,53	189	0,37	569
29.05.2014	13,94	0,97	18,61	1,32	18,36	52,31	169	0,32	437
30.05.2014	13,2	0,77	16,62	0,92	16,25	39,55	142	0,32	462
31.05.2014	16,83	1,1	23,06	1,33	22,68	47,4	215	0,43	741
01.06.2014	0,05	0,02	1,69	0,02	2,16	52,97	137	0	40
02.06.2014	12,01	1,32	15,47	1,33	15,31	51,34	138	0,21	493
03.06.2014	3,98	0,39	6,12	0,41	6,74	49,38	59	0,08	458
04.06.2014	0	0	0	0	0	39,37	57	0,15	555
05.06.2014	0	0	0	0	0	38,01	201	0,15	124
SUM	1089,76	166,07	1218,51	160,95	1134	-	49524,48	-	35566,54
AVG.	4,39	0,67	4,91	0,65	4,57	40,1	199,7	0,26	143,41
MAX	22,61	5,24	23,99	4,94	23,75	58,77	2598,14	1,27	942
MIN	0	0	0	0	0	14,67	0	-0,05	0

D.3 Pretreatment line B

	Driftstider					Pumpetank B		Skruepresse B	
	Fra Kvern B	Til Biosep C	Biosep C	Til Biosep D	Biosep D	Temp.	Mengde	Trykk	Mengde
Dato	t	t	t	t	t	C	m3	bar	m3
01.10.2013	4,75	1,68	4,47	1,04	4,28	36,22	232	0,06	74,1
02.10.2013	14,55	3,14	10,88	3,09	14,31	54,17	682,69	0,15	282,59
03.10.2013	8,35	2,25	7,06	2,33	8,59	47,1	403,19	0,14	169
04.10.2013	9,04	2,75	5,56	2,75	8,82	53,37	459,09	0,14	195,99
05.10.2013	6,21	1,6	4,49	1,32	5,39	49,06	362,49	0,28	149,5
06.10.2013	7,07	2,68	7,04	0,92	3,34	55,67	330,6	0,1	147,5
07.10.2013	7,53	3,3	7,42	1,23	4,56	60,97	476,19	0,13	209,19
08.10.2013	6,18	2,35	5,12	1,73	5,34	51,26	371,19	0,1	164
09.10.2013	9	1,36	2,97	3,81	9,22	54,12	385,59	0,12	172
10.10.2013	12,88	2,59	7,5	3,81	9,2	58,86	404,99	0,09	186,1
11.10.2013	13,26	0	0	5,45	12,86	47,66	312	0,09	143,49
12.10.2013	5,44	0	0	2,36	5,42	36,63	128,89	0,02	79,99
13.10.2013	0	0	0	0	0	47,25	3	0,03	2,2
14.10.2013	5,79	0	0	0	0	48,21	5,6	0,06	0
15.10.2013	0	0	0	0	0	39,16	1,3	0,03	0,7
16.10.2013	0	0	0	0	0	22,34	0	0,01	0
17.10.2013	0	0	0	0	0	21,85	0	0,01	0
18.10.2013	0	0	0	0	0	22,99	0	0,02	0
19.10.2013	0	0	0	0	0	24,08	0	0,03	0
20.10.2013	0	0	0	0	0	23,28	0	0,03	0
21.10.2013	0	0	0	0	0	33,88	0	0,04	0
22.10.2013	0	0	0	0	0	30,31	0	0,01	0
23.10.2013	0	0	0	0	0	29,94	882,69	-0,03	0
24.10.2013	0	0	0	0	0	35,76	884,09	0,24	0
25.10.2013	0	0	0	0	0	27,42	1115,79	-0,04	0
26.10.2013	0	0	0	0	0	25,93	1173,39	-0,05	0
27.10.2013	0	0	0	0	0	26,55	1277,18	-0,03	0
28.10.2013	0	0	0	0	0	25,56	1184,19	-0,03	0
29.10.2013	0	0	0	0	0	24,54	1153,48	-0,03	0
30.10.2013	1	0,26	1,09	0,34	1,18	31,06	949,69	-0,07	0
31.10.2013	4,64	0,97	2,74	1,2	3,74	47,81	178,3	-0,08	0
01.11.2013	0,22	0,1	0,32	0,01	0,29	45,19	38	-0,08	0
02.11.2013	0	0	0	0	0	35,26	0	-0,12	0
03.11.2013	0	0	0	0	0	38,42	1,5	-0,11	0
04.11.2013	0	0	0	0	0	38,25	0	-0,12	0
05.11.2013	0	0	0	0	0	35,27	0	-0,15	0
06.11.2013	0	0	0	0	0	30,94	0	-0,19	0
07.11.2013	0	0	0	0	0	30,93	0	-0,15	0
08.11.2013	0	0	0	0	0	31,17	0,3	-0,09	0
09.11.2013	0	0	0	0	0	27	0	-0,1	0
10.11.2013	0	0	0	0	0	29,34	0	-0,06	0
11.11.2013	0	0	0	0	0	31,23	0	-0,05	0
12.11.2013	0	0	0	0	0	35,98	0	-0,03	0
13.11.2013	0,2	0	0	0	0	44,01	0	-0,03	0
14.11.2013	0	0	0	0	0	42,5	0	-0,04	0
15.11.2013	0	0	0	0	0	41,03	0	-0,05	0
16.11.2013	0	0	0	0	0	39,66	0	-0,04	0
17.11.2013	0	0	0	0	0	38,36	0	-0,04	0
18.11.2013	0	0	0	0	0	36,78	0	-0,06	0
19.11.2013	0	0	0	0	0	32,32	0	-0,05	0
20.11.2013	7,16	1,35	9,06	0,96	9,01	37,5	52	0,05	50

21.11.2013	11,31	3,17	14,21	2,04	13,38	44,34	141	0,3	144
22.11.2013	8,54	1,15	5,28	0,61	4,62	46,59	56	0,2	62
23.11.2013	4,01	1,39	4,71	1,17	6,86	48,79	80	0,18	73
24.11.2013	0	0	0	0	0	39,23	0	0,08	1
25.11.2013	1,64	1	3,16	0,51	3,23	36,49	49	0,14	36
26.11.2013	10,3	3,75	14,81	2,44	16,12	47,57	152	0,39	190
27.11.2013	4,95	1,49	6,15	0,97	6,91	47,35	81	0,25	94
28.11.2013	3,5	0	0	1,06	4,82	47,32	37	0,13	35
29.11.2013	15,38	2,29	10,69	3,96	21,94	43,84	161	0,5	191
30.11.2013	7,11	2,24	11,68	1,21	11,07	42,95	97	0,34	121
01.12.2013	2,78	1,15	3,58	0,52	3,44	49,37	40	0,17	46
02.12.2013	7,33	0,11	0,57	1,79	8,42	48,83	55	0,24	75
03.12.2013	14,19	0	0	3,72	17,05	46,46	135	0,44	140
04.12.2013	12,67	0,21	0,61	3,16	17,08	46,45	108	0,4	117
05.12.2013	12,86	0,02	0,13	3,34	19,25	46,32	102	0,38	110
06.12.2013	12,18	0	0	3,2	14,42	50,12	100	0,31	101
07.12.2013	11,27	0	0	1,37	6,88	45,37	67	0,15	57
08.12.2013	5,06	0	0	1,21	6,43	35,03	48	0,09	135
09.12.2013	8,34	0	0	0,95	5,84	45,91	52	0,14	54
10.12.2013	0	0	0	0	0	26,08	2	0,05	20
11.12.2013	0	0	0	0	0	21,63	1	0,04	23
12.12.2013	0	0	0	0	0	20,57	2	0,04	21
13.12.2013	0	0	0	0	0	22,63	0	0,03	1
14.12.2013	0	0	0	0	0	21,65	4	0,03	0
15.12.2013	0	0	0	0	0	18,21	1	0,03	0
16.12.2013	0	0	0	0	0	22,79	3	0,04	0
17.12.2013	0	0	0	0	0	26,44	2	0,04	1
18.12.2013	0,02	0	0	0	0	28,47	1	0,04	0
19.12.2013	0	0	10,68	0	0,03	25,71	2	0,03	0
20.12.2013	8,15	1,77	10,1	0,51	9,77	36,84	150	0,24	363
21.12.2013	19,6	3,59	21,62	1,06	17,41	47,82	489	0,62	183
22.12.2013	9,22	0,78	4,53	1,57	10,75	46,38	212	0,32	87
23.12.2013	14,96	0,79	9,36	2,57	20,17	41,46	284	0,54	130
24.12.2013	5,21	0,83	7,72	0,6	6,47	47,47	131	0,2	229
25.12.2013	12,04	1,67	14,54	1,46	14,77	43,15	168	0,33	452
26.12.2013	12,88	1,84	18,24	1,24	18,61	47,62	172	0,43	392
27.12.2013	14,2	1,28	11,62	0,93	11,64	47,64	118	0,27	408
28.12.2013	21,18	1,41	12,39	1,1	12,87	44,94	129	0,28	186
29.12.2013	9,86	1,53	14,51	1,02	14,4	51,8	135	0,34	192
30.12.2013	11,97	1,27	12,02	0,88	12,21	48,81	164	0,33	163
31.12.2013	18,6	2,15	16,07	1,27	16,11	49,33	167	0,32	308
01.01.2014	8,71	2,04	13,56	0,64	8,37	49,93	125	0,23	420
02.01.2014	16,98	3,42	18,57	1,63	14,71	47,94	198	0,31	394
03.01.2014	15,55	2,28	9,95	1,37	9,94	44,23	123	0,14	417
04.01.2014	7,91	2,13	9,21	1,65	11,56	47,22	100	0,03	204
05.01.2014	2,34	0	0	0,62	3,84	49,3	21	-0,02	45
06.01.2014	11,26	2,57	13,61	1,7	13,4	47,55	102	0,03	213
07.01.2014	19,13	3,47	16,32	2,21	16,5	47,31	145	0,05	240
08.01.2014	4,04	1,42	5,75	1,03	5,8	46,8	47	0,01	105
09.01.2014	0,27	0,02	0,18	0,01	0,12	47,75	6	0,05	9
10.01.2014	0	0	0	0	0	48,7	3	0,01	8
11.01.2014	0	0	0	0	0	44,62	0	0	0
12.01.2014	0	0	0	0	0	38,97	0	0	0
13.01.2014	0	0	0	0	0	31,26	0	0	0
14.01.2014	4,75	0,87	5	0,45	5,01	28,69	27	0,02	47
15.01.2014	12,57	2,38	13,62	1,47	13,28	31,37	76	0,04	117
16.01.2014	17,24	2,33	19,27	1,47	18,76	43,83	91	0,13	170
17.01.2014	16,66	1,56	23,29	1,27	23,29	46,92	78	0,2	148
18.01.2014	10,57	1,73	14,36	1	14,06	48,37	91	0,13	302

19.01.2014	1,64	0,33	1,68	0,2	1,57	48,31	27	0,11	714
20.01.2014	3,56	0,43	4,74	0,24	4,69	46,53	26	0,13	678
21.01.2014	9,59	0,89	14,8	0,79	16,49	44,99	104	0,24	421
22.01.2014	2,57	0,15	3,74	0,11	3,64	35,77	183	0,36	142
23.01.2014	5	0	0,18	0,57	9,69	40,3	54	0,3	122
24.01.2014	3,36	0,44	3,99	0,24	3,75	44,26	108	0,26	81
25.01.2014	1,61	0,19	1,86	0,15	1,81	44,13	35	0,23	124
26.01.2014	6,82	0,45	5,79	0,67	10,28	42,34	75	0,22	117
27.01.2014	5,84	0,45	7,25	0,5	9,79	44,73	95	0,32	342
28.01.2014	8,47	0,85	14,33	0,72	15,21	45,59	142	0,38	251
29.01.2014	10,88	0,81	14,8	0,68	16,8	46	188	0,48	388
30.01.2014	7,5	1,18	9,01	0,96	8,93	44,12	102	0,24	143
31.01.2014	14,75	1,84	20	1,41	19,06	41,42	208	0,49	964
01.02.2014	6,08	1,18	7,93	0,81	7,69	47,09	69	0,38	951
02.02.2014	8,24	1,84	10,14	1,42	10,26	40,24	167	0,39	539
03.02.2014	10,95	2,15	13,13	1,39	13,42	40,82	180	0,4	829
04.02.2014	12,2	1,72	14,63	1,31	15,11	46,54	161	0,59	475
05.02.2014	8,21	1,29	9,75	1,08	10,39	41,93	172	0,39	492
06.02.2014	2,3	0,54	1,96	0,41	2,04	40,58	29	0,27	84
07.02.2014	9,1	1,35	11,52	1,06	11,48	43,28	120	0,43	237
08.02.2014	6,57	0,96	7,12	0,72	6,97	43,06	119	0,4	221
09.02.2014	7,09	0,84	5,02	0,55	4,58	46,07	67	0,27	91
10.02.2014	13,8	2,36	16,31	1,78	16,47	47,39	216	0,48	417
11.02.2014	5,92	0,98	9,09	0,74	8,71	45,95	93	0,38	275
12.02.2014	0,85	0,2	0,97	0,16	0,91	45,98	33	0,24	66
13.02.2014	12,09	1,47	16,66	1,26	15,72	46,41	205	0,46	954
14.02.2014	11,47	1,95	15,63	0,42	5,32	47,14	179	0,52	1106
15.02.2014	6,69	1,13	6,74	0,26	3,11	48,51	74	0,3	730
16.02.2014	0,94	0,1	0,82	0,07	0,76	51,8	6	0,15	561
17.02.2014	0	0	0	0	0	38,06	2	0,11	487
18.02.2014	1,43	0,11	1,21	0,1	1,17	43,59	13	0,13	112
19.02.2014	0	0	0	0	0	48,76	0	0,15	0
20.02.2014	11,62	3,01	12,73	2,01	12,61	45,15	253	0,32	236
21.02.2014	7,2	1,73	7,53	1,14	7,13	47,57	182	0,35	145
22.02.2014	4,37	1,15	6,75	0,78	6,85	49,57	115	0,26	95
23.02.2014	6,84	1,57	10,29	0,95	10,22	50,13	106	0,3	114
24.02.2014	8,05	1,12	9,98	0,76	9,67	49,49	115	0,41	308
25.02.2014	11,6	1,95	13,03	1,31	13,21	48,06	140	0,41	288
26.02.2014	1,82	0,4	3,42	0,2	3,26	59,09	24	0,36	449
27.02.2014	12,58	2,14	12,48	1,26	12,67	53,17	131	0,41	559
28.02.2014	18,4	2,93	20,02	2,55	21,45	47,45	282	0,59	811
01.03.2014	13,43	1,44	8,28	2,37	15,85	47,12	190	0,45	614
02.03.2014	16,91	0	0	3,07	21,71	47,92	207	0,58	965
03.03.2014	10,08	1,23	6,99	1,31	9,72	48,22	123	0,35	406
04.03.2014	19,19	1,86	14,41	1,53	13,83	48,17	141	0,37	1687
05.03.2014	12,8	2	16,81	1,48	15,94	47	226	0,46	2015
06.03.2014	9,42	0,82	5,48	1,46	11,2	46,63	164	0,37	1290
07.03.2014	15,19	2,49	15,45	1,35	9,96	46,8	306	0,49	1034
08.03.2014	9,2	1,05	11,37	1,12	11,05	47,66	197	0,37	1574
09.03.2014	5,4	0,56	5,48	0,53	5,43	48,63	128	0,33	479
10.03.2014	10,65	1,25	15,11	1,05	14,77	48,27	242	0,45	1056
11.03.2014	6,05	0,7	7,16	0,76	7,59	44,37	80	0,25	761
12.03.2014	18,77	2,54	22,83	2	22,79	46,69	262	0,88	366
13.03.2014	18,85	2,67	19,79	2,01	20,65	45,94	246	0,41	784
14.03.2014	9,97	1,57	11,3	1,14	11,19	44,07	116	0,25	264
15.03.2014	19,7	2,15	21,09	1,8	21,05	47	175	0,43	269
16.03.2014	14,78	1,57	19,48	1,47	18,95	47,11	179	0,4	262
17.03.2014	10,8	0,95	9,02	0,95	10,42	42,06	76	0,18	228
18.03.2014	21,91	2,78	23,99	2,2	22,6	45,86	146	0,58	1154

19.03.2014	15,83	2,98	16,02	2,63	15,67	44,36	164	0,27	1289
20.03.2014	19,07	3,07	15,9	2	14,62	42,61	152	0,06	292
21.03.2014	17,91	3,38	21,01	1,02	12,85	46	204	0,33	733
22.03.2014	15,33	2,87	19,86	2,14	19,32	48,43	158	0,65	1178
23.03.2014	14,77	2,17	16,32	1,87	16,01	48,21	131	0,69	1678
24.03.2014	19,57	1,88	12,8	1,34	12,87	49,02	92	0,62	457
25.03.2014	6,69	0,67	10,93	0,73	9,81	48,37	50	0,73	377
26.03.2014	4,97	0,99	6,18	0,8	5,82	47,89	40	0,51	1237
27.03.2014	13,32	0,65	8,99	0,5	9,05	49,54	72	0,61	1495
28.03.2014	9,34	1,61	11,59	1,13	11,77	49,11	112	0,63	1320
29.03.2014	0	0	0	0	0	27,19	5	0,07	360
30.03.2014	0	0	0	0	0	24,52	1	0,04	160
31.03.2014	0	0	0	0	0	22,22	0	0,04	116
01.04.2014	0	0	0	0	0	20,25	0	0,03	137
02.04.2014	0	0	0	0	0	20,56	0	0,02	89
03.04.2014	0	0	0	0	0	20,75	0	0,02	213
04.04.2014	0	0	0	0	0	20,23	0	0,02	308
05.04.2014	0	0	0	0	0	19,75	0	0,02	112
06.04.2014	0	0	0	0	0	19,38	0	0,02	110
07.04.2014	0	0	0	0	0	19,83	0	0,02	47
08.04.2014	0	0	0	0	0	19,67	0	0,02	83
09.04.2014	0	0	0	0	0	19,65	0	0,02	82
10.04.2014	0	0	0	0	0	19,36	1	0,02	241
11.04.2014	0	0	0	0	0	21,96	0	0,02	353
12.04.2014	0	0	0	0	0	48,9	0	0,02	26
13.04.2014	0	0	0	0	0	57,7	0	0,02	43
14.04.2014	0	0	0	0	0	60,78	0	0,02	42
15.04.2014	0	0	0	0	0	62,67	0	0,02	37
16.04.2014	0	0	0	0	0	64,11	0	0,02	68
17.04.2014	0	0	0	0	0	60,09	0	0,02	48
18.04.2014	0	0	0	0	0	46,14	0	0,02	22
19.04.2014	0	0	0	0	0	34,84	0	0,02	199
20.04.2014	0	0	0	0	0	28,59	0	0,02	157
21.04.2014	0	0	0	0	0	25,08	0	0,02	67
22.04.2014	0	0	0	0	0	22,93	0	0,02	42
23.04.2014	0	0	0	0	0	21,52	0	0,02	39
24.04.2014	0	0	0	0	0	20,4	0	0,02	191
25.04.2014	0	0	0	0	0	19,44	0	0,02	42
26.04.2014	0	0	0	0	0	18,56	0	0,02	239
27.04.2014	0	0	0	0	0	18,38	0	0,02	18
28.04.2014	0	0	0	0	0	18,27	0	0,02	60
29.04.2014	0	0	0	0	0	18,12	0	0,02	81
30.04.2014	0	0	0	0	0	17,45	0	0,02	26
01.05.2014	0	0	0	0	0	16,97	0	0,02	30
02.05.2014	0	0	0	0	0	16,69	0	0,02	126
03.05.2014	0	0	0	0	0	16,61	0	0,02	201
04.05.2014	0	0	0	0	0	16,5	0	0,02	113
05.05.2014	0	0	0	0	0	16,32	0	0,02	155
06.05.2014	0	0	0	0	0	16,43	0	0,02	108
07.05.2014	0	0	0	0	0	16,89	0	0,02	108
08.05.2014	0	0	0	0	0	17,04	0	0,02	37
09.05.2014	0	0	0	0	0	16,98	0	0,02	81
10.05.2014	0	0	0	0	0	17,21	0	0,02	148
11.05.2014	0	0	0	0	0	17,48	0	0,02	304
12.05.2014	0	0	0	0	0	17,46	0	0,02	460
13.05.2014	0	0	0	0	0	17,63	0	0,02	402
14.05.2014	0	0	0	0	0	17,67	0	0,02	10
15.05.2014	0	0	0	0	0	17,57	0	0,02	91
16.05.2014	0	0	0	0	0	18,38	0	0,02	172

17.05.2014	0	0	0	0	0	19,47	0	0,02	78
18.05.2014	0	0	0	0	0	20,23	0	0,02	127
19.05.2014	0	0	0	0	0	20,95	0	0,02	131
20.05.2014	0	0	0	0	0	21,84	0	0,02	138
21.05.2014	0	0	0	0	0	22,55	0	0,02	76
22.05.2014	0	0	0	0	0	23,13	0	0,02	56
23.05.2014	0	0	0	0	0	23,74	0	0,02	34
24.05.2014	0	0	0	0	0	23,99	0	0,02	20
25.05.2014	0	0	0	0	0	23,76	0	0,02	33
26.05.2014	0	0	0	0	0	23,25	0	0,02	15
27.05.2014	0	0	0	0	0	23,06	0	0,02	13
28.05.2014	0	0	0	0	0	22,97	0	0,02	13
29.05.2014	0	0	0	0	0	22,93	0	0,02	9
30.05.2014	0	0	0	0	0	22,8	0	0,02	5
31.05.2014	0	0	0	0	0	22,9	0	0,02	39
01.06.2014	0	0	0	0	0	22,91	0	0,02	131
02.06.2014	0	0	0	0	0	22,9	0	0,02	81
03.06.2014	4,24	0,33	1,3	0,73	4,64	32,7	69	0,18	202
04.06.2014	11,42	1,36	13,24	1,37	13,09	54,08	73	0,83	660
05.06.2014	8,53	1,02	9,5	0,62	7,28	53,43	81	0,77	1161
SUM	1274,65	184,27	1222,1	172,53	1387,55	-	27789,41	-	60615,35
AVG.	5,14	0,74	4,93	0,7	5,59	37,47	112,05	0,16	244,42
MAX	21,91	3,75	23,99	5,45	23,29	64,11	1277,18	0,88	2015
MIN	0	0	0	0	0	16,32	0	-0,19	0

D.4 THP

	Reaktor A		Reaktor B	
	Ant. Batch	Mengde	Ant. Batch	Mengde
Dato	ant	m3	ant	m3
03.10.2013	-	186	-	128
04.10.2013	-	260	-	229
05.10.2013	-	184	-	180
06.10.2013	-	316	-	264
07.10.2013	-	309	-	300
08.10.2013	-	260	-	130
09.10.2013	-	398	-	389
10.10.2013	-	0	-	63
11.10.2013	-	-	-	-
12.10.2013	-	-	-	-
13.10.2013	-	-	-	-
14.10.2013	-	-	-	-
15.10.2013	-	1860	-	1649
16.10.2013	-	252	-	131
17.10.2013	-	324	-	243
18.10.2013	-	368	-	189
19.10.2013	-	386	-	311
20.10.2013	-	267	-	310
21.10.2013	-	318	-	248
22.10.2013	-	306	-	330
23.10.2013	-	251	-	182
24.10.2013	-	318	-	319
25.10.2013	-	296	-	255
26.10.2013	-	337	-	273
27.10.2013	-	323	-	322
28.10.2013	-	392	-	258
29.10.2013	-	257	-	122
30.10.2013	-	465	-	404
31.10.2013	-	312	-	374
01.11.2013	-	400	-	259
02.11.2013	-	400	-	444
03.11.2013	-	401	-	329
04.11.2013	-	408	-	312
05.11.2013	-	272	-	187
06.11.2013	-	395	-	397
07.11.2013	-	392	-	267
08.11.2013	-	528	-	465
09.11.2013	-	267	-	257
10.11.2013	-	384	-	391
11.11.2013	-	249	-	217
12.11.2013	-	67	-	79
13.11.2013	-	74	-	67
14.11.2013	-	69	-	63
15.11.2013	-	67	-	55
16.11.2013	-	69	-	65
17.11.2013	-	104	-	0
18.11.2013	-	101	-	0
19.11.2013	-	115	-	11
20.11.2013	-	58	-	79
21.11.2013	-	55	-	65
22.11.2013	-	72	-	55
23.11.2013	-	66	-	68
24.11.2013	-	36	-	22

25.11.2013	-	46	-	33
26.11.2013	-	83	-	56
27.11.2013	-	68	-	62
28.11.2013	-	70	-	58
29.11.2013	-	76	-	69
30.11.2013	-	60	-	55
01.12.2013	-	79	-	51
02.12.2013	-	57	-	70
03.12.2013	-	71	-	71
04.12.2013	-	74	-	61
05.12.2013	-	73	-	64
06.12.2013	-	78	-	60
07.12.2013	-	79	-	71
08.12.2013	-	79	-	78
09.12.2013	-	65	-	67
10.12.2013	-	33	-	11
11.12.2013	-	0	-	0
12.12.2013	-	10	-	10
13.12.2013	-	0	-	0
14.12.2013	-	0	-	0
15.12.2013	-	10	-	11
16.12.2013	-	69	-	57
17.12.2013	-	78	-	76
18.12.2013	-	79	-	77
19.12.2013	-	64	-	55
20.12.2013	-	67	-	66
21.12.2013	-	82	-	80
22.12.2013	-	70	-	55
23.12.2013	-	0	-	34
24.12.2013	-	46	-	47
25.12.2013	-	31	-	22
26.12.2013	-	0	-	88
27.12.2013	-	22	-	48
28.12.2013	-	83	-	52
29.12.2013	-	83	-	80
30.12.2013	-	74	-	68
31.12.2013	-	82	-	79
01.01.2014	-	84	-	84
02.01.2014	-	85	-	79
03.01.2014	-	84	-	86
04.01.2014	-	74	-	89
05.01.2014	-	90	-	72
06.01.2014	-	87	-	79
07.01.2014	-	78	-	97
08.01.2014	-	71	-	59
09.01.2014	-	0	-	12
10.01.2014	-	0	-	48
11.01.2014	-	0	-	70
12.01.2014	-	0	-	0
13.01.2014	-	0	-	0
14.01.2014	-	12	-	11
15.01.2014	-	11	-	23
16.01.2014	-	95	-	69
17.01.2014	-	78	-	80
18.01.2014	-	71	-	67
19.01.2014	-	60	-	59
20.01.2014	-	47	-	34
21.01.2014	-	0	-	0
22.01.2014	-	22	-	0

23.01.2014	-	0	-	11
24.01.2014	-	23	-	11
25.01.2014	-	23	-	53
26.01.2014	-	0	-	65
27.01.2014	-	0	-	44
28.01.2014	-	47	-	48
29.01.2014	-	55	-	93
30.01.2014	-	67	-	66
31.01.2014	-	81	-	74
01.02.2014	-	46	-	34
02.02.2014	-	34	-	34
03.02.2014	-	63	-	48
04.02.2014	-	48	-	51
05.02.2014	-	0	-	0
06.02.2014	-	0	-	32
07.02.2014	-	0	-	54
08.02.2014	-	0	-	67
09.02.2014	-	48	-	59
10.02.2014	-	54	-	36
11.02.2014	-	62	-	24
12.02.2014	-	74	-	36
13.02.2014	-	52	-	58
14.02.2014	-	56	-	44
15.02.2014	-	62	-	68
16.02.2014	-	71	-	58
17.02.2014	-	55	-	58
18.02.2014	-	76	-	68
19.02.2014	-	73	-	72
20.02.2014	-	84	-	75
21.02.2014	-	34	-	75
22.02.2014	-	55	-	81
23.02.2014	-	56	-	77
24.02.2014	-	70	-	35
25.02.2014	-	71	-	46
26.02.2014	-	65	-	37
27.02.2014	-	82	-	59
28.02.2014	-	73	-	48
01.03.2014	-	75	-	80
02.03.2014	-	77	-	66
03.03.2014	-	65	-	74
04.03.2014	-	67	-	65
05.03.2014	-	54	-	55
06.03.2014	-	63	-	42
07.03.2014	-	64	-	77
08.03.2014	-	41	-	32
09.03.2014	-	42	-	10
10.03.2014	-	75	-	63
11.03.2014	-	62	-	53
12.03.2014	-	63	-	52
13.03.2014	-	76	-	82
14.03.2014	-	63	-	43
15.03.2014	-	54	-	60
16.03.2014	-	62	-	40
17.03.2014	-	43	-	30
18.03.2014	-	83	-	85
19.03.2014	-	73	-	81
20.03.2014	-	83	-	73
21.03.2014	-	83	-	84
22.03.2014	-	83	-	82

23.03.2014	-	84	-	84
24.03.2014	-	64	-	73
25.03.2014	-	42	-	32
26.03.2014	-	63	-	73
27.03.2014	-	76	-	72
28.03.2014	-	52	-	58
29.03.2014	-	66	-	54
30.03.2014	-	65	-	66
31.03.2014	-	75	-	46
01.04.2014	-	64	-	33
02.04.2014	-	43	-	34
03.04.2014	-	21	-	0
04.04.2014	-	87	-	87
05.04.2014	-	41	-	43
06.04.2014	-	53	-	32
07.04.2014	-	41	-	31
08.04.2014	-	84	-	73
09.04.2014	-	52	-	54
10.04.2014	-	44	-	43
11.04.2014	-	53	-	43
12.04.2014	-	87	-	85
13.04.2014	-	48	-	41
14.04.2014	-	0	-	0
15.04.2014	-	44	-	43
16.04.2014	-	76	-	75
17.04.2014	-	78	-	63
18.04.2014	-	0	-	30
19.04.2014	-	86	-	75
20.04.2014	-	64	-	72
21.04.2014	-	91	-	86
22.04.2014	-	81	-	81
23.04.2014	-	85	-	88
24.04.2014	-	87	-	86
25.04.2014	-	33	-	31
26.04.2014	-	63	-	52
27.04.2014	-	76	-	42
28.04.2014	-	21	-	30
29.04.2014	-	0	-	0
30.04.2014	-	17	-	42
01.05.2014	-	52	-	53
02.05.2014	-	55	-	32
03.05.2014	-	63	-	65
04.05.2014	-	32	-	10
05.05.2014	-	33	-	32
06.05.2014	-	20	-	11
07.05.2014	-	43	-	21
08.05.2014	-	42	-	20
09.05.2014	-	44	-	30
10.05.2014	-	54	-	53
11.05.2014	-	0	-	0
12.05.2014	-	0	-	0
13.05.2014	-	18	-	20
14.05.2014	-	33	-	33
15.05.2014	-	44	-	83
16.05.2014	-	52	-	63
17.05.2014	-	43	-	47
18.05.2014	-	63	-	52
19.05.2014	-	54	-	54
20.05.2014	-	76	-	62

21.05.2014	-	65	-	73
22.05.2014	-	79	-	62
23.05.2014	-	42	-	32
24.05.2014	-	0	-	0
25.05.2014	-	0	-	0
26.05.2014	-	22	-	19
27.05.2014	-	62	-	42
28.05.2014	-	55	-	43
29.05.2014	-	21	-	21
30.05.2014	-	21	-	19
31.05.2014	-	44	-	21
01.06.2014	-	55	-	43
02.06.2014	-	74	-	42
03.06.2014	-	40	-	50
04.06.2014	-	76	-	50
05.06.2014	-	44	-	32
SUM	0	24023	0	21388
AVG.	0	97,65	0	86,94
MAX	0	1860	0	1649
MIN	0	0	0	0

D.5 Digester A

	Bioreaktor A					
	Mengde inn	Kjøler, temp,inn	Kjøler, temp,ut	Temp nedre	Temp øvre	Mengde ut
Dato	m3	C	C	C	C	m3
01.10.2013	275,69	41,46	39,41	40,11	40,14	6510
02.10.2013	140,2	40,22	38,69	39,68	39,72	6521
03.10.2013	296,29	40,38	39,5	39,33	39,36	6066
04.10.2013	354,09	40,71	39,05	39,42	39,45	6503
05.10.2013	237	40,26	39,04	39,24	39,26	6452
06.10.2013	393,99	41,37	39,22	39,39	39,41	6399
07.10.2013	375,08	41,3	39,22	39,5	39,5	6398
08.10.2013	271,79	40,55	39,04	39,37	39,39	6416
09.10.2013	498,68	42,38	40,18	39,81	39,83	6383
10.10.2013	355,29	41,37	39,34	39,81	39,83	6386
11.10.2013	423,39	41,7	39,62	39,75	39,78	6344
12.10.2013	381,1	41,79	39,21	39,66	39,7	6341
13.10.2013	423,99	41,38	38,96	39,4	39,44	6403
14.10.2013	418,39	41,26	38,96	39,24	39,28	6379
15.10.2013	428,39	41,08	38,99	39,24	39,28	6399
16.10.2013	304,39	40,57	38,92	39,2	39,23	6418
17.10.2013	415,8	41,1	39,05	39,29	39,32	6313
18.10.2013	420,29	40,91	38,95	39,22	39,27	6350
19.10.2013	408,99	41,34	39,13	39,21	39,29	6299
20.10.2013	415,69	41,8	39,02	39,24	39,32	6362
21.10.2013	424,79	40,53	38,81	39,13	39,17	6318
22.10.2013	431,19	41,07	39,08	39,21	39,26	6329
23.10.2013	314,39	40,53	39,06	39,21	39,22	6311
24.10.2013	455,09	40,71	38,9	39,23	39,25	6262
25.10.2013	464,79	41,33	39,16	39,23	39,27	6305
26.10.2013	419,2	40,99	38,87	39,22	39,25	6306
27.10.2013	479,48	40,88	39,03	39,2	39,22	6552
28.10.2013	479,79	41,42	39,17	39,23	39,25	6287
29.10.2013	338,19	40,78	39,07	39,19	39,22	6292
30.10.2013	458,59	41,53	39,19	39,26	39,32	6256
31.10.2013	117	41,2	39,2	39,2	39,24	6085
01.11.2013	119,9	41,62	39,3	39,34	39,39	6288
02.11.2013	119,8	42,17	39,57	39,56	39,61	6290
03.11.2013	120,1	41,84	39,35	39,52	39,57	6277
04.11.2013	111,6	41,77	39,4	39,63	39,67	6292
05.11.2013	89,68	40,55	39,02	39,33	39,37	6279
06.11.2013	123,8	41,6	39,17	39,32	39,38	6289
07.11.2013	130,98	41,3	38,97	39,22	39,29	6303
08.11.2013	137,49	41,78	39,38	39,29	39,35	6317
09.11.2013	91,98	41,28	39,26	39,44	39,49	6284
10.11.2013	109,79	41,17	39,11	39,31	39,38	6302
11.11.2013	137,89	41,56	39,18	39,29	39,39	3678
12.11.2013	137,88	41,4	39,31	39,47	39,49	240
13.11.2013	139,99	40,66	38,87	39,14	39,3	240
14.11.2013	140,39	40,92	39,09	38,11	39,23	1319
15.11.2013	131,09	41,61	39,32	37,76	39,31	2397
16.11.2013	137,88	41,62	39,35	37,23	39,45	2398
17.11.2013	123,39	41,06	38,92	37,79	39,29	2398
18.11.2013	109,3	41,03	38,99	36,53	39,13	2398
19.11.2013	114,89	41,18	38,99	35,47	39,09	2398
20.11.2013	128,28	41,17	39,01	35	39,07	2398
21.11.2013	134,69	41,28	38,95	34,34	39,11	2398

22.11.2013	130,99	41,73	39,39	34,9	39,18	2398
23.11.2013	120,88	41,69	40,49	33,17	39,56	2398
24.11.2013	73	40,92	39,07	36,14	40	2256
25.11.2013	90,4	40,49	39,2	39,04	39,46	2283
26.11.2013	137,59	41,76	39,82	39,57	39,72	2417
27.11.2013	125,5	41,26	39,04	39,46	39,45	2398
28.11.2013	148,49	41,98	39,22	39,35	39,38	2398
29.11.2013	152,39	41,15	38,86	39,19	39,26	2398
30.11.2013	152,88	41,17	39,05	39,11	39,18	2397
01.12.2013	141,89	41,45	39,04	39,16	39,21	2398
02.12.2013	138,18	41,62	39,12	39,14	39,23	2398
03.12.2013	149,09	41,53	39,8	39,3	39,35	2398
04.12.2013	152,08	41,61	39,12	39,44	39,55	2397
05.12.2013	149,88	41,36	39,03	39,22	39,31	2398
06.12.2013	143,6	41,88	40,38	39,48	39,61	2398
07.12.2013	150,9	42,51	39,74	39,78	39,98	2398
08.12.2013	150,8	42,88	40	39,81	40,02	2402
09.12.2013	138,59	42,24	39,53	39,71	39,85	2398
10.12.2013	62,8	40,35	38,7	39,44	39,51	2398
11.12.2013	17,37	38,89	38,4	38,95	39	2398
12.12.2013	9,36	38,3	38	38,48	38,52	2398
13.12.2013	37,3	37,85	37,68	38,01	38,13	2397
14.12.2013	0,1	37,5	37,37	37,68	37,78	2398
15.12.2013	31,7	37,41	37,28	37,4	37,47	2398
16.12.2013	150,7	40,46	39,25	37,97	38,09	2397
17.12.2013	140,89	41,35	39,05	37,38	38,76	2398
18.12.2013	150	41,68	39,41	35,65	39,1	2398
19.12.2013	127,61	41,71	39,43	38,59	39,43	2397
20.12.2013	131,39	42,01	39,59	39,5	39,56	2398
21.12.2013	151,3	41,95	39,44	39,57	39,62	2397
22.12.2013	128,3	41,8	39,34	39,65	39,7	2398
23.12.2013	41,08	39,54	38,67	39,2	39,26	2397
24.12.2013	85,77	40,41	38,99	39,16	39,23	2398
25.12.2013	76,5	39,95	39,07	39,12	39,15	2397
26.12.2013	95,49	40,28	38,91	39,14	39,19	2398
27.12.2013	79,49	40,01	39,08	38,84	39,16	2398
28.12.2013	135,69	41,27	39,11	37,57	39,33	2397
29.12.2013	151,3	41,8	39,38	35,01	39,4	2398
30.12.2013	137,7	41,57	39,23	33,71	39,46	2397
31.12.2013	150,99	42,15	39,74	34,56	39,63	2398
01.01.2014	150,7	42,49	40,04	33,91	39,86	2397
02.01.2014	151,09	42,36	39,96	33,21	40,05	2398
03.01.2014	148,59	42,57	40,08	33,01	40,14	2397
04.01.2014	138,08	42,53	40,09	33,25	40,23	2398
05.01.2014	148,69	43,18	40,64	34,02	40,36	2397
06.01.2014	134,08	42,5	40,07	33,23	40,45	2398
07.01.2014	146,49	42,49	40,18	35,11	40,42	2397
08.01.2014	116,99	41,96	39,74	40,32	40,35	2398
09.01.2014	39,6	39,76	38,82	39,67	39,72	2398
10.01.2014	50,49	39,59	39,04	39,3	39,39	2398
11.01.2014	67,89	39,93	38,88	39,14	39,31	2398
12.01.2014	16,39	38,82	38,52	38,75	39,03	2397
13.01.2014	12,92	38,54	38,24	38,47	38,75	2398
14.01.2014	5,8	37,89	37,73	38,11	38,35	2398
15.01.2014	203,29	37,85	37,68	37,74	37,97	2398
16.01.2014	173,8	40,38	39,1	38,22	38,43	2398
17.01.2014	153,58	40,97	39,2	38,69	38,92	2398
18.01.2014	131	40,86	39,05	38,89	39,12	2398
19.01.2014	120,48	41	39,1	39,11	39,31	2398

20.01.2014	74,18	39,94	38,85	38,96	39,16	2398
21.01.2014	25,8	36,06	32,58	38,63	39,13	699
22.01.2014	5,8	33,23	32,75	38,52	38,97	0
23.01.2014	7,7	29,82	31,95	37,91	38,9	122
24.01.2014	50,79	39,21	38,81	38,59	38,86	2398
25.01.2014	81,5	40,07	39,02	38,73	38,96	2398
26.01.2014	82,39	40,28	39,01	38,84	39,06	2398
27.01.2014	57,3	39,69	38,92	38,87	39,05	2398
28.01.2014	98,27	40,62	39,08	38,95	39,09	2397
29.01.2014	137,3	41,37	39,3	39,01	39,18	2398
30.01.2014	146,49	41,52	39,03	39,12	39,33	2398
31.01.2014	121,19	40,74	38,98	38,89	39,08	2397
01.02.2014	89,09	40,07	38,75	38,8	38,98	2398
02.02.2014	76,59	39,53	38,56	38,84	38,91	2397
03.02.2014	102,49	40,12	38,96	38,84	38,9	2398
04.02.2014	96,39	40,25	38,81	38,99	39,07	2293
05.02.2014	5,9	38,5	38	38,62	38,71	2398
06.02.2014	51,49	38,59	38,29	38,28	38,38	2397
07.02.2014	76	39,31	38,98	38,6	38,68	2398
08.02.2014	81,89	39,53	39	38,85	38,93	2397
09.02.2014	107,71	40,1	39,09	39,02	39,08	2396
10.02.2014	118,49	40,37	38,95	39,13	39,16	2398
11.02.2014	102,01	40,04	38,99	39,11	39,16	2321
12.02.2014	130,79	40,92	39,39	39,23	39,29	2279
13.02.2014	108,99	40,67	38,97	39,27	39,36	2397
14.02.2014	111,4	40,75	39,09	39,19	39,25	2398
15.02.2014	126,78	41,36	39,39	39,28	39,36	2398
16.02.2014	133,2	41,65	39,52	39,54	39,6	2375
17.02.2014	109,88	41,1	39,05	39,3	39,39	2398
18.02.2014	143,39	41,33	38,88	39,14	39,28	2397
19.02.2014	146,5	40,88	38,95	38,97	39,12	2398
20.02.2014	148,91	40,97	38,99	39,04	39,18	2398
21.02.2014	143,1	40,77	39,01	39,1	39,17	2397
22.02.2014	135,4	40,79	39,09	39,17	39,22	2398
23.02.2014	140,11	41,16	39,01	39,24	39,3	2397
24.02.2014	145,2	40,69	38,92	39,18	39,21	2398
25.02.2014	154,7	40,66	38,99	39,17	39,2	2397
26.02.2014	112,91	40,39	38,92	39,13	39,19	2398
27.02.2014	130,3	40,74	39,2	39,19	39,24	2263
28.02.2014	169,5	41,33	39,24	39,34	39,41	2398
01.03.2014	153,9	41,46	39,29	39,42	39,49	2397
02.03.2014	148,89	41,3	39,19	39,44	39,51	2389
03.03.2014	172,81	41,63	39,61	39,58	39,67	2398
04.03.2014	168,5	41,9	39,87	39,97	40,05	2398
05.03.2014	123,9	40,97	38,91	37,72	39,89	2397
06.03.2014	152,09	40,93	39,26	36,43	39,56	2398
07.03.2014	154,19	41,44	39,37	39,62	39,67	2398
08.03.2014	86,71	40,22	38,72	39,44	39,49	2398
09.03.2014	77,19	39,88	38,86	39,28	39,33	2325
10.03.2014	141,39	41,11	39,39	39,43	39,46	2398
11.03.2014	129,5	40,92	38,94	39,46	39,52	2398
12.03.2014	138,79	40,92	39,02	39,34	39,39	2398
13.03.2014	162,01	41,67	39,44	39,53	39,58	2398
14.03.2014	117,29	41,24	39,47	39,78	39,82	2398
15.03.2014	112,4	40,88	39,2	39,61	39,64	2398
16.03.2014	111,2	40,96	39,17	39,78	39,83	2398
17.03.2014	81,28	39,92	38,79	39,37	39,43	2399
18.03.2014	171,81	41,68	39,57	39,63	39,69	2399
19.03.2014	156,61	41,8	39,81	40,09	40,18	2398

20.03.2014	163,69	42,2	40,15	40,29	40,35	2398
21.03.2014	168,89	42,78	40,75	40,67	40,7	2399
22.03.2014	169,89	43,47	41,51	41,26	41,31	2399
23.03.2014	158,51	43,63	41,44	41,75	41,8	2399
24.03.2014	147,71	43,48	41,47	41,76	41,81	2399
25.03.2014	91,37	42,43	40,62	41,61	41,66	2400
26.03.2014	137,01	43	41,27	41,38	41,43	2399
27.03.2014	143,6	43,19	41,24	41,39	41,43	2399
28.03.2014	122,39	43,22	41,27	41,64	41,68	2399
29.03.2014	119,49	42,59	40,48	41,22	41,26	2398
30.03.2014	133,4	43,11	41,32	41,27	41,31	2299
31.03.2014	139,9	43,36	41,04	41,58	41,61	2399
01.04.2014	96,09	41,87	39,28	40,72	40,79	2397
02.04.2014	76,91	39,96	36,9	40,26	40,35	1368
03.04.2014	46,61	35,17	32,94	39,98	40,29	730
04.04.2014	155,4	42,28	40,08	39,27	40,15	2398
05.04.2014	104,68	41,42	39,52	40,27	40,32	2399
06.04.2014	79,69	40,56	38,77	39,72	39,76	2398
07.04.2014	84,59	40,14	38,58	39,21	39,26	2398
08.04.2014	157,4	41,48	39,57	37,47	39,48	2397
09.04.2014	133,7	41,48	39,56	36,91	39,93	2398
10.04.2014	102,69	40,89	38,39	37,64	39,76	1845
11.04.2014	75,59	40,07	38,02	39,27	39,29	2153
12.04.2014	167,79	42,32	40,28	39,56	39,74	2440
13.04.2014	106,2	41,25	38,85	37,64	40,32	1763
14.04.2014	27,51	35,22	33,02	35,86	40,09	473
15.04.2014	84,49	40,03	38,41	39,26	39,36	2422
16.04.2014	148,68	41,41	39,21	37,96	39,24	2414
17.04.2014	142,1	41,78	39,8	36,37	39,69	2399
18.04.2014	33	38,99	37,53	35,83	38,86	2404
19.04.2014	156,79	41,08	39,18	35,84	38,7	2426
20.04.2014	154,7	41,14	39,26	36,61	39,14	2400
21.04.2014	172,1	42,25	40,13	36,94	39,66	2443
22.04.2014	179,69	42,49	39,87	37,57	40,08	2447
23.04.2014	188,11	42,42	39,52	38,06	40,06	2421
24.04.2014	187,81	42,33	39,53	37,34	39,97	2397
25.04.2014	99,29	40,8	38,73	36,53	39,68	2398
26.04.2014	101,98	40,25	38,48	37,75	38,92	2397
27.04.2014	140,98	40,94	39,34	39,16	39,22	2398
28.04.2014	72,22	41,95	36,22	39,43	39,47	873
29.04.2014	2,81	32,31	32,82	38,56	39,39	0
30.04.2014	114,68	36,08	36,19	38,04	39,2	1525
01.05.2014	126,61	40,6	39,17	39,06	39,1	2397
02.05.2014	109,48	40,47	39,08	38,66	39,24	2397
03.05.2014	137,41	41,14	38,64	35,82	39,44	1833
04.05.2014	52,31	39,34	37,61	35,48	39,06	2287
05.05.2014	76	38,9	36,35	38,73	38,84	1436
06.05.2014	51,89	37,28	35,53	38,75	38,88	970
07.05.2014	78,1	38,77	36,79	38,25	38,61	1870
08.05.2014	72,19	38,88	37,55	37,05	38,21	2398
09.05.2014	101,88	39,19	37,89	37,96	38	2414
10.05.2014	148,09	40,18	38,78	36,59	38,29	2407
11.05.2014	12,4	38,09	36,96	35,68	38,22	2425
12.05.2014	2,31	35,94	35,63	37,43	37,54	1735
13.05.2014	36,79	37,01	36,68	36,24	37,29	2174
14.05.2014	71	37,98	37,16	36,84	37,22	2409
15.05.2014	128,69	39,96	38,61	37,8	37,82	2398
16.05.2014	141,88	39,93	38,47	38,54	38,53	2398
17.05.2014	134,51	39,76	38,31	38,69	38,69	2397

18.05.2014	147,59	40,65	39,27	39,17	39,18	2398
19.05.2014	159,89	41,2	39,51	39,67	39,68	2398
20.05.2014	178,7	41,47	39,51	39,87	39,87	2397
21.05.2014	194,69	41,95	39,78	40,03	40,03	2398
22.05.2014	179,08	42,35	40,2	40,41	40,41	2398
23.05.2014	99,09	41,8	39,99	40,59	40,61	2444
24.05.2014	0,61	39,49	38,12	39,61	39,62	2397
25.05.2014	0	38,27	37,08	38,41	38,41	2397
26.05.2014	48,28	37,76	36,85	36,98	37,53	2398
27.05.2014	142,17	39,64	39,05	34,76	37,82	2397
28.05.2014	117,49	41,42	41,43	39,7	39,71	2429
29.05.2014	101,39	42,15	42,17	41,02	41,04	2397
30.05.2014	26,4	41,58	40,59	41,49	41,5	2398
31.05.2014	78,99	41,39	39,29	40,66	40,66	2398
01.06.2014	105,69	41,47	39,55	40,27	40,25	2397
02.06.2014	120,9	41,58	39,48	40,16	40,16	2397
03.06.2014	111,11	41,43	39,49	40,12	40,13	2398
04.06.2014	138,38	42,09	39,99	40,27	40,27	2397
05.06.2014	77,89	41,82	39,58	40,28	40,28	1399
SUM	36110,01	-	-	-	-	728902
AVG.	145,6	40,73	38,96	38,68	39,44	2939,12
MAX	498,68	43,63	42,17	41,76	41,81	6552
MIN	0	29,82	31,95	33,01	37,22	0

D6. Goods and products

	Produkt rejekt ut							
	Fast bio-gjødsel, containere	Flytende bio-gjødsel, tankbil	Konsentrert bio-gjødsel, tankbil	Rejekt containere for plastikk	Rejekt containere for fiber rejekt uren sone	Rejekt containere for sedimenter	Rejekt containere for metall	Rejekt container fiber ren sone
Dato	tonn	tonn	tonn	tonn	tonn	tonn	tonn	tonn
02.10.2013	29,52	-	-	2,18	-	-	-	-
03.10.2013	61,04	-	-	-	10,66	-	-	-
04.10.2013	-	-	-	5,1	-	-	-	-
05.10.2013	-	-	-	3,66	-	-	-	-
06.10.2013	-	-	-	1,9	-	-	-	-
07.10.2013	-	-	-	4,14	18,12	-	-	-
08.10.2013	-	-	-	2,14	11,98	-	-	-
10.10.2013	-	-	-	4,56	10,18	-	-	-
11.10.2013	16,32	-	-	0,9	4,36	-	-	-
14.10.2013	28,72	-	-	3,48	9,38	-	-	-
15.10.2013	-	-	-	2,78	8,86	-	-	-
16.10.2013	-	-	-	3,8	-	-	-	-
17.10.2013	-	-	-	0,36	12,08	-	-	-
18.10.2013	21,3	-	-	1,62	5,42	-	-	-
21.10.2013	-	-	-	2,64	10,2	-	-	-
22.10.2013	24,8	-	-	3,78	-	-	2,16	-
23.10.2013	-	-	-	-	12,38	-	-	-
24.10.2013	12,74	-	-	-	-	-	-	-
25.10.2013	-	-	-	6,6	6,96	-	-	-
28.10.2013	25,8	-	-	1,28	-	-	-	-
29.10.2013	15,06	-	-	3,96	14,1	-	-	-
01.11.2013	14,26	-	-	5,92	15,48	-	-	-
04.11.2013	-	-	-	5,1	-	-	-	-
05.11.2013	-	-	-	3,66	9,48	-	-	-
06.11.2013	18,04	-	-	1,9	6,46	-	-	-
07.11.2013	-	-	-	4,14	9,66	0	-	-
08.11.2013	39,6	-	-	1,48	-	-	-	-
11.11.2013	14,08	-	-	0,56	-	-	-	-
12.11.2013	-	-	-	5,38	16,64	-	-	-
13.11.2013	21,5	-	-	-	-	-	-	-
14.11.2013	21,46	-	-	9,34	14,44	-	-	-
15.11.2013	-	-	-	1,18	5,66	-	-	-
18.11.2013	44,24	-	-	5,32	-	-	-	-
19.11.2013	-	-	-	1,7	17,22	-	-	-
20.11.2013	21,12	-	-	4,28	6,3	-	-	-
21.11.2013	-	-	-	3,08	10,68	-	-	-
22.11.2013	9,28	-	-	2,54	10,28	-	-	-
25.11.2013	20,34	-	-	2,32	10,8	-	-	-
26.11.2013	24,26	-	-	4,3	8,92	-	0	-
27.11.2013	19,62	-	-	2,26	9,68	-	3,06	-
28.11.2013	-	-	-	2,48	4,7	-	1,42	-
29.11.2013	-	-	-	1,52	5,38	-	-	-
02.12.2013	-	-	-	7,68	22,44	-	-	-
03.12.2013	15,68	-	-	-	11,88	-	-	-
04.12.2013	-	-	-	3,78	12,56	-	-	-
05.12.2013	9,46	-	-	3,44	9,06	-	-	-
06.12.2013	19,8	-	-	0,58	9,16	-	-	-
09.12.2013	24,34	-	-	4,9	17,94	-	-	-

10.12.2013	8,38	-	-	-	-	-	-	-
11.12.2013	-	-	-	3,38	9,68	-	-	-
12.12.2013	-	-	-	1,48	4,14	-	-	-
16.12.2013	22,18	-	-	-	-	-	1,3	-
17.12.2013	-	-	-	2,48	8,52	-	-	-
18.12.2013	14	-	-	2,14	7,98	-	-	-
19.12.2013	16,26	-	-	-	-	-	-	-
20.12.2013	9,9	-	-	1,1	2,7	-	-	-
22.12.2013	-	-	-	5,02	-	-	-	-
23.12.2013	18,68	-	-	2,5	35,92	-	-	-
24.12.2013	-	-	-	2,02	2,84	-	-	-
26.12.2013	-	-	-	-	14,28	-	-	-
27.12.2013	-	-	-	-	11,24	-	-	-
28.12.2013	-	-	-	3,7	-	-	-	-
30.12.2013	39	-	-	3,1	19,52	-	-	-
02.01.2014	10,08	-	-	-	12,16	-	-	-
03.01.2014	9,26	-	-	7	9,34	-	-	-
06.01.2014	18,34	-	-	5,08	-	-	-	-
08.01.2014	19,9	-	-	6,3	-	-	-	-
09.01.2014	-	-	-	-	-	-	2,8	-
10.01.2014	8,58	-	-	1,2	4,9	-	-	-
15.01.2014	19,6	-	-	-	-	-	-	-
17.01.2014	20,12	-	-	3,16	6,84	-	-	-
20.01.2014	20,98	-	-	7,26	6,84	-	-	-
21.01.2014	-	-	-	0,86	9,98	-	-	-
23.01.2014	-	-	-	4,18	-	-	-	-
24.01.2014	-	-	-	0,22	4,28	-	-	-
27.01.2014	20,36	-	-	-	-	-	-	-
29.01.2014	18,24	-	-	2,8	10,2	-	-	-
30.01.2014	10,78	-	-	0,68	7,36	-	-	-
31.01.2014	-	-	-	1,06	6,82	-	-	-
03.02.2014	18,04	-	-	5,06	9,16	-	-	-
04.02.2014	8,18	-	-	5,32	7,78	-	-	-
05.02.2014	8,98	-	-	-	-	-	-	-
07.02.2014	14,42	-	-	4,44	3,1	-	-	-
10.02.2014	-	-	-	2,1	3,36	-	-	-
11.02.2014	35,32	-	-	-	-	-	-	-
12.02.2014	6,02	-	-	-	7,6	-	-	-
13.02.2014	-	-	-	2,16	3,54	-	-	-
14.02.2014	19,92	-	-	1,06	3,22	-	-	-
17.02.2014	22,1	-	-	2,62	9,6	-	-	-
18.02.2014	-	-	-	1,74	2,24	-	-	-
19.02.2014	21,58	-	-	3,08	25,02	-	-	-
20.02.2014	16,96	-	-	4,66	-	-	-	-
21.02.2014	9,7	-	-	2,2	2,76	-	-	-
24.02.2014	25,12	120	-	2,7	2,66	-	-	-
26.02.2014	20,1	-	-	4,18	-	-	-	-
27.02.2014	19,12	-	-	-	-	-	-	-
28.02.2014	15,94	-	-	4,26	11,32	-	-	-
03.03.2014	-	-	-	10,3	25,66	-	-	-
05.03.2014	-	-	-	5,66	-	-	3,44	-
07.03.2014	-	-	-	4,16	10,08	-	-	-
10.03.2014	-	-	-	2,36	6,72	-	-	-
12.03.2014	-	-	-	5,02	-	-	-	-
14.03.2014	-	-	-	4,18	14,02	-	-	-
17.03.2014	-	-	-	6,34	-	-	-	-
18.03.2014	-	-	-	4,66	-	-	-	-
19.03.2014	-	-	-	3,68	-	-	-	-
20.03.2014	-	-	-	3,48	-	-	-	-

21.03.2014	-	-	-	2,36	6,5	-	-	-
24.03.2014	-	-	-	11,34	9,26	-	-	-
25.03.2014	15,4	-	-	-	-	-	-	-
27.03.2014	-	-	-	7,28	4,8	-	-	-
28.03.2014	-	-	-	-	3,4	-	-	-
31.03.2014	-	-	-	8,9	23,42	-	-	-
01.04.2014	16,95	-	-	3,22	16,1	-	5,5	-
02.04.2014	-	-	-	-	7,98	-	-	-
03.04.2014	-	-	-	1,06	4,54	-	-	-
04.04.2014	-	-	-	1,32	3,9	-	-	-
07.04.2014	27,55	-	-	5,22	19,96	-	-	-
08.04.2014	-	-	-	-	13,26	-	-	-
09.04.2014	-	-	-	4,5	-	-	-	-
10.04.2014	-	-	-	4,32	10,52	-	-	-
11.04.2014	-	-	-	1,34	3,32	-	-	-
12.04.2014	26,9	-	-	-	-	-	-	-
14.04.2014	-	-	-	4,4	14,26	-	-	-
16.04.2014	15,8	-	-	5,06	-	-	-	-
17.04.2014	-	-	-	-	15	-	-	-
18.04.2014	27,5	-	-	-	-	-	-	-
19.04.2014	-	-	-	3,82	14,12	-	-	-
21.04.2014	17,5	-	-	-	-	-	-	-
22.04.2014	19,3	-	-	10,48	21,04	-	-	-
23.04.2014	17,2	-	-	-	-	-	2,72	-
24.04.2014	42,8	-	-	5,36	24,42	-	-	-
25.04.2014	11,45	-	-	-	18,32	-	-	-
27.04.2014	14,1	-	-	-	-	-	-	-
28.04.2014	36,25	-	-	2,88	7,3	-	-	-
30.04.2014	-	-	-	-	8,8	-	-	-
02.05.2014	-	-	-	2,2	4,62	-	-	-
03.05.2014	-	-	-	2,12	8,22	-	-	-
05.05.2014	16,95	-	-	1,96	5,8	-	-	-
06.05.2014	-	-	-	1,02	1,42	-	-	-
08.05.2014	-	-	-	1,92	-	-	-	-
09.05.2014	27,35	-	-	2,08	10,72	-	-	-
13.05.2014	18,65	-	-	-	-	-	-	-
16.05.2014	-	-	-	-	-	-	-	14,86
19.05.2014	-	-	-	8,18	17,04	-	-	-
20.05.2014	28,7	-	-	-	11,1	-	-	-
21.05.2014	-	-	-	4,84	-	-	-	-
22.05.2014	-	-	-	7,1	11,98	-	2,72	-
23.05.2014	-	-	-	3,16	5,54	-	-	-
28.05.2014	-	-	-	4,9	11,28	-	-	-
29.05.2014	-	-	-	5,42	10,36	-	-	-
SUM	1518,87	120	0	433,62	1071,18	0	25,12	14,86
AVG.	20,25	120	0	3,67	10,3	0	2,51	14,86
MAX	61,04	120	0	11,34	35,92	0	5,5	14,86
MIN	6,02	120	0	0,22	1,42	0	0	14,86