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University of Veterinary Medicine
Research Institute of Veterinary Medicine
Hlinkova 1/A
040 01 Košice
Slovak Republic

YOUR BODY, RENEWABLE ORGANIC WASTE AND THE ENVIRONMENT
Sustainable Management of **So**lid and **Li**quid **Wa**ste - **"SOLIWA"**

Ruzena Svedelius and Simon J. Watkin

NGO - Aktion Skĺ ne-Miljö, Visirvägen 8, S - 246 33 Löddeköpinge, Sweden
ruzgaj@usa.net or rsvedelius@hotmail.com

"The mistakes we allow in waste management today have a direct or indirect impact on our food and health."

ABSTRACT

Your body needs "safe" food. Therefore, we need to create novel, effective and efficient bioconversion systems, in order for the majority of the energy and elements from the renewable organic materials to be reused in "safe" cultivation systems. During the bioconversion process, renewable organic material from all human activities acts as a raw material and can be upgraded to valuable products. Localised bioconversion facilities, optimised for aerobic and anaerobic processes of bioconversion, will apply to modern and user friendly technology. Renewable organic materials will be converted by microorga-nisms in a series of bioreactors into energy-rich microbial metabolite methane in biogas, and into biofertilisers of a high and reproducible quality. Thus, the novel bioconversion systems include sub-systems, which are subjected to economically and ecologically efficient, long-term environmentally sound waste management. This can be modified to meet the local needs and implemented for society as a whole.

Keywords: Aerobic, Anaerobic, Biofertiliser, Biogas, Bioreactor, Compost, Localised Bioconversion Facility, and Organic Waste.
Abbreviations: ROM - Renewable Organic Material; MSW - Municipal Solid Waste; NPK - Nitrogen, Phosphorus, Potassium; "G&G-System" - name of the novel integrated bioconversion system (in Swedish Gas & Gödsel/Fertiliser).

1. INTRODUCTION

They say that you are what you eat. Everything that affects your body is important for your health, and the health of your children. Are you sure that you can breath clean air and drink clean water, eat safe and tasty food, wear clothes without allergy inducing chemicals and buy products that are not treated with toxic agrochemicals?
It is clear that there is a connection between:

- Food and Health;
- Organic Waste Management and Health;
- Soil Fertility & Productivity and Health;
- Cultivation Systems (conventional or ecological) and Health;
- Use of Synthetic Chemicals and Health.

Soil fertility and productivity in ecological and conventional cultivation systems can increase when renewable organic materials (ROM) from our waste is reused as a biofertiliser. Thereby reducing the amount of synthetic chemicals in food products.

Many people do not receive enough calories due to the world-wide reduction of soil fertility, and low efficiency of natural resource use, among other factors.

'The European Environment Agency' presented in 'Official Publications of the European Communities (1998)', an overview of the state of the environment in Europe and the main areas requiring action at national or international level. Only **"waste"** and **"soil degradation"** showed little or no change in the state of the environment, and little development of policies or unfavourable development for the state of the environment.

The requirement of new strategies for sustainable waste management, and for the sustainable production of food, feed, fibre and fuel, is obvious. Therefore, the following hypothesis has to be tested:
ROM from waste can be in novel closed systems efficiently utilised as a raw material for:

- The recovery of renewable energy as methane in biogas;
- The production of soil amendments/biofertilisers that contain energy, plant nutrients, and beneficial microorganisms;
- The protection of the environment as each yearly addition will increase the carbon sequestering abilities of soils.

2. HOLISTIC DEVICE

There is lack of a holistic view of plant nutrients, and bioenergy flows through different spheres of human activity. For example, people in one sector are involved in conventional waste management and waste water treatment. They use a lot of energy to get rid of ROM's, which contain plant nutrients and energy from the sun, bound in biochemical compounds that could give positive effects on cultivated soils. Another sector which takes part in conventional cultivation systems, with a goal to maintain/increase crop yields for the production of food, feed, fibre and fuel. Unfortunately, to make up for the deficiency of plant nutrients, the cultivation factors are optimised by using agrochemicals. Here the third sector pursued their goal through an effective marketing strategy. The production of agrochemicals uses plenty of energy, mostly from fossil sources and pollutes the environment. In addition the transportation methods used are a polluting factor.

All people should feel a responsibility for soil fertility and productivity, which strongly affects food quality and human health. In the above example, people have to pay for the disposal of organic compounds in ROM, which are then replaced by artificially produced inputs of newly paid energy. There is also the environmental damage caused as a result, in addition to the to healthcare cost.

The great challenge facing us, is to efficiently reuse both the nutrient elements, and the energy bound in ROM. It is not possible to recover all plant nutrients, or all bioenergy hidden in ROM as inevitably some losses occur during processing. A smaller amount of synthetic fertilisers still have to be used in order to compensate for the loss of nutrient elements. Their role is to optimise the delivery of plant nutrients for achieving maximum yields.

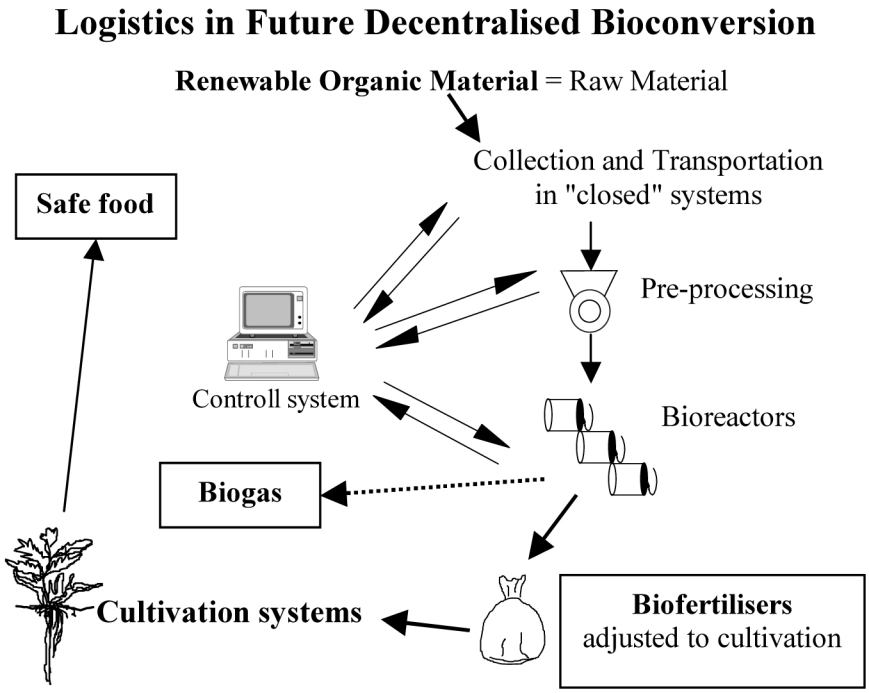
So it may be said that we need an organic waste management system which will be ecologically favourable, economically profitable, environmentally friendly, holistic, and resource efficient. No small feat, but not impossible if you consider the research and technology already available today.

3. BIOCONVERSION IN THE CONCEPT "WASTE 2002"

Bioconversion of ROM in waste, works on similar principles as the bioconversion in food processing, for example baking bread, making wine or cheese. It is time to realise the potential for new technology to deal with the waste problem. Therefore the concept "WASTE 2002" that describe bioconversion in "G&G-System" is presented in **Sustainable Management of Solid and Liquid Waste - "SOLIWA"** (Appendix A) as one example for a solution to the future.

In order to achieve the maximum yield from ROM in waste, the safe food efficient logistics system is required (Fig. 1).

Figure 1: Logistics in a modern system for bioconversion of organic material in waste that is called "G&G-System" (©R. Svedelius 2002).



Various microorganisms can effectively transform ROM in the waste stream into highly valuable products, when managed under a controlled bioconversion in a completely sealed environment. For example, methane, alcohols, enzymes, proteins and humic substances are some the important intermediates of microbial transformation. It is only ROM that has not been altered with a too high amount of substances, which disturb the microbial processes, or that can cause damage to cultivated soil. This can be used as a raw material in bioconversion.

The highest percentage of municipal solid waste (MSW) is of organic origin. The current expensive collection, transportation and processing of ROM in MSW can be replaced by modern localised facilities for bioconversion.

Human excreta without the addition of water will also be treated in these facilities. An unhealthy working environment within sewage system will be avoided, and amount of polluted water and costs for wastewater treatment could be reduced. Instead of expensive sewage systems, new collection systems for human excreta, which depend on the skilfulness of designers and engineers, have to be used. For example, the improved BioToi, www.polargruppen.com .
In the "G&G-System" a series of bioreactors called "BioTransForm" are working in each facility. So far the results from experiments show a great improvement in processing of ROM with aerobic methods in bioreactors, compared with aerobic methods in open systems (Tab.1).

Table 1: Comparison between open and closed aerobic systems.

	Windrows, heaps and other open methods	**Bioreactors BioTransForm**
Output (weight)	30 – 40 %	70 – 80 %
Retention time	Several days	Several weeks or month
Inactivation of pathogens	Unsafe	Safe
Losses of energy and nutrients	High	Low
Pollution of air and water	High	Low

The costs for bioconversion at the introduction stage will be about the same, as the present costs for the treatment of solid waste. However, in long-term such costs will reduce. In addition, the positive effects will lead to sustainable waste management, sustainable cultivation systems and safer food.

4. ECOLOGICAL, ECONOMIC AND SOCIAL IMPACTS OF THE "G&G-SYSTEM"

Ecological impacts of "G&G-System"

Environmental aspects which have, or can have a significant and *indirect effect* on the environment include:

- A reduction in air pollution;
- A reduction in the negative impact on water and cultivated soil, its fertility and productivity;
- Better quality food, which affects human health.

Beyond the financial savings made by use of biofertilisers instead of synthetic agrochemicals, there lies a multitude of environmental benefits such as:

- The decrease of emissions that in-turn decreases peoples' exposure to unhealthy conditions during collection, through transportation and discharge. The processing of renewable organic waste with outdated methods of composting and rotting, on landfills, at incineration plants (Tab. 2), and/or wastewater treatment plants.

Table 2: Effects of centralised waste incineration plants and localised bioconversion plants

	Incineration in centralised plants	**Bioconversion in local plants**
Energy recovery	As heat or electricity	As biogas and in biofertilisers
Residue	Ash and fly ash - plant nutrients are not coming back to cultivation systems	Biofertilisers with soil beneficial microorganisms, humus and nutrients
Costs for transportation	High	Low
Pollution of air and water	High	Low
Toxic compounds appear	In exhaust, ash and fly ash	No

- Improving the physical, chemical and biological properties of cultivated soils in the long-term. Thereby, resulting in reduced soil erosion, increasing crop yields and improving their quality. In addition to a higher resistance of cultivated crops to weeds, parasites and disease, reducing harmful agricultural run-off by cutting the use of fossil-based pesticides, herbicides and fertilisers. Further conservation of water by increasing the water holding capacity of the soil, and therefore decreasing percolation, evaporation and runoff of plant nutrients and increased sequestration of carbon.

More about the importance of soil protection is explained in; ***"Towards a Thematic Strategy for Soil Protection"***
http://eionet.eu.int/Topic_Areas/Terrestrial_Environment/SoilProtection.pdf

Economic impacts of the "G&G-System" are:

- Lower total costs for waste treatment;
- Lower costs for collection and transportation;
- Profit from biofertilisers;
- Profit from biogas.

By expanding the agricultural possibilities of biofertilisers, produced from renewable solid and liquid organic urban waste in decentralised bioconversion plants, several million SEK could be saved annually in Sweden. These savings would come from:

- Reduced transportation costs;
- Increased yields of cultivated crops;
- Reduced use of fossil-based fertiliser, pesticides, and herbicides;
- Water savings;
- Energy savings.

Social impacts of the "G&G-System" include:

- User friendly, good working milieu and thus high acceptance of the system;
- Inhabitants satisfaction through being part of an ecologically sustainable system suitable for all societies;
- Holistic approach with an impact on the global environment;
- Novel technology, with the possibility creating new employment.

5. WASTE MANAGEMENT IN SWEDEN

Solid waste

Each of the 8.7 million inhabitants produces about 370-kg MSW per year (Swedish Environmental Protection Agency 1994). Categories in MSW are presented in Tab. 3. Costs for the collection, transportation and administration of MSW correspond to 65%, and treatment costs are 35% of the fee paid by inhabitants (personal communication, Bo Audelius, Swedish Association of Waste Management, 2000).

Table 3: Categories of MSW in Sweden.

Categories	%	**Categories**	%
ROM's in Waste:		Recyclabes:	
Compostable	38	Glass	6
Paper	32	Plastic	6
Disposable napkins	6	Metal	3
Textile, Rubber and Leather	2	Laminates	3
Other Wastes	3	Harmful Wastes	1

The collection and transportation of mixed waste is accompanied by exhaust fumes from the lorries, dust from the roads, vibrations, and noise pollution. It also stimulates the growing and spreading of various microorganisms, which send out spores and odorous compounds. At the moment there are losses both polluting the environment, and negatively affecting human health.

Treatment of waste includes recycling, incineration, landfilling and a few per cent of MSW were treated by biologically based methods. Unfortunately, the biological treatments used were old-fashioned composting methods on heaps or in vessels. Most of these systems were developed a long time ago, and do not correspond to the optimal requirements of microorganisms. Thus reducing the possibility to regulate the process properly. Therefore, the microbial activity, efficiency and total output are low. Meanwhile costs, energy losses and pollution are high. Incineration of waste presented as "waste to energy" means burning ROM in waste to toxic ashes.

Liquid waste

Each person generates on average per day, 1.2 kg urine and faeces. (Data based on information from University Hospital in Lund). Between 200 and 550 litre wastewater per person per day is treated in wastewater treatment facilities. These, similar to landfills, generate, by uncontrolled microbial transformation gaseous emissions of compounds that contain nitrogen, sulphur and other elements. By using outdated methods for wastewater treatment, the degradation of ROM's in human excreta causes losses of bioenergy and elements important for cultivation. Present waste and wastewater management is costly, induces unsanitary working conditions (reference), pollutes the environment, and thus poses a great ecological and economical threat.

Table 2: Average amount in litres in Sweden. Blackwater (from WC) is about 15% of wastewater.

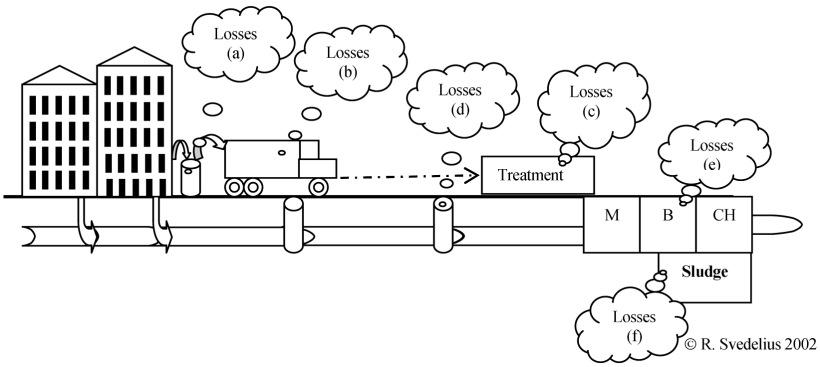
	Per person per day	**Per person per year**
Wastewater	350	127 750
Human excreta	1.2	438

6. COMPARISON BETWEEN PRESENT AND FUTURE WASTE MANAGEMENT

Figures 2. and 3. briefly compare present and possible future systems for handling waste and wastewater. By using outdated methods for waste management (Fig. 2) the bioenergy and nutrient elements, do not return to cultivation systems. Losses pollute the environment and negatively affect human health.

Combined bioconversion is **waste to energy by microbial transformation** (Fig. 3). Biogas is one of the main products, and a second one is the solid remainder called biofertiliser. Thus bioenergy, elements, beneficial microorganisms and humic substances from the ROM of the waste stream, will be reused in the ecologically sound system of "closing the loops".

Figure 2: Present waste and wastewater "by end of pipe" management in open and centralised systems.

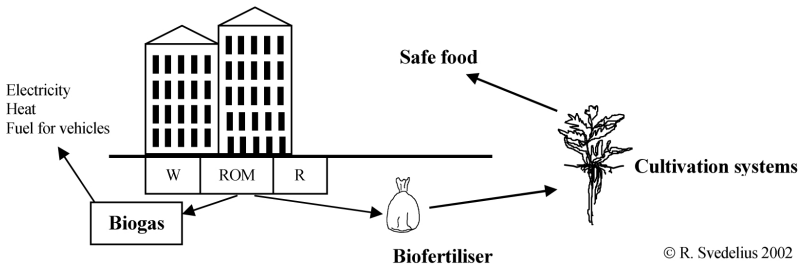


Losses of energy and plant nutrients appear:

- When renewable organic material in solid waste is collected in dust bins (a), transported (b) and treated (c) in incineration plants, on landfills, in central composting plants and in biogas plants using rotting methods; or
- When liquid waste (human excreta) is diluted, transported in sewage system (d) and treated mechanically, biologically(e) and chemically in wastewater treatment plants and when sewage sludge (f) of doubtful quality can not be used on cultivated soils.

Some of the losses are pollutants transported across international boundaries.
Costs for construction and operating are huge. Most of the above-described management is principally based on old-fashioned systems, which cause environmental damage and are a health hazard.

Figure 3: Future waste and wastewater "at source" management in closed decentralised systems.



Losses of energy and plant nutrients are minimised when concept "Waste 2002" is used.
Greywater (W) is treated in "Bio H2O".
Renewable organic material (ROM) from solid and liquid waste is by microorganisms transformed to biogas and biofertilisers in "G&G-System".
Mixed waste (R) of inorganic and non-renewable materials such as glass, plastic, metal and toxic waste are sorted in "Refuse House" and then handled by specialists for reuse, recovery, destruction or burying on landfills.

7. CAN WE RECOVER THE BIOENERGY AND RECYCLE THE PLANT NUTRIENTS IN SUSTAINABLE WAY?

There were at the 1st January 2002, exactly 376 461 772 inhabitants in EU. The total amount of ROM in waste together with human excreta was about 753 000 tonnes per day. This renewable raw material contained at least 825 TWh of bioenergy per year. To this figure can be added the great amount of bioenergy in ROM from industrial waste and in residues from agriculture, horticulture and forestry. Imagine that bioenergy in this ROM is transformed biologically and recovered as biogas (about 1/3), and recycled as ROM including plant nutrients in biofertilisers (about 1/2). How much water and energy from fossil sources are used today for getting rid of ROM from all these sources?

The choice is yours how to achieve modernisation of waste and wastewater management. You pay for the food, for drinking water, for the waste and wastewater management and you can have possibilities to ask for environmentally safe products and services. Hygienic safety should be the minimum in legislation for the handling of synthetic chemicals, waste, wastewater and fertilisers.

In spatial planning, among others, are involved planners, politicians, architects and economists. They are to a greater extent responsible for the development of the whole society. You must influence their understanding regarding the environmental impact of their decisions on people's health both in urban and rural areas.

Many of us are involved in activities where we are dependent upon decision-makers that are influenced by lobbyists serving the present system. How much does it cost in environmental damage? When do we realise that *all mistakes we allow in organic waste management today have direct or indirect impact on our food and health, both now and in the future?*

The suggested concept "Waste 2002" is only one of many possibilities to achieve sustainability in waste and wastewater management. Let's open the discussion on holistic solutions. It says in the Bible that "we came from dust and unto dust we will return". Now it is your challenge to work out how to slow down the process.

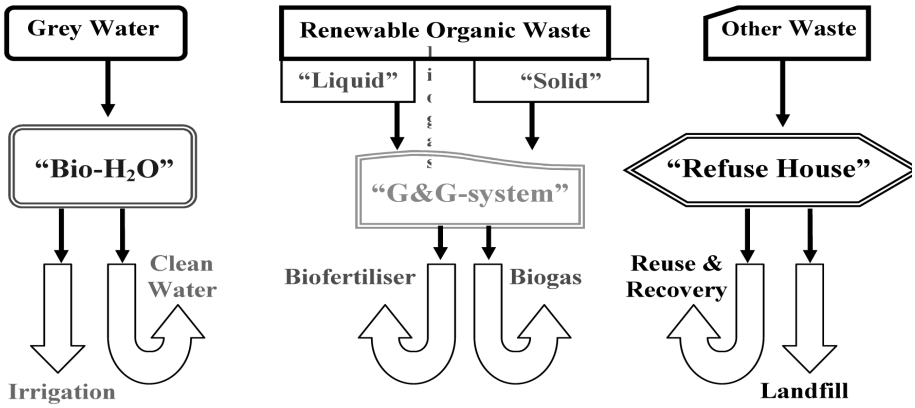
Appendix A
Sustainable Management of Solid and Liquid Waste - "SOLIWA"

UN GA RES 37/7 **World Charter for Nature** (1982)
…"The allocation of areas of the earth to various uses shall be planned and due account shall be taken of the physical constraints, the biological productivity and diversity and the natural beauty of the areas concerned."
…"The productivity of soils shall be maintained or enhanced through measures which safeguard their long-term fertility and the process of organic decomposition, and prevent

erosion and all other forms of degradation."
…"Resources, including water, which are not consumed as they are used shall be reused or recycled."

THE "WASTE 2002" CONCEPT

Figure 1. Flows in "Waste 2002" when used for local waste management in a housing area.



"Bio-H2O"

Grey water can be cleaned biologically. About 16 per cent less water will be polluted, as human excreta is collected in novel toilets. The cleaned grey water can be reused for irrigation or for other purposes.

"G&G-System"

The aim is an efficient batch system for bioconversion of renewable organic materials into biogas and biofertiliser. Raw materials for bioconversion can be taken from renewable organic solid[1] and liquid[2] waste from households, from central markets, from the food and feed industry, slaughterhouses as well as animal manure, organic residues from forestry, horti/agriculture, and fuel crops.

A mixture with a high content of dry matter is treated in a three-step process of bioconversion. Firstly, aerobic, then anaerobic and finally aerobic transformation is carried out in a new kind of closed bioreactor connected to a bio filter. The contents of the bio filters are reused in the process.

The biogas produced in the anaerobic step can be converted into electricity and heat, used as fuel for vehicles, or both. Part of the electricity will be used for equipment in the system. Biofertilisers, adjusted for cultivation needs, contain energy rich organic structures, plant nutrients and beneficial microorganisms. Structures are important for soil organisms and as CO_2 sinks. The content and quality of biofertilisers can be modified with respect to needs of crops and the state of the soil.

[1] Solid organic wastes can be dry or wet. Examples of dry organic materials are: paper, paper packages, straw, wood and wooden residues, bark, dry leaves. Examples of wet organic materials are: food residues, grass clippings, weed plants and crop residues. In today's Western Europe, household waste is being generated at a rate of over 1kg per person per day. *In Sweden 76 per cent are of organic origin (REFORSK, 1998)!*

[2] Liquid organic waste is both from human and animal excreta. Human excreta in developed countries averages 1.2 kg per person per day. *In Sweden, human excreta is diluted with 200 to 550 litres of wastewater per day!*

"Refuse House"

Mixed waste of inorganic and non-renewable materials such as glass, plastic, metal and toxic waste are sorted, and then handled by specialists for reuse, recovery, destruction or burying on landfills.

Waste and Wastewater Management in Municipalities in Sweden

ROM = Renewable Organic Material

Table 1: Treatment

	Present Situation		Concept "WASTE 2002"	
Solid Waste	Incineration produces 25-30 % toxic ash	45%	Bioconversion of ROM	70%
	Dumping in landfill sites	40%	Recycling	20%
	Recycling	<13%	Dumping in landfill sites	5%
	Old fashioned composting and rotting	>3%	Incineration of only toxic waste	5%
Wastewater	Grey water	85%	Grey water	100%
	Blackwater	14.5%	Blackwater does not appear	
	Human excreta	<0.5%	Human excreta to bioconversion	

Table 2: Sorting, Collection and Transportation

	Present Situation	Concept "WASTE 2002"
Solid Waste	The correct source separation does not occur. Waste in bins starts to decompose. Long distance to centralised plants.	The correct source separation is needed. Easy degradable waste is treated daily. Short distance to local plants.
Wastewater	Long distance in sewage systems to centralised wastewater plants. Clean water is used for the transportation of human excreta.	Greywater is treated locally. Human excreta is collected and treated with other ROM's.

Table 3: Pollution and Losses

	Present Situation	Concept "WASTE 2002"
Solid Waste	Emissions from collection, transportation, treatment plants and landfills cause a health risk to air, water and soil. Losses of energy and nutrients are high.	Equipment for local integrated waste management is designed to minimise, emissions and losses in all steps. Bioenergy and plant nutrients are reused.
Wastewater	Emissions cause health risks from leaking sewage systems, its gutters and manholes, from wastewater treatment plants and from sewage sludge. Energy input is high and losses of bioenergy and nutrients from renewable organic waste are high.	Grey water is transported in a closed system to localised closed equipment, for biological treatment. Human excreta is safety transformed together with ROM's to biogas and biofertilisers. Emissions and losses are minimised.

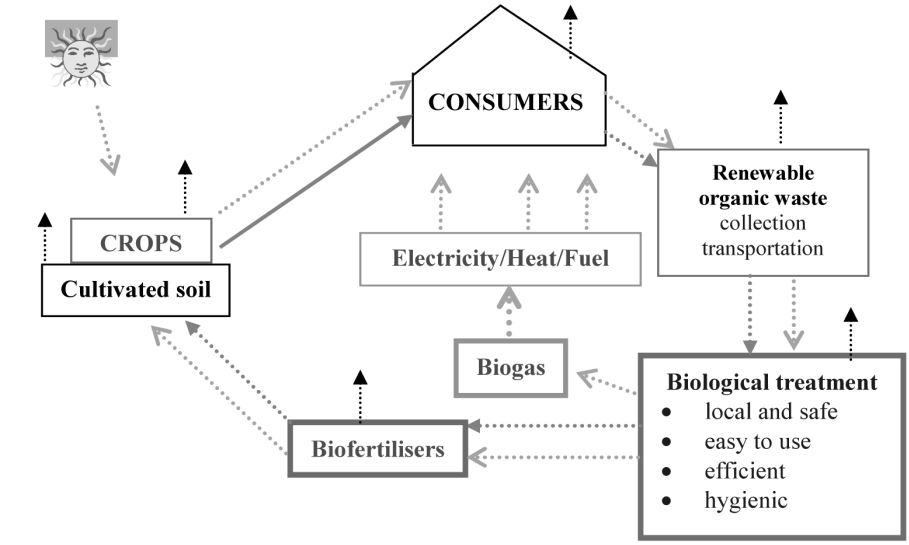
Table 4: Costs

	Present Situation	Concept "WASTE 2002"
Solid Waste	Costs for collection, transportation and administration are about 2/3 of the fee paid by inhabitants. Costs for incineration and landfilling still increase.	The holistic local concept that uses modern technology will be less expensive than the present system, it is cheaper to build and even more cost effective in the long run.
Wastewater	High costs for the sewage system are included in the rent. Treatment costs do not include the real costs.	Low costs for treatment of grey water include both construction and operating costs.
Total costs	Between 2 000 to 4 000 SEK per person per year	1 850 SEK (+/- 30%) per person per year

RESEARCH APPROACH AND HOW IT IS CARRIED THROUGH

The holistic approach of the **"G&G-System"** (Fig. 2) **bridges the gap between the use and the production of biomass.** It can also help to solve many environmental, logistical and social problems occurring in present waste management.

Figure 2. G&G-System is closing the loop. Plant nutrients are recycled of and bioenergy is reused.



Transportation of plant nutrients from soil to consumers.
In the "G&G-System" plant nutrients are transported back to cultivated soil.
Energy from the sun is bound as bioenergy in crops and is firstly used by humans and then through the "G&G-System" partly reused in biogas and partly returned to cultivated soil.
Emissions that are polluting losses.

Efficient and safe utilisation of plant nutrients and bioenergy bound in biomass

"Biomass is all plant and animal matter on the Earth's surface. Harvesting biomass such as crops, trees or dung and using it to generate energy, that is heat, electricity or motion, is **bioenergy**. Biomass was the first fuel that mankind learned to use for energy; the first fires of primitive man burning wood for warmth and cooking." (Billins P. 2001)

Biomass is the most important fuel and source of nutrients in food. Microorganisms can convert (=bioconversion) food waste, human excreta and other ROM's into biogas and biofertilisers. When the methane in biogas has been produced in closed equipment, there is still bioenergy left in the organic structures in biofertilisers. The biofertilisers contain fuel and nutrients for soil microorganisms and nutrients for plants.

Biofertilisers increase carbon content in cultivated soils and improve physical, chemical and biological properties of cultivated soils. Fifty years ago the topsoil in Scania, the southern part of Sweden, contained about 5 per cent of organic matter while today there is only 1.5 per cent left. The deficit calculated as carbon (C) is approximately 45 tons per ha. Thus biofertilisers are also sinks for CO_2.

For the production of **safe food** it is necessary to have **safe biofertilisers**. Efficient

recycling of plant nutrients and the proficient/competent reuse of bio energy in safe bioconversion systems is needed for sustainable development of the society and of course **survival of humans**.

REFERENCE

Billins P., 2001. Bioenergy: 21st century fuel http://www.energyresource2001.com/.