norden

rvf

Biological Waste Treatment in Norway and Sweden: What works well and what can be improved?

A synthesis of the nine projects in BUS

Translated by Vida Rozite

TemaNord 2006:551

Biological Waste Treatment in Norway and Sweden: What works well and what can be improved?
A synthesis of the nine projects in BUS

TemaNord 2006:551

ISBN 92-893-1368-4

Copies: Print-onDemand
This publication can be ordered on www.norden.org/order. Other Nordic publications are available at www.norden.org/publications

Nordic Council of Ministers
Store Strandstræde 18
DK-1255 Copenhagen K
Phone (+45) 3396 0200
Fax (+45) 3396 0202

Nordic Council
Store Strandstræde 18
DK-1255 Copenhagen K
Phone (+45) 3396 0400
Fax (+45) 3311 1870

www.norden.org

Nordic Environmental Co-operation

The Nordic Environmental Action Plan 2005-2008 forms the framework for the Nordic countries' environmental co-operation both within the Nordic region and in relation to the adjacent areas, the Arctic, the EU and other international forums. The programme aims for results that will consolidate the position of the Nordic region as the leader in the environmental field. One of the overall goals is to create a healthier living environment for the Nordic people.

Nordic co-operation

Nordic co-operation, one of the oldest and most wide-ranging regional partnerships in the world, involves Denmark, Finland, Iceland, Norway, Sweden, the Faroe Islands, Greenland and Åland. Co-operation reinforces the sense of Nordic community while respecting national differences and similarities, makes it possible to uphold Nordic interests in the world at large and promotes positive relations between neighbouring peoples.

Co-operation was formalised in 1952 when *the Nordic Council* was set up as a forum for parliamentarians and governments. The Helsinki Treaty of 1962 has formed the framework for Nordic partnership ever since. The *Nordic Council of Ministers* was set up in 1971 as the formal forum for co-operation between the governments of the Nordic countries and the political leadership of the autonomous areas, i.e. the Faroe Islands, Greenland and Åland.

The BUS project: Follow-up and evaluation of large-scale systems for composting and digestion of source separated biological waste

Project 1: Evaluation of large-scale systems for composting and digestion of source separated biological waste (RVF Development, report no. 2005:06)

Project 2: Methods to measure and reduce emissions from digestion and biogas upgrading systems (RVF Development, report no. 2005:07)

Project 3: Operational data collection via the Internet (no report)

Project 4: Collection of biological waste from apartment blocks - solutions and measures for comprehensive solutions (RVF Development, report no. 2005:08)

Project 5: Suggestions and recommendations for qualitative work with collection of source separated biological waste (RVF Development, report no. 2005:09)

Project 6: Use of biological fertiliser (RVF Development, report no. 2005: 10)

Project 7: Spread of infection via compost and biological fertiliser from treatment of organic waste - literature review and risk management (RVF Development, report no. 2005: 11)

Project 8: Organic pollutants in compost and biological fertiliser (RVF Development, report no. 2005:12)

Project 9: Emissions from composting (RVF Development, report no. 2005:13)

Project 10: Biological waste treatment in Norway and Sweden: what works well and what can be improved? A synthesis study of the nine projects within BUS (RVF Development, report no. 2005:14)

The BUS project is financed by:
- RVF - the Swedish Association of Waste Management
- The Swedish Environmental Protection Agency
- The Swedish Energy Agency
- NRF - the Norwegian Association of Solid Waste Management
- VA Forsk
- Reforsk

Preface

During the past years, significant investments have been made in systems for biological waste treatment. At the same time, the technology that is used in the plants is relatively new and is still being developed. Therefore, there are compelling reasons for evaluating existing plants. By collecting experiences from plant operations and by making this information accessible, new systems can be planned and constructed in a safer and better way. This is the main motivation for the series of evaluations that have been collected under the working title BUS. In the initial phase, experience and operational information has been collected from all parts of the waste collection, processing and product-use chain. This information has then been documented in a systemised manner in an *evaluation programme*. All project reports are accessible in electronic format. The entire framework programme has been summarised in this report that has been compiled by Jan-Olof Sundqvist, the Swedish Environmental Institute (IVL). The projects have been carried out and financed in cooperation between the Swedish Energy Authority (STEM), the Norwegian Association of Solid Waste Management (NRF), the Swedish Environmental Protection Agency, the Development Committee of the Swedish Association of Waste Management (RVF), the Swedish Waste Companies Research Organization (Stiftelsen Reforsk), and the Swedish Water and Waste Water Association (VA-Forsk).

June, 2005

Håkan Rylander	Weine Wiqvist
Chairman RVF, Development Committee	Executive Director, RVF

Content

Summary

The governments in Norway and Sweden have the aim of achieving an increased implementation of biological waste management. The motivation for this has mainly been to capture nutrients that can be returned to the soil and, primarily, to decrease the landfilling of waste that can be treated in other ways. Both in Norway and in Sweden, the governments have also emphasised the benefits of biological treatment of food waste as opposed to incineration of this waste. However, biological waste treatment has been connected to various problems such as the operation of plants, emission of odours etc.

During 2002-2004, a Swedish-Norwegian project for the follow-up and evaluation of large-scale systems for composting and digestion of source separated biological waste has been implemented. The project is entitled BUS (Biological waste treatment – evaluation of systems).

Several of the studies of the environmental aspects connected to biological waste management that have been conducted within BUS show that:

- Biological waste management is complementary to incineration for complying with the prohibition on landfilling organic waste.
- Biological waste management is an environmentally acceptable alternative to incineration. While the incineration of biological waste together with other waste is still a cheaper and more effective way to deal with the waste problem, biological treatment is an important step towards a sustainable society based on eco-cycling principles.

Within BUS, a comprehensive investigation of digestion and composting plants has been conducted. Many of the plants have various operational problems. Through BUS it has been possible to identify that the operational problems have had two main causes: 1) "wrong" waste has been accepted, and 2) wrong equipment choices have been made in the planning phases, often the mechanical equipment chosen has not had sufficient capacity. These problems can be addressed through a better control of the waste accepted, as well as through improved planning in regard to equipment and technology choices. Functioning equipment for biological waste treatment is available, but careful considerations need to be made in the planning and procurement phases.

Biological waste treatment is justly associated with odour problems. During the decomposition processes, odours are emitted and it is difficult to avoid dispersal. Through various measures it is possible to decrease the odorous emissions to a certain extent, but not completely. Therefore,

plants for biological treatment should be located with consideration to this and thus not be placed near residential areas.

Within BUS, issues such as economics, social aspects and work environment have not been subject to in-depth analysis. However, it is important to include these aspects in the planning of new systems and in the development of existing systems.

In connection to digestion and composting, it has at times been discussed whether the primary focus of operation is waste treatment that produces fertilisers or fertiliser production that at the same time treats waste. It may seem to be the same thing, but there is a difference in concern to what is the primary intent – to get rid of waste or to produce fertiliser. This issue is not further dealt with in this paper, but it should be emphasised that both aspects need to be taken into consideration when systems for biological waste management/fertiliser production are being planned.

Even if there are problems connected to biological waste management today, the solution is not to return to incineration or landfilling. Biological treatment complies with the fundamental expectations and aims of a sustainable system i.e. to attain recirculation of nutrients; however continued technological development is needed in all phases from consumers to fertiliser users.

As mentioned, the governments aim to increase biological waste management. The central question then is – who owns the problem? Up to date, most of the initiatives have come from the municipalities because they have the responsibility for the treatment of household waste and similar issues. However, apart from the municipalities, there are also other actors that are affected by the issue:

- Those that generate waste e.g. households, owners of residential buildings, restaurants and other enterprises.
- Those that use compost and biological fertiliser: the agricultural sector and companies dealing with land issues.
- Those that use biogas: energy companies, gas industry, gasoline companies and similar actors.

It is important that the systems for biological waste treatment are developed with the involvement of <u>all</u> actors in the planning, design and construction phases. There are several examples where such collaboration has taken place.

In the beginning of the 1980s, a comprehensive follow-up of the operation of plants for separating/composting and incineration was conducted (see chapter 5: Previous experiences). This investigation led to most of the plants for separation and composting being shut down. Incineration on the other hand, was developed. The technology for incineration was improved and the emissions were decreased by 50-98% for most of the emitted substances. Also the capacity for incineration has successively been increased. Biological waste management has a development potential today, which is similar to the one that was identified for waste incineration in 1985. BUS has shown that biological waste treatment is environmentally sound and technically feasible. What is needed to initiate a shift towards increased biological treatment is that someone clearly takes on the ownership of the issue and drives the development forward.

The BUS project has to a large extent been a collection and combination of existing knowledge on biogas and composting plants. During the work, several areas that require more development and research were noted. Some of the research and development needs that were identified are:

- Work environment
- Economics in a holistic perspective
- Social aspects
- Measurement of emissions from modern composting plants
- Development of steering and control systems for digestion
- Development of steering and control systems for composting
- Optimisation of operation of composting
- More knowledge on which waste types/materials give positive and negative effects on the digestion and composting process
- Methods for on-line characterisation of incoming waste
- Understanding of biological processes
- Markets for compost and bio-fertiliser
- Odour problem

1. Introduction

1.1 Background

Since the 1970s there has been a movement in Sweden towards the development of a waste management system with an increased utilisation of the waste. The development has been characterised both by successes and failures. Among the successes, the decrease of the quantity of waste landfilled without prior treatment can be noted. Failures are largely connected to new technology not working in a satisfactory manner. The government has used various regulations to develop the waste management sector. From the beginning of the 1970s, the main types of regulation used were economic subsidies to treatment plants and permit demands based on environmental legislation. Successively new regulatory tools have been developed such as producer responsibility, waste taxes and the prohibition of landfilling unsorted burnable waste and organic waste. The implementation of the EU-directives on the landfilling of waste (2001:512) and the ordinance on landfilling of waste (2002:1060) has also had impact on this development. The Swedish Parliament has in the national environmental objectives decreed that 35% of food waste shall be treated biologically starting from year 2010.

The development has been similar in Norway, where the composting of source separated household waste was initiated earlier than in Sweden. The Norwegian Pollution Control Authority discussed a landfilling prohibition of wet organic waste already in 1992; this was implemented in 2001 when the EU landfilling directive was enforced through the Ordinance on the landfilling of waste of the 21st of March 2002. This has led to a situation where municipalities that do not have access to incineration plants, have implemented programmes for the source separation and composting of wet organic waste to be able to continue landfilling the remainder of the waste.

Legislation and other regulatory instruments have led to an increased importance of biological treatment through digestion and composting since the beginning of the 1990s. In Sweden, approximately 800 million SEK have been invested in biogas production plants and close to 200 million SEK in composting plants. Currently, in Sweden there are 11 digestion plants for waste and 22 more advanced composting plants that treat source separated household waste. Since 1997, the establishment of these plants has been supported by the government through the state financial support for the municipalities´ local investment programme, the so-called LIP subsidies. In Norway the treatment of biological waste has also been developed during the past years. There is currently no updated overview of the number of composting and biogas production plants that treat source separated food waste from households in Norway. An overview made by NRF shows that there are approximately 30-40 large-scale plants. In year 2003 67% of the population of Norway source separated their household waste[1].

The construction of biological treatment plants has been connected to large technical challenges and entailed significant development work. Operational problems have been frequent. Many of the plants, especially composting plants, have had odour problems. Biological waste treatment can, therefore, still be said to be in a developmental phase and the need for robust and operationally stable systems that function for all types of organic materials and correspond to strict quality demands is significant.

During 2002 – 2004, a Swedish-Norwegian project for the follow-up and evaluation of large-scale systems for composting and digestion of source separated biological waste has been carried out. The project is entitled BUS (Biological waste treatment – evaluation of systems). The objective has been to evaluate large-scale systems for composting and digestion with biogas production.

The project has been financed by RVF (the Swedish Association of Waste Management), Reforsk (the Swedish Waste Companies Research Organization), the Swedish Energy Agency (STEM) through the Swedish Biogas Association, NRF (the Norwegian Association of Solid Waste Management) through the ORIO-programme, the Swedish Environmental Protection Agency and VA-Forsk (the Swedish Water and Waste-Water Association). The budget of the project was 4.8 million SEK. RVF has been the coordinator and main project leader. A steering group has been set up in connection to the project. The group had the tasks of a) monitoring the initiation and conclusion of the project in accordance with set plans in regard to scope, time-frame and quality, b) deciding on how to disseminate the project results, and c) deciding on how awarded funding should be used. The steering group included representatives from the financers and plant owners, as well as researchers. The steering group was composed of the following representatives:

- Kaj Andersson, Chairman of the Recycling Office in Gothenburg (Kretsloppskontoret Göteborg)
- Bengt Andersson, Malmö City, VA-Forsk
- Hanna Hellström/Leif Nilsson, project leader, RVF
- Owe Jönsson, the Swedish Gas Centre
- Anders Kihl, Ragnsells (REFORSK)
- Simon Lundeberg, the Swedish Environmental Protection Agency
- Henrik Lystad, NRF, the Norwegian Association of Solid Waste Management
- Per-Erik Persson, VAFAB

[1] http://www.sb.no/emner/01/05/10/avkomm/tab-2004-06-25-04.html

- Jan-Olov Sundqvist, IVL, the Swedish Environmental Research Institute
- Sigurd Tvedt, RKR, the municipal solid waste authority serving the Kristiansand region in southern Norway
- Weine Wiqvist, RVF

BUS has included projects carried out by different project leaders:
1. Basic evaluation and follow-up of digestion and composting plants. Project leader: SWECO.
2. Emissions from biogas plants. Project leader: SwedPower AB.
3. Development of a database for data collection. Project leader: Maersk Data.
4. Collection system for organic waste from apartment blocks. Project leader: MEPEX Konsult.
5. Routines for quality control. Project leader: RVFs Expert Group for Source Separation of Biological Waste.
6. The use of biological fertiliser. Project leader: Verna Konsult.
7. Avoidance of the spread of infectious disease. Project leader: SMI, the Swedish Institute for Infectious Disease Control.
8. Mapping of organic waste. Project leader: Jordforsk, the Norwegian Centre for Soil and Environmental Research, in cooperation with Aquateam, the Norwegian Water Technology Centre.
9. Emissions from composting. Project leader: SINTEF, the Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology (NTH) in cooperation with GLT-Waste and Jordforsk, the Norwegian Centre for Soil and Environmental Research.
10. Synthesis of the BUS project. Project leader: IVL, the Swedish Environmental Research Institute, in cooperation with the BUS steering group.

Each individual project has published a report (in the form of a RVF report, Swedish Environmental Protection Agency (NV) report and/or a STEM report).

1.2 Objectives of the synthesis project

The objective of the synthesis project is to make a collation of the other individual projects within BUS thus providing an overall summary of the projects and presentation of general conclusions, as well as, on the basis of the results, the identification of future research and development needs. Synthesis is here taken to mean a focus on information and conclusions that cannot be drawn from the individual projects, but that instead have to be based on the results of a combination of several projects.

2. Overview of BUS

2.1 Aim and objectives

The aim of BUS has been, in accordance with existing conditions, to evaluate large-scale systems for composting and digestion with biogas production, and to develop a follow-up programme. The purpose has been to secure these biological treatment systems on behalf of actors in the collection and treatment phase, distributors and end-users of compost and biogas, authorities and industry organisations. The above used phrase ”to secure these biological treatment systems...” is taken to mean making the processes more predictable, controllable and operationally stable, as well as the ensuring of a continuous market for gas and treated material (compost and biological fertiliser), so that biological treatment can become a link in a sustainable society.

The objectives of BUS have been:

- That the evaluation of existing systems shall lead to a collection of operational experience that is made accessible, so that new systems that are planned in Norway or Sweden or intended for export can be constructed and built in a safe and reliable manner based on local conditions.
- The development of a system for collection of operational data.
- The establishment of channels for the rapid sharing of experience from the programme.
- The establishment of contacts with plants and corresponding evaluation and follow-up programmes in other countries.
- To increase the knowledge of personnel working within biological waste treatment systems on how their systems and other systems are constructed and operate.
- To define existing research and development needs.

The long-term objectives of BUS have been that existing systems for biological waste shall:

- Have stable processes where uncontrolled operational disruptions, interruptions or unacceptable emissions do not occur.
- Have an acceptable working environment.
- Collect operational data that enables comparisons between different plants.
- Have as stable market for biogas and produced soil improvement material.

2.2 Overview of the individual projects within BUS

The individual projects were started up successively. The first project (BUS 1 – operation follow-up) started in the beginning of 2003. When the results from BUS 1 were accessible, new projects were formulated to cover the problems and knowledge gaps that were identified through, among other activities, the BUS 1 work. The other individual projects were carried out mainly during the autumn of 2004 and the winter of 2005.

It was a conscious decision to include the whole system from households to users of products in the scope of the projects. This is also seen in the project list which covers the whole chain.

When the prioritisation of project proposals was discussed, the steering group focused on project ideas that were primarily connected to technology and outer environment, since most of the uncertainties and problems are related to these issues. Economic aspects were not prioritised in the individual projects, a decision that was primarily based on the concerns of the steering group that the plants' willingness to participate in the investigations would decrease if extensive economic data was requested. Furthermore, many of the plants were in start-up phases or under reconstruction, which would have further contributed to the difficulties in collecting relevant economic data.

Social aspects have been superficially touched upon in some of the projects. An in-depth analysis of social aspects has not been conducted.

When selecting projects, also those dealing with aspects relating to work environment were not prioritised. The steering group determined that there was a greater need of the mapping of, for example, infection risks, gas leakage, and the conducting of an inventory of plants before relevant work environment projects can be initiated. In Norway, after the completion of BUS, a work environment project connected to biological waste treatment has been initiated by NFR.

An overview of the individual projects is provided in the following section.

2.2.1 BUS 1. Evaluation of large-scale systems for composting and digestion of organic waste

BUS 1 has been the largest and most important project. The work has mainly concerned a follow-up of the operation of 16 biogas plants, 13 gas upgrading plants and 10 composting plants (including 4 Norwegian plants). The operational follow-up was conducted with the help of questionnaires and visits to the plants. During the operational follow-up, information pertaining to, for example, mechanical and procedural operational stability for various types of plants, capacity of plants, and the influence of the design of plants on environmental impact, was collected.

During the project, the evaluation was expanded to also include a questionnaire covering the source separation of waste in the municipalities that send waste for treatment to the plants investigated. This part of the project included 36 Swedish municipalities, 12 Norwegian municipalities and 2 Norwegian waste companies (representing 13 municipalities).

An evaluation of the environmental impact of composting and digestion was also conducted during the project.

BUS 1 was conducted in coordination with a Swedish Environmental Protection Agency project for LIP-evaluation of biological treatment plants. Therefore, the project includes some parts that lie outside the actual scope of the BUS 1 project.

2.2.2 BUS 2. Emissions from systems with digestion and upgrading of biogas

Within BUS 2, the evaluation and testing of various instruments and methods to measure emissions from digestion and upgrading plants was conducted. Furthermore, through measurements, an estimation of the quantity and place of origin of emissions was made. Moreover, several possible measures for decreasing emissions have been proposed.

2.2.3 BUS 3. Data-base for data collection

In BUS 3 a data base for the management of data from plant operation was developed. RVF has started to use the operational data base.

2.2.4 BUS 4. Collection of biological waste from apartment blocks

Bus 4 includes a study of experiences from the collection of biological waste in apartment blocks. Previously, many municipalities have experienced that the quality of biological waste from apartment blocks is lower that the biological waste that has been collected from single family houses. Within the project, information on experiences was collected through meetings, study visits, telephone interviews and literature reviews. It was concluded that there is a potential for the collection of good quality biological waste, but that this requires special information and motivation measures.

2.2.5 BUS 5. Suggestions for work with quality control of source separated biological waste

Within BUS 5, an inventory of good examples on how the quality of collected biological waste can be improved was made. The purpose of the quality securing of biological waste is to ensure that the produced products have a market. The quality of the end-product is to a large extent determined by how well the households and enterprises source separate the material, but is also dependent upon factors such as proper collection and correct treatment at the plant.

2.2.6 BUS 6. Collation of experiences of using biological fertiliser in cultivation

Within BUS 6, a collation of experiences of using biological fertiliser in cultivation was made. A literature review of field trials in Sweden was conducted. Furthermore, farmers, biogas plants and organisations were interviewed.

2.2.7 BUS 7. Spread of infectious disease via compost and biological fertiliser from the treatment of organic waste

Within BUS 7, a literature review of the current knowledge on infection risks for humans connected to the use of products from composting and digestion was made. In addition, a discussion on risk management was conducted. It was concluded that various infection agents (pathogens) can potentially occur in organic waste. Various measures to decrease risks are discussed in the report.

2.2.8 BUS 8. Organic pollutants in compost and biological fertiliser

Bus 8 provides a discussion on which types of organic pollutants can occur in biological waste, compost and biological fertiliser. Also the impact of organic substances in the structural material is considered.

2.2.9 BUS 9. Emissions from composting

In BUS 9 a literature review on emissions from composting was made. The most important emissions were found to be:

- To air: CH_4, NH_3 and N_20 that primarily are formed during the actual composting process.
- To water (leachate from compost): metals, N, P, and organically degradable substance.
- Odour may occur from most parts of the plant.
- Micro-organisms can occur during the reception, preparation and composting phases.

The project also included an overview on how to decrease emissions.

3. Summary of results – synthesis

3.1 Collection of biological waste: techniques, economy, information and people (BUS 1, 4, 5)

The collection of biological waste has been dealt with in several of the BUS projects (BUS 1, 4, 5).

The technical collection system can be said to start in the kitchen with the waste generators and end by the reception of the plant. The projects BUS 1, 4 and 5 show that there are several different technical solutions for the various parts of the collection system, for example:

- Collection in households in paper bags, plastic bags, and starch bags (sometimes called bio-bags).
- External collections in indoor or outdoor waste collection areas. Collection can take place in closed containers, ventilated containers, paper bags etc. A new system that is being implemented is based on underground containers with waste chutes or similar structures above ground.
- There are systems that are based on joint handling with other fractions, e.g. in coloured plastic bags (”optibag”), that are then separated optically. There are also systems with multi-compartment containers where different fractions are collected in different compartments of the same container.
- Collection can take place with trucks with one compartment or trucks with several compartments.

Mainly in BUS 4 and BUS 5, and partially in BUS 1, more detailed descriptions on existing collections systems are provided.

The results of the three projects that are connected to collection show that there is no single system that can be seen as preferable in comparison to other systems. Most systems function well if they are implemented properly.

The collection of biological waste in apartment blocks has often been connected with low collection rates and high degrees of contamination. In BUS 4, an analysis of experiences in collection in apartment blocks is made. The results show that it is possible to attain a good collection with high collection rates and low contamination degree. The choice of collection technique seems to be less important than the actual communication with people, the pedagogical presentation and the design of the systems.

All three projects show that communication with users is an important part of the collection system. Communication should not be one-way, but must instead be a two-way dialogue. Information is provided by the municipality to the people/waste generators, but they must also be able to participate in the development of the system. Another important issue is the feedback of results. The best collection results have been attained in municipalities where home visits and information meetings have been conducted.

A well-functioning collection system must also be designed in a pedagogical manner. People's contact with the collection system starts in the kitchen where food waste and other biological waste is collected. It has, for example, been noted that collection in plastic bags can give higher rates of incorrect separation than collection in paper or starch bags. It is also important to view the collection system itself as an opportunity to convey information, for example, through printed bags, signs in collection areas etc.

Quality control is also an important issue, for more on this topic see chapter 3.2. Control of separation in connection to collection is also an important part of the ensuring of quality. It is, therefore, beneficial if the collection system is designed in a way as to facilitate this.

Separate collection of biological waste leads to high collection costs. In BUS 1, information from three municipalities indicates that the additional cost of separate collection is approximately 100-160 SEK per year and household. In addition, information costs can constitute 13-50 SEK per household in the start-up phase. The Swedish Environmental Protection Agency's Report 5177 (An Ecologically Sustainable Management of Waste) [2], mentions the amounts of 100 SEK per household per year (approximately 1000 SEK/ton) for apartment blocks and 170 SEK per household per year (approximately 1700 SEK per ton) for single family houses.

It can be debated whether separate collection of biological waste leads to increased transportation and thus increased environmental impact. According to BUS 1, the experiences of some municipalities show that the transport can increase, decrease or remain unchanged depending on how the collection system is changed. If a shift is made to a 14-day collection from a 7-day collection system, the transportation can decrease. However, if initially there is a 14-day collection system in place that remains unchanged, then the transportation can increase. The change in transportation can also affect the change in costs (see also the previous paragraph).

The collection of biological waste is also connected to an odour problem. According to BUS 1, it seems as though collection in paper bags has given rise to more complaints about odour than collection in plastic

[2] Naturvårdsverket Rapport 5177: Ett ekologiskt hållbart omhändertagande av avfall

bags. A partial explanation for this could be that the paper bags are handled in an incorrect manner.

It also seems apparent that also the treatment plant should participate in the design of the collection system. According to BUS 1, this has not occurred in one municipality and the municipality has developed the collection system without taking into consideration the requirements of the treatment plant.

3.2 Quality control of biological waste at the source and in the plant (BUS 5)

In BUS 5 it is stated that the aim of quality control is to make sure that the collected biological waste contains as little incorrectly separated material as possible. The primary reasons for this are:

- To get an end-product (compost, biological fertiliser) that is free from chemical and mechanical contaminants and that can be sold.
- To avoid the inclusion of such materials or substances in the waste that can give rise to problems in the treatment process.
- To ensure the inclusion of the waste components that give the desired characteristics to end-product or products, e.g. in regard to gas composition and nutrient content.

The quality control process should be conducted in several places in the management chain:

1. Control of the waste at the source, e.g. through visual random samples during collection.
2. Control of the waste during reception at the plant, e.g. through sample analysis of randomly selected deliveries.
3. Control of ready products before delivery of compost and biological fertiliser.

In the quality control process, it is also important that feed-back is provided to the households, both to individual households that source separate incorrectly and to the households collectively, so that the importance of the purity of the biological waste is conveyed. There are several ways of making households more aware of the importance of correct separation:

- Firstly, through feed-back and repeated contacts emphasise the importance of correct source separation. For example, this can be done by automated letters that are initiated by the collection personnel.

- Contaminated biological waste can be classified as unsorted waste or a similar categorisation. In cases of repeated contamination, an increase of waste fee could be warranted.

The report from BUS 5 provides additional suggestions on quality control.

3.3 Digestion: operation, environment (BUS 1, 2)

According to BUS 1, the biogas plants can be divided into three main types:

- Fertiliser-digestion plants for liquid or semi-fluid waste from industries (e.g. slaughterhouses). Some plants receive limited quantities household waste. The waste is pre-treated when it comes to the plant and has low levels of contamination. The plant is characterised by simple technology and high capacity.
- Complex plants intended to receive and treat household waste and other solid waste. This type of plant has technically more complex systems and demands pre-treatment on location in the form of shredding and sorting out of non-digestible material.
- Simple, small plants intended for receiving and treating household waste and other solid wastes. These plants have simple technology and low capacity, usually around 1000 – 5000 tons per year. This type of plant has been suggested as a simple, cheap system for smaller municipalities.

The evaluation made in BUS 1 shows that the types of operational problems that occur are:

- Fertiliser-digestion plants often have mechanical problems with their mixers. Further difficulties arise from steering the process, e.g. to avoid the occurrence of acidic hydrolysis.
- Complex plants for household waste are still being developed and there is limited operational experience. In existing plants, mechanical problems in the pre-treatment phase have often occurred.
- Simple, small plants for household waste are built accordingly and are also relatively cheap, so most of these have serious operational problems. Various types re-construction is currently taking place in all reviewed small plants.

The production of gas varies depending on the plant's capacity and what type of waste is digested. In the plants investigated, the generation of methane varied from 320 – 860 Nm^3 per ton incoming organic material (measured as VS – Volatile Substance). The level of decomposition in the remaining material/compost varied from 53 – 77%.

BUS 1 provides more detailed information on operational problems and capacity for the various types of plants.

The steering group has made the following analysis of the operational problems: The operational problems often arise from the "wrong" type of waste coming into the plant. As long as the input consists of the right type of waste, the plants function well. Part of the operational problems also stem from wrong choices in regard to equipment taken during the design and planning stage. Often the capacity of the equipment is too low and the equipment has not been produced for the type of incoming material that the plant receives. Problems connected to "wrong waste" can be solved through information to waste depositors and the development of a functioning quality control system for the collection phase. The problems connected to wrong choice of equipment can be addressed by improved exchange of experience and primarily through ensuring that the designers and project developers realise that waste is a complex material to manage.

Some emissions arise from the biogas plants. Environmental aspects related to biogas plants have been discussed in BUS 1 and BUS 2. It has been noted that the release of methane can occur from certain places in the plant, e.g. during the output of biological fertiliser and fertiliser storage. It is also important to note that emissions of nitrous oxide (N_20) are significant. Nitrous oxide occurs in relatively low concentrations but is an aggressive greenhouse gas. 1 kg nitrous oxide corresponds to 310 kg carbon dioxide, while 1 kg methane corresponds to 23 kg carbon dioxide. According to BUS 2, this leads to a situation where the impact on climate change from nitrous oxide emissions, at certain emission points, is of the same significance as the impact on climate change from methane emissions (however, seen from the whole plant, the methane emissions are deemed to be dominant). The measurements made within BUS 2, show that the methane losses in well-dimensioned and well-managed plants are approximately 0.5-1% of the produced methane. There should thus be a potential possibility to reduce these emissions.

The emission of odorous substances is primarily connected to the ventilation process from sanitisation tanks and biological compost tanks.

3.4 Biogas: upgrading (BUS 1, 2)

The upgrading of gas aims to separate the carbon dioxide from the biogas, so that the end-product consists mainly of pure methane. The upgraded gas can then be used as vehicle fuel or be fed into the natural gas network, in places where this is possible. In cases where the gas is intended for district heating production, it is not necessary to upgrade it. The experiences from upgrading are varied. Early plants sometimes had, according to BUS 1, operational problems and large emissions. Newer plants with more modern technology show better results. The problems in the early plants were primarily caused by incorrect dimensioning in combination with the wrong choice of machinery, e.g. drying equipment and compressors.

In the evaluation of operations, conduced during BUS 1, it was found that the plants only used part of their capacity. The main cause for this seems to be that insufficient quantities of biogas were produced in the associated biogas plant.

The environmental impact caused by upgrading is related to methane emissions to air, primarily the unextracted methane in the residual gas. Some of the older plants have had significant methane emissions, while newer plants have had much lower emissions. BUS 2 shows that the emissions today are 1-4% of the incoming crude gas; however, it should be possible to reduce this in future plants. Searching actively for leaks is an important method to decrease methane emissions. BUS 2 provides various examples of leakage-prevention measures.

3.5 Biogas use

BUS 1 provides an overview of environmental aspects from biogas use. Biogas can be used in the following ways:

- Part of the biogas is always used internally for heating the waste that is being sanitised and for other internal heating.
- Biogas can be used to produce district heating, e.g. through combustion in boilers by the plant where the heat is captured through heat exchange with the existing district heating networks (the returning pipe).
- Biogas can be upgraded and used as vehicle fuel.
- Biogas can be upgraded and fed into the natural gas network. This is not done today in any of the plants studied, but there are some examples from the waste-water sector.
- Biogas can also be used to produce electricity and heat in gas motors or smaller gas turbines. However, according to BUS 1, this is not done in any of the plants today.

The use of biogas as an energy source makes it possible to decrease the use of other fuels. If biogas is used as a vehicle fuel, fossil diesel or gasoline can be replaced. If biogas is used for district heating production, it mainly replaces other bio fuels (however, types of fuels vary in different municipalities depending of the district heating system used). **In regard to this issue, the steering group disagrees with BUS 1 that states that the use of fossil fuels can be decreased by using biogas in district heat production, since actually oil is used in district heating systems only at peak loads, while biogas would be used for base loads and thus compete with, for example, other bio fuels and waste incineration.**

BUS 1 provides an overview of the environmental aspects connected to the various uses of biogas. It is shown that biogas use leads to decreased emissions from fossil carbon dioxide and nitrogen oxides.

3.6 Composting: operation and environment (BUS 1, 9)

3.6.1 Operation

Composting plants have mainly been dealt with in BUS 1. In BUS 9 a collation of emissions from composing has been made.

In BUS 1, composting plants are divided into three main types (note: the steering group has amended some of the definitions provided in BUS 1):

- Open composting without regulated aeration. This type of plant contains very simple technology where aeration is conduced through manual turning of the material; this type mainly includes mechanical windrow composting.
- Static pile composting with regulated aeration. Also this type of plant is relatively simple, but includes regulated aeration. The process is open (windrow) or enclosed (membrane composting).
- Dynamic, enclosed composting with regulated aeration. This type of composting requires more complex technology. The process takes place with automatic mixing and regulated input of air and is represented by automatic container composting with regulated aeration.

The composting plants that have been studied in BUS 1 show, with some exceptions, a very good level of mechanical operational stability. The limited number of problems that have been experienced are mainly related to material handling in automatic systems i.e. similar problems to those at biogas plants like problems with feeding in or mixing of material, blockages etc. Most of these problems can be solved through the adjusting of the systems.

Naturally, the risks for machinery problems increase the more machine intensive the used technology is. BUS 1 mentions that an earlier container composting plant in Gothenburg had to be shut down and be rebuilt with simpler technology due to the considerable operational problems with the used machine intense technology. However, according to a representative from Gothenburg (Kaj Andersson, the Recycling Office), the actual cause of the problem was not the machine intense technology, but rather incorrect equipment choices – the plant was, namely, constructed for composting of sludge, but was instead used for the composting of household waste.

In the plants that were studied the level of decomposition[3] of the compost out-put was 44-50%. The quantity of produced compost was 680-760 kg per ton household waste, including added structural material, the quantity of which varies between 180 – 530 kg per ton waste.

In BUS 1, various principles for the steering of composting processes are discussed. Stability tests (testing of maturity) are conducted on ready compost, which gives good and appropriate practical information for the operation (i.e. to attain stable compost), but is a rather coarse measurement for process steering. Stability tests do not provide sufficient information to determine the level of decomposition in the compost. How well the actual compost process, i.e. the aerobic decomposition, actually is functioning is in most cases difficult to measure today (despite the fact that stable compost is attained).

In BUS 1, it is proposed that the level of decomposition [(VS_{in} – VS_{out})/VS_{in}] per unit of time is probably the most reliable measurement of the effectiveness of a composting process and that this value could, therefore, be used as a point of reference for process and energy optimisation. During the BUS-seminar on the 27th of April, 2005, the possibility to steer processes through the analysis of emitted air was also proposed.

The process control in the composting plants is, according to BUS 1, currently functional as seen from a practical operational perspective, but is insufficient from a process-oriented viewpoint. It is considered that there is generally insufficient knowledge about and understanding of the biological processes.

While automated closed container composting processes are the most expensive, according to BUS 1, they probably have the best preconditions to attain the most effective composting process (i.e. rapid aerobic decomposition). If the given process rates for various methods are compared, it is, however, unclear whether effectiveness measured as the speed of the composting process can motivate the larger investment requirements. Instead, the potential environmental benefits in the form of deceased

---

[3] The level of decomposition is measured as the amount of organic material that has been decomposed per amount initial organic material in the waste.

emissions to air (including odour) of an automated process and completely enclosed plant could provide this motivation. Experience from many plants in Central Europe shows that operational accessibility in automated plants is low, which also seems to be confirmed by the now reconstructed plant in Gothenburg.

Windrow composting with turners is considered by BUS 1 to have less potential to reach good aerobic conditions. In many cases there is a risk that part of the decomposition takes place anaerobically in these types of plants. This gives rise to increased environmental impact in the form of emissions to air from the compost. This has been confirmed by, among others, a Norwegian study.

More data on performance is provided in BUS 1.

In connection to this, the steering group has discussed the pros and cons of simple and more advanced technology. To reduce emissions and ensure sanitation of the compost, more advanced technology is warranted (e.g. enclosed composting and treatment of the emitted air). However, simple technology may be warranted during an initial phase when the composting system is being established. It is then possible to successively develop the collection and attain increased knowledge about quantities and waste qualities before the system is bound to a larger plant.

3.6.2 Environment (emissions)

The environmental impact from composting plants takes various forms: odour, gas emissions, emissions of micro organisms and waterborne emissions (leachate from compost).

The odour problem is the most widespread and frequently discussed problem. According to BUS 1, most plants report that odour is emitted during the normal course of operations. The design of the plant and the degree of enclosure has a significant importance on odour dispersing to the vicinity, thus open processes have a bigger odour problem and correspondingly enclosed processes have a greater possibility to provide an odour-free environment for nearby inhabitants. A badly functioning composting process is the main culprit in regard to odour. According to BUS 1, Windrow composting with turning gives rise to most of the process related odour problems.

In BUS 9, a deeper analysis of emissions from composting is provided. It is shown that emissions of micro-organisms can be expected to occur in all parts of the plant. Carbon dioxide, methane, ammonium and nitrous oxide emissions stem from the actual composting process. The carbon dioxide from composting is usually classified as biogenic carbon dioxide and thus not impacting on climate change, while methane and nitrous oxide are classified as greenhouse gases. The quantities of emissions are largely dependent upon the type of plant; an enclosed plant gives rise to less emission than an open plant. During open composting, a large part of the emissions occur when the compost is turned. It can thus be claimed that a more advanced technology gives rise to less emissions.

The literature review in BUS 9 provides the following quantities of emissions that have been reported during various studies:

- Methane emissions are in the range of 0.01 – 11 kg/ton waste (0.2-230 kg CO_2 equivalent per ton waste).
- Nitrous oxide emissions are in the range of 0.001-0.4 kg/ton waste (0.3-120 kg CO_2 equivalent per ton waste). It can thus be said that nitrous gas emissions are as significant as methane emissions.
- Ammonia emissions are in the range of 0.02 – 1.2 kg/ton waste.

3.7 Use of biological fertiliser and compost: environment and benefits (BUS 6, 7, 8)

The use of biological fertilisers has mainly been reviewed in BUS 6, while the issue of the spread of infections has been covered in BUS 7 and the issue of organic pollutants in biological fertiliser and compost has been examined in BUS 8.

3.7.1 The benefits of biological fertiliser in cultivation

The benefits of biological fertilisers and compost can be viewed from various time perspectives. In a long-term perspective, for example, the sustainable recirculation of nutrients is important. In a shorter time perspective the more direct impact on yield is important. In BUS only the short-term aspects have been taken into consideration.

In BUS 6, an overview of the benefits of biological fertilisers has been made. Cultivation trials that have been conducted show large differences in attained yields. Trials on grain cultivation with biological fertilisers show yields of 68-146% compared to cultivation with corresponding quantities commercial fertilisers; most of the values are around 100%. This shows that the biological fertilisers' content of total nitrogen has in most cases been as accessible as nitrogen in commercial fertilisers. The variations in results indicate that several other factors influence yields such as, for example, the characteristics of the soil.

The attitude of farmers towards biological fertilisers is significant for the outlet possibilities. In BUS 6 interviews with, among others, farmers were conducted. The results from the interviews show that the contacted farmers were positive towards biological fertilisers. The farmers stated that in practice, it is calculated that approximately 70-80% of the nitrogen in ammonia in biological fertilisers is accessible. The farmers have also indicated that they usually have good communication with the plants producing biological fertilisers.

3.7.2 Environmental impacts

3.7.2.1 Environmental benefits

Biological fertilisers and compost are considered to have several benefits when they are used as soil improvement agents. They contain nutrients such as phosphorous, nitrogen, potassium and lead to a decreased use of commercial fertilisers. The organic material also gives a range of other benefits in the cultivation process, for example, improved water retention capacity, increased resistance to disease, increased heat retention capacity etc. that lead to increased yields. The environmental benefits of compost and biological fertilisers are discussed in detail in a Jordforsk report[4]. In the Jordforsk report, the benefits are also quantified in economic terms.

In accordance with the governmental vision on the recycling of nutrients, almost all of the biological fertiliser produced in the biogas treatment plants is returned to the agricultural sector.

The use of compost can be discussed. Compost has real benefits when its nutrient and structural material content is utilised, for instance in gardens or in agriculture (however, today practically no compost is used in agriculture). In these cases, the compost can replace commercial fertilisers and gardening peat and is part of a long-term sustainable nutrient cycle. However, the use of compost for other more passive applications such as ground cover in shooting courses and golf courses is more questionable.

3.7.2.2 Gas and water emissions in the use phase

After delivery to farms, biological fertiliser is stored, often in open containers. This leads to the storage phase giving rise to emissions of methane, including retained volatile methane in the fertiliser and new methane that is formed if the decomposition process has not been completed.

3.7.2.3 Spread of infections

The issue of the spread of infections due to the use of biological fertilise and compost is often discussed. These issues are covered in BUS 7. In BUS 7 it is emphasised that waste from slaughterhouses and manure often includes pathogens. Also garden waste and waste from parks may include pathogens, e.g. excrements from animals. During composting and digestion, organic material is stabilised, at the same time as sanitation

---

[4] Henrik Lystad, Kristin Magnussen, Arne Grønlund, Jan Netland and Øistein Vethe, Socioeconomic benefits in connection to the use of products from biologically degradable waste in soil. [Samfunnsøkonomisk nytte ved användelse av produkter fra biologisk nedbrytbart avfall i jord.] Jordforsk rapport nr. 4/03. Can be ordered from Jordforsk: http://www.jordforks.no or as a pdf file http://www.jordforsk.no/rapporter/4-03.pdf

takes place if the temperature is high enough. The correct temperature during a sufficiently long time period is considered to be vital for the elimination of infectious agents. In biogas plants for manure and slaughter waste, a sanitation process at a temperature of +70ºC for one hour is required. This significantly decreased the presence of infectious agents. Even if pasteurisation is conducted prior to the main process, the end-product may still be sensitive to re-infection and re-growth, which means that bacteria can grow in the material even from low levels. It is, therefore, crucial that the subsequent handling, transport and possible storage are conducted in a hygienically acceptable way. The Swedish Environmental Protection Agency provides information on suitable temperatures and heating duration for compost in its general recommendations. Covering compost decreases exposure risk for humans and animals and provides a more homogeneous temperature distribution and thus a safer sanitisation of the product. Composting in the temperature range of >50ºC usually ensures a safe product.

The selection of materials, process requirements and restrictions on handling and use of products are measures through which the risks for spreading infection are currently contained. This is achieved by use of legislation, regulations and voluntary agreements. The primary aim is to keep the presence of infections agents at a level where the use of compost and biological fertiliser does not contribute to an increased occurrence of illnesses in society. Of course, it is possible that something in the process goes wrong and it is also possible that existing control systems do not detect this. Therefore, the possibility that pathogens enter the environment through the use of compost and biological fertiliser cannot be excluded. However, the probability that considerable quantities of pathogens enter the environment is considered to be low. In addition to good control of the whole management chain, for example, through the certification system, it would also be desirable, in the future, that the assessment parameters for compost and biological fertiliser are further developed.

3.7.2.4 Organic compounds in compost and biological fertiliser

The literature review conducted in BUS 8 shows that a number of different organic compounds (organic environmental toxins) can be present in incoming waste. For example, the concentrations of such substances are higher in park and garden waste from cities than from rural areas. Organic substances may also occur in the structural material that is used. There is also an apparent tendency for larger amounts of organic substances to be present in biological fertiliser than in compost. This is probably due to the composting process leading to the decomposition of more organic compounds than the digestion process.

Based on the findings in BUS 8, the concentrations of toxins are so low that they increase the risk of human exposure to dangerous organic substances only to a very limited extent. According to current knowledge on the effects of organic compounds on soils, the use of compost and biological fertiliser will not lead to negative impacts on soil micro-organisms.

3.8 Overview of environmental aspects – system aspects

The environmental benefits of biological treatment have been investigated in several life-cycle studies and system studies in Sweden[5] and Norway[6]. The Swedish system analyses have shown that incineration and biological treatment of food waste are difficult to compare. All methods have pros and cons and according to the analyses, neither method is environmentally preferable to the other. The findings in BUS do not contradict this conclusion.

On the basis of the previously conducted life-cycle analyses and the results attained by BUS, it is possible to coarsely rank the various biological methods according to the following hierarchy with regard to environmental benefits:

1. Digestion where biogas is used to replace fossil fuels, e.g. used as vehicle fuel.
2. Digestion where biogas is used to replace bio fuels, e.g. in district heating systems.
3. Enclosed composting where the emitted air is treated.
4. Open composting without air treatment.

Compared to landfilling all biological treatment is environmentally beneficial. Compared with incineration, at least digestion with use of biogas as a vehicle fuel provides the same level of benefit. The outcome of comparisons depends on how various types of environmental impacts are evaluated. In the life-cycle analyses, consideration has not been taken to the benefit of the recycling of phosphorous (a non-renewable natural resource); neither have the benefits of the structural material in biological fertiliser and compost been considered (see section 3.7.2.1 Environmental benefit).

---

[5] See, for example, Sundqvist J-O, Finnveden G, Sundberg J. (2002b), Synthesis of system analyses of waste management. [Syntes av systemanalyser av avfallshantering]. IVL Report B 1491 http://www.ivl.se

[6] See reference in footnote 3

It can be concluded that:

- Biological waste treatment is a complement to incineration for the compliance with the prohibition on landfilling organic waste.
- Biologic waste management is an environmentally acceptable alternative to incineration.

4. Evaluation of the BUS project

4.1 Work method

4.1.1 Steering group

BUS has been led by a steering group. The steering group has been the project's executive decision-making body and has determined the significance of contracts and other formal agreements, as well as decided on the initiation and the acceptance of individual projects. The tasks of the steering group have been to:

- Monitor the initiation and conclusion of the project in accordance to set plans in regard to the scope, time-frame and quality of the project.
- Decide on how the project results are to be disseminated.
- Decide on how the assigned funds are to be used.

To carry out its work, the steering group has appointed a project leadership that has been composed of personnel from RVFs chancery.

In accordance to the set conditions, the steering group members were expected to be active in the work during the whole project. The members in the steering group have participated at their own expense (in regard to time and work). The project has covered travel and board for the participants in the steering group's work. Procurement of sub-consultants has been conducted through a tendering process and the steering group has made decisions based on a review of the tenders.

The results of the steering group's work are evaluated positively. The steering group has functioned according to plan.

4.1.2 Cooperation between Norway – Sweden

BUS has entailed cooperation between Norway and Sweden. NRF has provided financing and participated in the steering group. Several of the individual projects have been carried out by Norwegian sub-contractors. It should be mentioned that Norwegian and Swedish consultants have competed against each other in the tendering process for all the individual projects, aside from BUS 1, and that the choice of consultants has not been politically directed, instead contracts have been awarded to the best proposals.

The cooperation between Norway and Sweden has been positive in regard to all aspects. Norway and Sweden have similar problems and both countries have different research groups and consultants with significant competence in the area. Through cooperation, the project has been able to reach further than would have been possible with only Swedish participation. Furthermore, BUS has led to the establishment of a platform for continued Swedish-Norwegian cooperation within the waste area.

4.1.3 Coordination with LIP – evaluation

During year 2002 when BUS was initiated, a separate project was planned by the Swedish Environmental Protection Agency in regard to the LIP-evaluation of composting and digestion plants. BUS and the LIP-evaluation had similar parts, as well as differences in scope and focus. The two initiatives were coordinated so that the LIP-evaluations became a part of BUS. The actual LIP-evaluations were conducted within BUS 1. This led to a situation where the BUS 1 report contains parts that are mainly related to BUS, and parts that concern the Swedish Environmental Protection Agency's LIP-evaluation, and large parts that are common to both projects. On the whole, this has been a positive solution both in regard to finances and the work-load for the plants that have participated in the study.

4.2 Attained results compared to set objectives

Table 4.1 below shows a comparison between the objectives that have been set for BUS and the results that have been attained.

Table 4.1 BUS attainment of set objectives

Set objectives (according to the framework programme for biological waste management)	Results
The evaluation of existing systems shall lead to a collection of operational experience that is made accessible, so that new systems that are planned in Norway or Sweden or intended for export can be designed and constructed in a safe and reliable manner based on local conditions.	The evaluation is compiled in the BUS report series. The information provided makes it possible to design and construct reliable and operationally safe new plants.
A system for collection of operational data shall be developed.	A system for the operational data has been established and is being used by RVF.
Channels for rapid sharing of experience shall be established.	The BUS report series, as well as the BUS seminar on the 27th of April, 2005, is an example on how knowledge is disseminated. The BUS report series will be published in pdf format on RVFs homepage. Furthermore, information about the availability of the series will be conveyed during RVFs annual meeting and in the newsletter RVF nytt.

Set objectives (according to the framework programme for biological waste management)	**Results**
Contacts with plants and corresponding evaluation and follow-up programmes in other countries shall be established.	The programme's finances were not sufficient for extensive contacts with plants in other countries.
The knowledge of personnel working within biological waste treatment systems on how their systems and other systems are constructed and operate shall be increased.	Within BUS, it has not been possible to spread all the collected knowledge to personnel working in systems for biological waste treatment. The BUS report series and the BUS seminar, as well as planned courses will provide such opportunities in the future.
Existing research and development needs shall be defined.	The research and development needs have been identified and are presented in this report.

In the start-up phase also long-term objectives were formulated; see section Objectives of the synthesis project. The long-term objectives were set to ensure that existing systems for biological waste shall:

- Have stable processes where uncontrolled operational disruptions, interruptions or unacceptable emissions do not occur.
- Have an acceptable working environment.
- Collect operational data that enables comparisons between plants in Sweden and plants in other countries.
- Have a stable market for biogas and produced soil improvement material.

It should be mentioned that it was not the intention of fulfilling these objectives in the framework of the first phase of BUS (that has been implemented during 2002-2004); rather this is a vision for what a continuation of the BUS should lead to.

5. Previous experiences

There is nothing new under the sun. Composting is a method that has been used for a long time. In the end of the 1970s several composting plants were built in Sweden. These were based on unsorted waste that was first shredded, and then a compostable fraction was separated out. During 1982 and 1985 an extensive operational evaluation entitled ”DRAV Operational Study Waste Treatment” was carried out[7]. Several of the experiences from DRAV are still relevant. The following conclusions/results concerning composting plants were reported (citation from the report):

- Adjustment time is relatively long.
- Accessibility and function can be improved through careful waste control, preventative maintenance and cooperation with collection organisations.
- Use of capacity is often lower than 50%.
- The regulation possibilities of equipment are limited and the effects of fine-tuning are often counter-acted by disruptions due to the composition of waste, continuous wearing out of machine parts and blockages.
- Experiences from composting reactors are negative and the two reactors located in Sweden have been closed.
- Composting can be made to be more effective through:
  – Improving the systems for air distribution so regulation and steering can be made easier.
  – Keeping an even moisture level and adding water when required.
  – Developing operational parameters and operational instruments that enable more secure operational steering and control.
  – Increasing knowledge about the plant's individual operational functions.

A lot of this is still relevant! It seems as though part of the problems that have occurred in biological treatment plants could have been avoided if the DRAV report had been studied.

[7] DRAV Operational study of waste treatment [DRAV Driftstudie Avfallsbehandling] in the report Technology, economics and environment in connection to waste treatment. Final report from the DRAV project. [Teknik, ekonomi och miljö vid avfallsbehandling. Slutrapport från DRAV-projektet]. NV rappport 3032. RVF Rapport 85:10 (1985)

6. Conclusions and discussion

6.1 Conclusions

6.1.1 Background to biological treatment

The Swedish government and parliament have aimed to increase the utilisation of biological waste management. The various regulatory instruments that have been used to drive this development in Sweden have mainly been:

- Prohibition against the landfilling of organic waste from 2005.
- State financial support to the municipal local investment programme, the so called LIP-subsidy.
- The environmental objective that 35% of the food waste shall be treated biologically.

In Norway mainly the prohibition against the landfilling of wet organic waste has been a driving force for this development.

The motivations for the development of biological waste management have mainly been to return nutrients to cultivation[8] and, primarily, to decrease the landfilling of waste that can be treated in other ways. The government has also stated that there are additional benefits with biological treatment of food waste, compared to incineration, because it enables the recycling of plant nutrients to the soil.

6.1.2 Environmental benefits

The environmental benefits of biological treatment have been investigated in several life-cycle studies and system studies in Sweden[9] and Norway[10]. The Swedish system analyses have shown that incineration and biological treatment of food waste are difficult to compare. All methods have pros and cons and according to the analyses, neither method is environmentally preferable to the other. The findings in BUS do not contradict this conclusion.

Compared to landfilling all biological treatment is environmentally beneficial. Compared to incineration, at least digestion with use of biogas as a vehicle fuel provides the same level of benefit. The outcome of com-

[8] Swedish government proposition 2002/03:117
[9] See reference in footnote 4
[10] See reference in footnote 3

parisons depends on how various types of environmental effects are evaluated. In the life-cycle analyses, consideration has not been taken to the benefit of the recycling of phosphorous (a non-renewable natural resource); neither have the benefits of the structural material in biological fertiliser and compost been considered (see section 3.7.2.1 Environmental benefit).

This issue can be summarised as follows:

- Biological waste treatment is a complement to incineration for the compliance with the prohibition on landfilling organic material.
- Biological waste management is an environmentally acceptable alternative to incineration.

It should be mentioned that emissions from modern composting plants are insufficiently measured and various life-cycle analyses are to a certain extent based on old data.

6.1.3 Technology

In BUS a comprehensive analysis of digestion and composting plants has been made. Many of the plants have had various operational problems. BUS has found that the operational problems mainly have two causes:

1. Acceptance of "wrong" waste.
2. Incorrect equipment choice in the planning and design stage, often equipment with insufficient capacity has been chosen.

These problems can be addressed by:

1. Better control of the waste that is received.
2. Well-considered choice of equipment - avoiding underestimation of the difficulties connected to waste management and learning from other's experiences.
3. Learning from other experiences, testing of new technologies in pilot projects.

Functioning technology for biological treatment is available, but it is crucial to make the right choices.

6.1.4 Odour problems

Biological waste treatment is justly associated with odour problems. During the decomposition processes odorous substances are formed and it is difficult to avoid dispersal. Through various measures it is possible to decrease the emissions of odorous substances to a certain extent, but not completely. Therefore, plants for biological waste treatment should be localised in suitable places and not be constructed near residential areas.

6.1.5 Economics, social aspects, work environment etc.

The issues of economics, social aspects or work environment have not been subject to in-depth analysis in BUS. It is, however, important to include these aspects in the planning of new systems and the development of existing systems.

6.2 Identification of future research and development needs

To a large extent the BUS project has been a collection and summary of existing knowledge on biogas and composting plants. During the investigation, various needs for continued development and research have been identified.

Work environment: Work environment has not been investigated within BUS. However, several of the projects have shown that emissions of odorous substances, micro-organisms, dust, gases etc. that can affect the work environment may occur. Also the issue of ergonomics may be a problem. A project suggestion is to make an investigation in one or several well-managed plants and identify the most serious work environment problems and then study the effects of various measures. A similar project has recently been initiated in Norway by NRF.

Economics in a holistic perspective. BUS has touched upon economics in connection to the collection systems. There is a need for more research of economics in a holistic perspective that covers the whole chain from household to energy use and compost and biological fertiliser use. This could, for example, be done in bench-marking studies.

Social aspects have been touched upon in BUS. The human aspects are important in the design of the source separation system. Therefore, there is a need for more behavioural science research that aims to investigate what sort of technology, information, incentives etc. are needed for households to participate in separation of waste in accordance with set requirements.

Environmental impact from composting. As was mentioned in the long-term objectives of BUS, it is important that unacceptable emissions do not take place. Up to now many comparisons of waste treatment alternatives have mainly concerned composting and landfilling of organically degradable waste. Taking into consideration that in the future comparisons will not be made to landfilling but rather to incineration, it is important that correct emission data for composting is available. Therefore, the environmental impacts of composting (future enclosed methods) should be evaluated not just through literature studies but also by practical measurements in relevant plants, and lead to proposals of appropriate measures to improve the performance of the composting process. In regard to digestion, actual measurements and practical recommendations have already been made.

Development of steering and control systems for digestion. Some biogas plants sometimes have problems with over-loading. This can be addressed through the development of better steering and control systems. Steering and control technology can also be developed for increasing the capacity of the plants. Within the Swedish Energy Agency's research programme Energy from Waste, several projects aimed at studying improved steering and control have been have been carried out with positive results.

Development of steering and control systems for composting. SLU (the Swedish University of Agricultural Sciences) research has shown that emissions from composting are dependent upon temperature. By maintaining a correct temperature, the depletion of nitrogen (decrease of ammonia emission and thus increased nitrogen levels in the compost) can be decreased. This should be tested and verified in actual operations. One such project is planned with the participation of plants from Norway and Sweden.

Optimisation of composting processes. In BUS 1 it is explained that it is very difficult to steer and optimise the process in various ways (e.g. in respect to aeration needs). Furthermore, it is also difficult to compare the effectiveness of various composting methods because it is not possible to reliably measure the effects of various methods in a quantitative way. The process control in composting plants seems to be functional from a purely practical operational perspective, but insufficient from a process centred perspective. There are needs to develop and test operational parameters to follow the composting process and enable optimisation of the operations.

Follow-up of operational data. In the operational data collection process that was initiated in BUS, very useful information will be collected. This information should be analysed carefully and the results should be disseminated to relevant actors.

More knowledge about which waste types/materials have positive or negative impacts on the digestion and composting process. Different materials have different decomposition characteristics. A material may both have positive and negative characteristics depending on the composition of the rest of the substrate. Some materials can disrupt the process, e.g. too much fat in the compost-digestion plants leads to the development of foam. More knowledge is needed on how different materials and material mixes act in digestion and composting processes and how different materials should be mixed to increase the yield of biogas or compost, and increase process security.

Methods for online characterisation of incoming waste. This issue is to a large extent connected to the previous topic (increased knowledge about various materials). Currently, basically only visual control of incoming waste is conducted. If it is possible to analyse or measure important parameters already in the feeding-in stage or preparatory stage, then the possibilities for optimising processes and pre-empt potential disruptions increase.

Understanding of biological processes. Composting and digestion are biological processes, something that most of the actors in the waste treatment industry should be well aware of. Despite this, often both composting and digestion are treated as more or less mechanical processes. There is a need to increase and develop the awareness of personnel that are directly or indirectly involved in digestion and composting systems, for example management, operational personnel, people responsible for waste planning etc., about biological processes. There is already significant knowledge about this in the research community, but this knowledge needs to be spread to practical applications. There is also a need to continue research on the fundamental processes.

Markets for compost and biological fertiliser. The experiences concerning the marketing compost and biological fertiliser vary. Some plants have established good markets, while others have had more problems. There is a need for research about how to create an acceptance and increased incentives for the use of compost and biological fertiliser. There is also a need for increased customer orientation in regard to the purchasers of compost i.e. to focus on what preferences they have in regard to water content, composition of nutrients etc., and on how to fulfil these demands. Another issue that could be important is to what extent the nutrients in compost and biological fertiliser should be concentrated for the product to be attractive to the customers to, for instance, decrease the energy use for transports and distribution. An increased market for compost and biological fertiliser would also increase the value of the products.

Odour. Odour problems have been reported from both biogas plants and composting plants. The biological processes that take place during digestion and composting give rise to odorous substances. Odour will probably always be a feature of the plants. However, the odours can be deceased in various ways. More research and development is therefore needed about how to decrease odour problems and on various odour reducing measures.

6.3 Discussion

6.3.1 How the problems with biological waste treatment can be solved

Even if there are problems connected to biological waste treatment today, the solution is not to return to incineration or landfilling. Biological treatment corresponds to fundamental environmental expectations and objectives, namely to achieve nutrient cycling. However, continued technical development in all phases from customer to fertiliser user is needed.

6.3.2 Waste treatment or fertiliser production

In connection to digestion or composting, sometimes it has been discussed whether the activity should be classified as waste treatment that produces fertiliser or fertiliser production that at the same time performs a waste treatment function. While it may seem to be the same thing, there is an important difference if the primary intention is to get rid of waste or to produce fertiliser.

- From the municipal perspective, it is easy to see digestion and composting primarily as a waste treatment method. The main issue then is to collect as much waste as possible and to choose a process and technology that can handle the types of waste that need to be treated. The quality of the biological fertiliser or the compost then becomes a secondary issue.
- The other viewpoint is the user perspective. The agricultural sector needs fertiliser and has actually no motivation to help to deal with a waste problem. The sector needs fertiliser with the particular and known composition and with guarantees that it is free from undesirable chemical or mechanical pollutants. In this case, there is a need to be more restrictive in regard to what raw material/waste that the plants accept and a need to ensure that technology that promotes compost quality and output is chosen.

We will not to attempt to resolve this issue, but want to emphasise that it is necessary to take both aspects into consideration when planning a system for biological waste management/compost production.

6.3.3 Increased biological treatment - ownership of the issue

The government wants an increased level of biological waste management. The issue then is - who owns the problem. Up to date, most initiatives have come from municipalities since they are responsible for the treatment of household waste and similar issues. Apart from the municipalities, there are also other actors that are affected by the issue:

- Waste generators e.g. owners of apartment blocks, restaurants and other enterprises.
- The users of compost and biological fertiliser - farmers.
- The users of biogas: energy companies, gas industry, gasoline companies and similar actors.

Our objective is not to point out one specific actor as been the one with the main responsibility. Since it is the municipality that is responsible for waste planning and the collection and treatment of household waste and similar issues, the municipality is the actor that is affected the most and should have the main responsibility. It is, however, important that the systems for biological waste treatment are developed with the participation of all actors in the planning and design phase.

6.3.4 Development potential

In the beginning of the 1980s a comprehensive follow-up of the operations of plants for separation/composting and incineration (see chapter 5 Previous experiences). This led to the closure of most of the separation and composting plants. Incineration, on the other hand, was developed. The technology for incineration was improved and emissions of most of the emitted substances were decreased by 50-98%. Also the capacity for incineration has successively been increased. One reason for this increase was the need for energy for district heating production and in most cases the waste management industry and the energy industry have been cooperating in driving this development. Initially (during the 1980s), most of the district heating production took place in municipal plants operated by municipal energy companies, this entailed that there was mainly a need for cooperation between various municipal organisations. Subsequently, private energy companies have taken over a large part of the district heating production. This development took place without special state financing , but rather through the use of internal means of financing.

Biological waste management has a potential for development. Actually biological waste treatment today has the same development potential as waste incineration had in 1985. BUS has shown that biological waste treatment is environmentally sound and technically feasible. What is needed is to establish a situation where one actor takes on responsibility for the issue and drives the development forward.

Appendix 1. Nomenclature and definitions

Biogas - The gaseous product that is formed during digestion. Biogas usually contains 60-75% methane CH_4.

Biogas plant - A plant where biological waste is treated through digestion.

Biological fertiliser - The remainder from the digestion process that is certified or corresponds to demands for use for soil improvement, see certification.

Biological waste - Organically degradable waste that is suited for treatment through digestion or composting, e.g. food waste from households, restaurants etc. In the report biological waste is taken to mean source separated waste.

BUS - Biological waste management - follow-up of systems

Certification - Certification entails the recognition from an independent third party that a product confirms with demands set in standards or other forms of specification. The demands are set in special certification regulations (SPCR 120 for biological fertiliser and SPCR for compost)

CH_4 - Methane

CO_2 - Carbon dioxide

Compost - Solid residue from composting.

Composting - A biological decomposition process that is mainly aerobic (takes place in the presence of oxygen).

Composting plant - Plant where biological waste is treated through composting.

Digestion- A biological decomposition process that is mainly anaerobic (takes place in an oxygen-free setting).

Digestion residual - The solid, semi-solid or liquid residue that is produced during digestion, see also biological fertiliser.

Digestion level - In digestion: proportion incoming organic material (VS) that has not been decomposed.

Decomposition level - In digestion and composting: amount organic material (VS) that has been decomposed in relation to total incoming organic material (VS).

Gas upgrading plant - A plant where biogas is treated so that it can be used as a fuel for vehicles. Gas upgrading mainly entails that carbon dioxide is removed from the biogas.

N - Nitrogen

NH_3 - Ammonia

P - Phosphorous

VS - Volatile Substance. Measurement of the content/percentage of organic material.