Front page

Proposal full title

Energy Generation by Efficient Biological Transformation of Renewable Biomass

Proposal acronym

ENEFBIOTRANS

Date of preparation
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Proposal summary page

Proposal full title

Energy Generation by Efficient Biological Transformation of Renewable Biomass

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Priority 6.1. Sustainable Energy Systems
Research activities having an impact in the short and medium term

Priority thematic area of research "Sustainable development, global change and ecosystems". Sub-priority *"Sustainable energy systems"*
Area: Section 6.1.3.1.2.1 "Eco-buildings"
Topic: Integration of renewable energy technologies and efficient technological solutions

Proposal abstract
Energy recovery from renewable biomass (RB) contributes to primary energy conservation. RB contains the highest unexploited potential of renewable energy called bioenergy (5 - 25 GJ/ton). When the bioenergy is recovered by improved microbial conversion not only higher yield of energy is achieved but also additional positive effects for our survival such as maintained or increased soil productivity, health, employment and decreased losses, pollution and vulnerability.

We propose a system based on radical changes and innovations in the management of RB. Using combined aerobic and anaerobic operating systems which are high-rate, simple to operate and have reliable performance, the new knowledge necessary for creating the appropriate technology for biotechnology-based processes, that are necessary for efficient use of energy bound in RB, will be developed. This will lead to enhanced energy recovery and savings, decreased energy use, carbon and nitrogen capture, storage and use, and in consequence the negative impact on climate change will be reduced.

The technology refers to a system of three-step bioconversion in bioreactors BTF where high-solids digestion is applied. This system is suitable both to small and large-scale users both in urban and rural areas, for the production of energy rich methane in biogas and energy rich biofertilisers that at the same time contain most of the nutrients from the RB. The use of this system will avoid the use of correspondent quantities of fossil energy sources. By developing and using a mobile line approach, the system will be adjusted to local needs and following commercialisation will then become marketable.

Projects results will increase field experience of energy supply and demand patterns, in local energy economies having a high percentage of renewable energy supply. The well monitored projects outcome will increase knowledge on the performance and reliability of the innovative energy supply and end use technologies.

B.1 Scientific and technological objectives of the project and state of the art

"We can't solve problems by using the same kind of thinking we used when we created them." A. Einstein

This IP reflects the broad scientific and technical scope of **energy in renewable biomass** across the processing and utilisation chain.
Biogas will be used in co-generation units for **production of electricity** and heat. Biogas can also be used **as fuel** in cars, busses, tractors, etc.
Biofertilisers will be analysed on energy content, nutrients and examined in bioassays.

This project will support sustainable development in the energy context. It intends to **improve the technology** and to **modernise methods of bioconversion** with the **objective of developing efficient system** by solving several problems that still appear when bioenergy hidden in renewable biomass is extracted by old-fashioned methods.
Therefore our goals are:

- to determine factors with major influence on **maximising of biogas production** and factors important for **production of biofertilisers** adjusted to needs in cultivation systems by development of **efficient bioconversion facilities** a) for research and b) for demonstrations c) for transparency of the novel advanced system
- to **minimise negative impacts** on environment and human health
- to **meet users and industry demands.**

In view of this objective a several **technologies**, developed in other industrial sectors such as robotics, artificial vision and automated systems, will be utilised in order to solve problems that appear in bioconversion of renewable biomass to two valuable and energy rich products – biogas and biofertilisers. This will bring the benefits of these disciplines and applications to a sector, which up to now doesn't have the appropriate technological knowledge and means to solve them.

The tasks, which need to be carried out to reach objectives of this project, are:

1. Development of a standardized **Experimental Line** for gathering information and data from experiments on bioconversion carried out by partners. Optimising of microbial processes with the aim to **maximise production of biogas**, and minimise losses and pollution.
2. **Modelling** of equipment and process using data from experiments.
3. Preparation of **reports** from experiments and modelling.
4. Development and testing of a complete **Demonstration Line** for bioconversion based on results from experiments and modelling. Verification of the models and development of useful mathematical tool for future design and process up-scale.
5. Organisation of workshops/conferences – **dissemination of results** under the project.
6. Preparation of a **final report** for a broad audience in and outside Europe, which is or becomes involved in the implementation of efficient bioconversion during processing of renewable biomass and utilisation of energy in biogas and biofertilisers.
7. Establishment of the "**European Bioenergy Pool**" on Internet.

Enhanced energy efficiency is a key strategy for decreasing the cost of and environmental damage caused by energy conversion. In this IP we suggest a design in which energy efficiency improvements are aligned with the whole technical energy system and several other systems such as infrastructure (modern logistics), transport, waste and wastewater management, planning, building, policy making in EU, etc.
We will address the research questions in four studies that consider

- The efficiency of **energy flows** within system that use biological transformation of renewable biomass to biogas and biofertilisers;
- The impact of above mentioned methods on air, water, soil, food and health as well as on working, local and global **environment** compared with combustion of renewable biomass;
- The impact of **novel methods** of biological transformation on industry;
- The impact of these methods on employment and on other **social aspects.**

1) The efficiency of energy flows

The efficiency during bioconversion (microbial conversion) can be significantly improved by use of modern technology. Processes in three-step batch bioreactors BioTransForm (BTF) for high-solid digestion will be carried out by methods using higher precision and therefore higher yield will be achieved. The expected energy flows during bioconversion of renewable biomass in systems and comparison with combustion are presented in Fig.1.

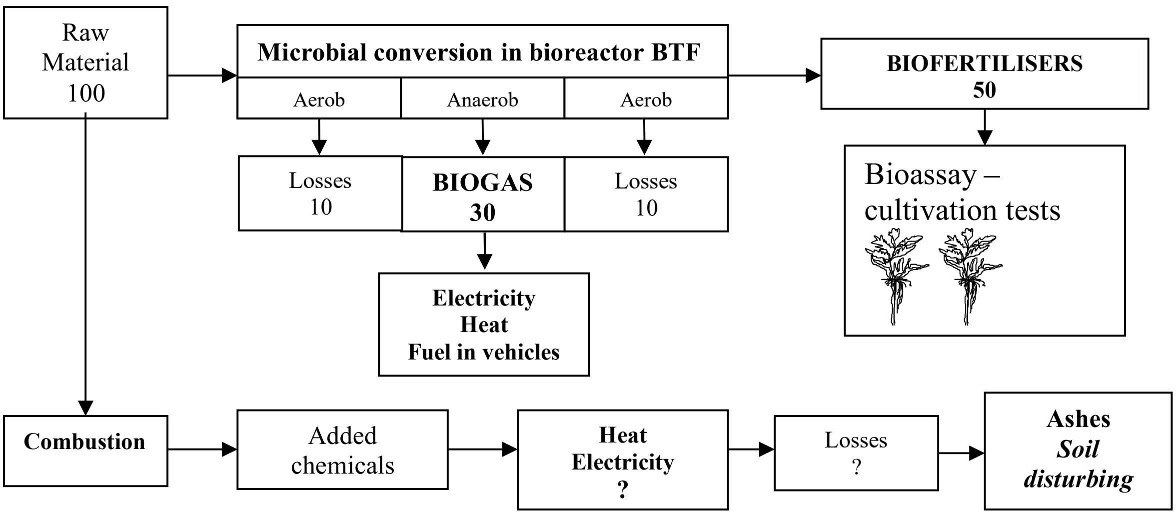


Figure B1-1: Bionergy in raw material that means in the **renewable biomass** will be utilised by microorganisms and transformed to energy valuable for humans: methane in biogas and bioenergy in biofertilisers.

In bioreactors BTF bioconversion is carried out in three well-controlled steps. Anaerobic digestion is a process that utilizes anaerobic bacteria to produce methane and carbon dioxide gas from organic matter. It is currently used (with old-fashioned methods since 1920) to reduce the organic matter in domestic, municipal, agricultural, and industrial wastes and wastewaters to a usable fuel gas referred to as biogas. Improved technologies will significantly reduce costs and anaerobic digestion in bioreactors BTF will be commercially viable upgrading of renewable biomass.

2) The impact on environment and health

Microbial transformation will be carried out in local, closed facilities. Biofilters, containing material suitable for bioconversion, protect air from bad smelling compounds and catch several elements that are later available in the process. Less pollution in the working and global environment allows better protection of human health. A positive impact on the environment derives also from localized energy production, which allows for the reduction of transport emissions (and costs) and of distribution lines. Vulnerability will also decrease. Production of energy from renewable sources has positive impact on the environment by decrease of CO_2 and other pollutants (SO_2, NO_x and fly ash) emissions into atmosphere. It replaces the combustion of fossil fuels, which are limited, and valuable for chemical industry, by renewable biomass, which is in many cases wasted. Reduction of emissions of hazardous gases improves the state of natural ecosystems by decrease of pollution and acid rains' danger. That improves the state of human habitat, which results in better living conditions and influences the human health. The proposed method is a clean (green) technology, without wastes; all by-products are usable and after some treatment are utilized: biofertilisers in agriculture, horticulture, forestry and parks and biogas for energy production.
All these environmentally-oriented issues of the new technology will give an input into development of the policy of environment preservation and control.

3) The impact on industry

New knowledge will be used in manufacturing industry for production of components. It is important to underline the advantages that industries operating in the various fields dealing with waste and agricultural products (collection and sorting, transport, and above all transformation), but also food industry in general, can potentially find relevant advantages in the transformation of their residuals in a source of income, direct (in case of energy auto production) or indirect (in case their residuals are sold as energy source).
The reduction of combustion of fossil fuels will preserve the natural resources of coal, crude oil and gas, which are very important row materials for chemical industry and their deposits are limited.
The implementation of novel technology will improve the knowledge and technical culture which will be beneficial for that sector of industry, which will use that advanced technique.

4) The impact on employment and on other social aspects

New jobs will be created in education, planning, design, logistics, engineering, modelling, manufacturing, process control, analysing, research for further improvements, etc. The industries operating systems that use microbial conversion can offer transparency that is important for acceptance of the novel advanced systems by citizens.
The proposed modern technology will give an input to creation of knowledge-based society and economy; will result in improvement of education, and improvement of human resources.

State of the art

Today[1], it is estimated that there are nearly 3 000 methanisation plants in Europe to which the 450 waste storage centres which valorise biogas must be added. Annual production of these

[1] EurObserv 'ER 2001, last update: 31-07-2003 http://europa.eu.int/comm/energy/res/sectors/bioenergy_en.htm

installations is estimated at 2 304 ktoe. The sector represents approximately 5% of all the energy resulting from biomass in Europe. Nevertheless, an important point must be emphasised: all the biogas production units do not necessarily valorise this renewable energy source in the form of final energy (electricity or heat). Part of this production (approximately one half) does not find any market outlet and ends up being burnt off in flare stacks.
The European Commission is targeting 1 000 megawatts of installations at the conclusion of the Campaign for Take-Off (at the end of 2003) and 15 million toe of biogas production in 2010. The 2010 objective is going to be much more difficult to attain. Beginning in 2003, only an annual growth rate of 30% will make it possible to reach the threshold as desired by the European Commission. Therefore 30% growth is necessary.
The EUs commitment to a significant reduction in greenhouse gas levels combined with legislation arising from a number of European Directives has emphasised *the need for alternatives to combustion.*
Unfortunately, present systems for biological transformation (composting and rotting) use old-fashioned methods that are neither efficient nor environmentally sustainable. Therefore we want to **radically improve both technology and methods**.
Most of the energy from renewable biomass today comes from wood products, dried vegetation, crop residues, and aquatic plants. RB has become one of the most commonly used renewable sources of energy in the last two decades, second only to hydropower in the generation of electricity. Due to its low cost and renewable nature, biomass now accounts for almost 15% of the world's total energy supply and as much as 35% in developing countries, where it is mostly used for cooking and heating… RB will succeed at some level as an alternative source of renewable energy because it is capable of being implemented at all levels of society (information from http://www.altenergy.org/Renewable/Biomass/biomass.html).

Example: Residues from slaughterhouses, carcass, and human and animal excreta, and are seldom used as raw material. For example in 1998 the European rendering industry transformed a total of 16.1 million tons of animal material into 3 million tonnes of meat-and-bone meal and 1.5 million tonnes of fat suitable for use in animal feed. While most of these 16.1 million tonnes came from healthy animals inspected in slaughterhouses, 1.8 million tonnes came from animals that died outside slaughterhouses or other condemned materials. As the excluding of above-mentioned materials from the food chain is necessary, the alternative option is to use their RB and produce biogas and biofertilisers in modern facilities. These 16.1 million tons of animal contain approximately 80 TWh bioenergy. Using the concept of bioconversion presented in this proposal will result in biogas with energetic value of 26 TWh and about 40 TWh of energy will remain in biofertilisers.

Expected results of this IP:
Realization, demonstration and verification of the new G&G-System using innovative logistics and batch bioreactors BTF for high-solid digestion of RB that could be used in other EU countries; Increased utilization of bioenergy bound in various types of RB; Increased recycling of plant nutrients, energy rich compounds and beneficial microorganisms to soils; Increased job opportunities; Decreased pollution, losses and vulnerability; Strengthening local economics; Increased interest and general public awareness in biomass use; Enforcement of legislation improvement in the field of renewable energy.

B.2 Relevance to the objectives of this Priority Thematic Area

"The building sector is at present responsible for more than 40% of EU energy consumption."
This IP addresses the *large scale integration of renewable energy sources into energy supplies* **by building many decentralised energy efficient facilities**. The main aim is to substantially **improve the performance of energy systems by use of safe and clean G&G-System** based on **microbial conversion of renewable biomass (RB)** in high-solid batch bioreactors BTF, for new and / or existing communities, aiming to improve the sustainability of their systems. This project also applies **highly efficient energy saving measures** and significantly increases the percentage of renewable energy supplies.
Exploitation of the microbial conversion in utilization of RB, especially when directed to technologies that can be transferred and applied successfully at the village/farm level or in urban areas in clusters of local facilities is of high importance for energy savings, transport minimisation, and reduction of pollution, losses of energy and vulnerability.
This projects will meet the requirements of Section ***6.1.3.1.2.1 Eco-buildings*** with a focus on the optimisation of the whole self-supply-demand chain, and address **small, medium or large scale applications**, for example a) residential for the individual requirements of residential houses, **integrated into a larger network** of the community; b) collective or tertiary with district heating applications and electricity suppliers.
Project team include researchers with the expertise to address the measurement and analysis of energy flows, as well as socio-economic experience and have contact with local energy end users, stakeholders, community decision makers and other local market actors.

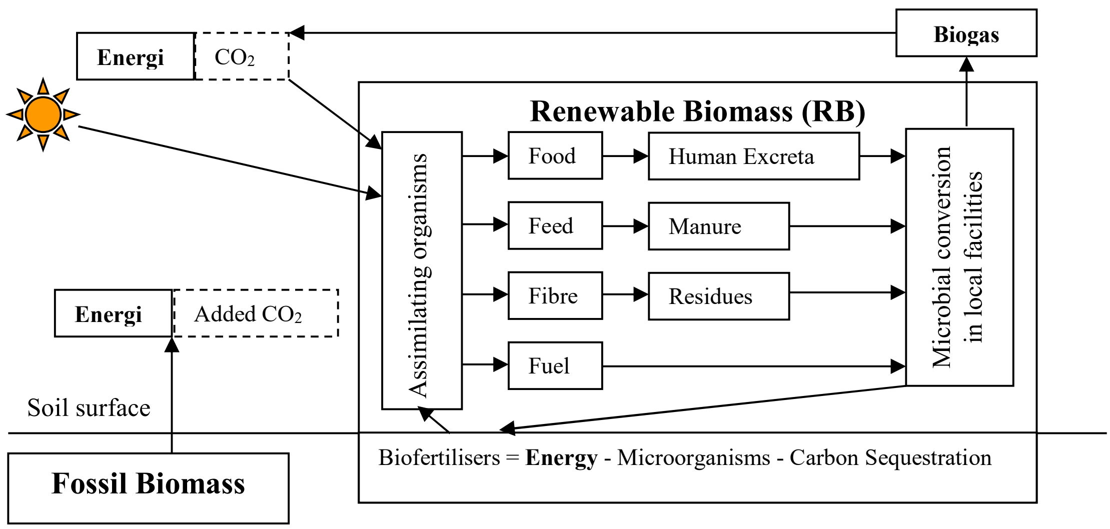


Figure B2-1. Energy from renewable biomass is useful for humans not only as biogas but also in energy rich compounds (humus) and microorganisms that maintain or improve fertility/productivity of cultivated soils. In addition appear environmental benefits with increased microbial biodiversity and when various humic substances symbolise short and/or long time carbon sequestration.
It should be pointed out that biofertilisers helps to prevent erosion, thus conserving soil and water and maintaining the soil structure. Several million tons of topsoil are said to be lost annually from the cultivation of corn, cotton, and other crops, in addition to the loss of 123 kg per hectare of nitrogen by the removal of residues. Biofertilisers can significantly improve subsequent crop yields where the soil has low initial humus content. This is a cross border energy and environmental issue.

Potential of renewable energy from renewable biomass (RB)

It is known that **one tonne of RB contains between 1.5 and 7 MWh energy** in form of bioenergy bound in organic structures. RB can be classified in a number of ways for example by

a) origin (from forestry, agri- and horticulture, fisheries, related industries, municipality)
b) physical state (solid, slurry, liquid, gaseous)
c) common properties (barks, saw dusts, straws, fruit pulps, etc.)
d) common main component (sugar, starch, cellulose, protein, fat, etc.)
e) chemical composition (organic matter, ash, crude protein, crude fibre, nitrogen-free, etc.)
f) geographical location (national, regional, rural, urban, etc.).

Some of RB properties are of particular relevance to the subject of conversion by the action of microorganisms. Of the produce grown on arable land, by far the major part is discarded as residue (Fig. 3). These residues are available to convert into useful products by novel industrial process for example high-solid digestion in bioreactors BTF.

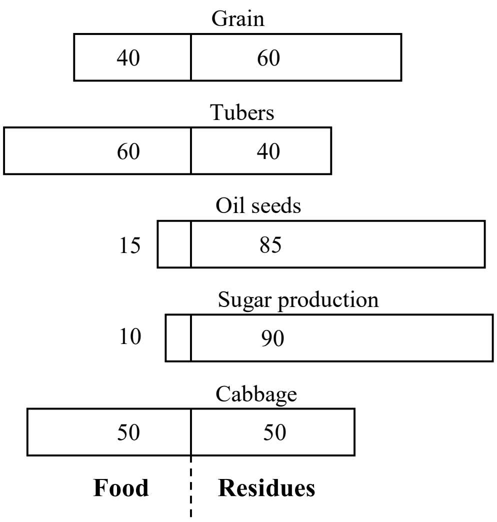


Figure B2-2. Some of the most important crops. On the left side we find the percentage considered to be the main food component of the crops. On the right side are the residues that can be used as raw material in mixtures optimised for microbial conversion. Residues contain 2.7 to 4.7 MWh energy/ton (10 to 17 GJ/ton).

The crop residues can be used for **biogas production** directly when mixed with manure, carcass, kitchen residues, etc. or stored and used when energy demand appears. Biofertilisers produced from homogenous raw material are suitable for horticulture, where high quality is required.

Figure B2-3. Equipment during experiments at Malmö University, Technology and Society, 2003. Bioreactor BioTransForm (BTF) developed at Swedish University of Agricultural Sciences by R. Svedelius.

Bioreactors BTF are being developed for an effective, non-smelling and hygienic processing of renewable biomass. In a decentralised so-called **G&G-System** (Gas&Gödsel/Fertiliser-System) can be produced **biogas and biofertilisers**.

B.3 Potential impact

Bioenergy hidden in renewable biomass has a very high potential for energy recovery and saving fossil energy as well as reducing carbon dioxide emissions and providing other environmental benefits - factors of particular importance in light of the Kyoto protocol's demands on industrialised nations to drastically cut CO_2 emissions by 2012.

Renewable biomass (RB) contains all kind organisms from plant and animal kingdom, their residues and also products created from them. It includes forestry and agricultural crops and residues; wood and food processing wastes; animals and their excreta; and the **largest part of municipal solid waste (MSW) - in Sweden 76 %** (RVF, Report 145, 1998). In Europe, more than 50 % of MSW is RB.

Every 10 kg of renewable biomass contains the same amount of bioenergy that 1.5 to 7 litre petrol. The variation depends on type of organic compound – fat has the highest energy content. Many organic compounds decompose on heaps and landfills without taking care of the energy.

This IP covers many different aspects, ranging from energetic and environmental questions to socio-economic ones, as well as the environmental consequences of increased bioenergy production and utilisation. A considerable part of renewable biomass activities and employment will be rooted mainly in rural areas or in close neighbourhood to cities where traditional activities are continuously declining.

The G&G-System would enable the advantages of biological transformation - higher energy conversion than traditional systems, minimising of emissions and improvements in cultivated soils - to be exploited, without the traditional carbon dioxide emission associated with fossil fuel use.

Introduction of **improved bioconversion system** that use clean advanced technology and novel methods will support the overall objective of this call - to substantially **contribute directly or indirectly to the EU five targets:**

(1) reducing energy intensity by 18% for the year 2010 - by use of less energy in alternative infrastructure and novel methods

(2) achieving a *global indicative community target of 18% of electricity consumption from co-generation by the year 2010 – by use of biogas for production of electricity*

(3) doubling the share of renewables from 6% to 12% for the year 2010 – by utilisation of many sources of renewable biomass that is today still treated as troublesome residues or as waste material

(4) contributing to achieving the objectives of the internal market for energy – at the beginning in rural areas where renewable biomass is mostly without impurities

(5) the policy of security of energy supply. Projects should also make a concrete input to the European Climate Change Programme.

In Report 5177, Febr.02, Achieving ecologically sustainable waste management, the **Swedish Environmental Protection Agency** wrote:
"The overall aim of environmental protection is to ensure that we leave the next generation a society in which the main environmental problems have been solved. This requires us to reduce impacts on the environment to sustainable levels….
Current waste management wastes resources. Materials and energy are not put to the best use; waste that could be recycled is still being landfilled. Nutrients in food waste and other organic waste are removed from the eco-cycle when they are landfilled straight away or as a constituent in ash from incineration….
* Long-term low emissions from waste management. - All forms of waste management should be conducted so that, in both the short and the long term, they do not generate emissions posing a risk to human health or the environment.
* Resource management. - The resource that waste represents in the form of **materials or energy must be utilised to the maximum possible extent and with the greatest possible degree of refinement**.
This will make it possible to effectively use both renewable and finite resources so as to **reduce the environmental impact** caused by products throughout their life-cycle, and will also help to create sustainable production systems."

In its Resolution on the **Green Paper** "Towards a European Strategy for the Security of Energy Supply"(5), the European Parliament identified **energy efficiency and savings as first priority**. It called for the promotion of an "intelligent" approach to energy use, making Europe the most energy-efficient economy in the world.
… the European Union is becoming increasingly dependent on external energy sources and that its dependence could rise to 70 % in 20 to 30 years' time (compared with 50 % at present) and therefore stresses the need to balance supply policy against clear action for a demand policy and **calls for a genuine change in consumers' behaviour** so as to orientate demand towards better managed, more efficient and more environmentally friendly consumption, particularly in the transport and building sectors, and to give priority to the development of new and renewable sources on the energy supply side in order to respond to the challenge of global warming.
…the European Parliament, in its Resolution on the **White Paper**, underlined the need for a substantial, **sustained increase in the utilisation of renewable energy sources** in the Community…

Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001 on the **promotion of electricity produced from renewable energy sources** in the internal electricity market (7) requires Member States to set national indicative targets consistent with the Community global indicative target of 12 % of gross national energy consumption by 2010 and in particular with the 22,1 % indicative share of electricity produced from renewable energy sources in total Community electricity consumption by 2010.
The "Final Implementation Plan" of the World Summit on Sustainable Development, agreed on 2 September 2002, committed the signatory countries, including the EU, to making efforts to: … **promote increased research and development in renewable energy sources, energy efficiency and cleaner conventional fuel technologies.**

The need **to promote the best practices** developed in the Community in the fields of renewable energy sources and energy efficiency, and to transfer them to the developing countries in particular, is one of the Community's priorities as regards international commitments.
Exchange of know-how, best practice and project results, coordination within the programme and with other Community policies, continuity with existing programmes, stability of rules of participation, sufficient human resources as well as a rapid implementation will be crucial for the success of the "Intelligent Energy - Europe" programme.

An advantage of this IP is that it will be realized within 42 months after the start of the project. This enables full and efficient utilisation of the information gathered in this project by interested organisation when building full-scale facilities before 2010. Thus by use of bioenergy from renewable biomass phase out a part of fossil energy - reach the reducing carbon dioxide emissions and providing other environmental benefits - factors of particular importance in light of the Kyoto protocol's demands on industrialised nations to drastically cut CO_2 emissions by 2012.

The results generated from this project should help shape a future, sustainable market for the renewable biomass.

B.3.1 Contributions to standards

The goal of ENEFBIOTRANS is to fill the gaps in the production and use of renewable biomass as energy and biofertilisers source in the spirit of biomass energy policy objectives at the EU and national level.
The EU described its targets for renewable energy in the ‘EU White Paper on Renewable Energy Sources’ published in 1997. The main goals of the European Union in the energy sector are to meet the Kyoto objectives, double the share of RES by 2010, improve energy efficiency and improve security and diversity of supply, competitiveness and job creation. In this context, **biomass is projected to be a major future contributor** to the EU’s future primary energy mix. In Sweden by 2010 should be 35% of food residue treated biologically.

The White Paper on renewable energy indicates a target for biomass and waste in 2010 of 135 Mt, of which 45 Mt would be provided by **energy crops**. It also indicates that the production of liquid biofuels (biodiesel and ethanol) in 2010 would make use of 18 Mt of biomass from energy crops but with smart improvements in microbial conversion to methane in biogas the economic evaluation can show the multifunctional impact when part of bioenergy returns to cultivated soils as biofertilisers.

There is a lack of integration across the policy agendas that impedes understanding of the constraints affecting biomass energy and hinders its development. There is a need for policy integration that will make different biomass energy drivers converge and catalyse its economically and environmentally beneficial use.

Results from this project will be important contributions to national and international standards.

B.4 Outline implementation plan

The proposed **technical approach** is the design, improvement, management and operation of three-step batch bioreactors BioTransform (BTF) for high-solid digestion, aiming at optimal microbial conversion of various materials of renewable biomass into biogas and biofertilisers.

The proposed **scientific approach** is to reach a deeper knowledge
1. On the bioconversion process optimum - that will give maximum output - through the creation of a wide set of experiments dealing with a) mixtures of various types of renewable biomass, b) use of additives, c) experiments on inactivation of pathogens and weeds and d) experiments on decomposition of biodegradable plastics and other synthetic compounds and
2. On the impact of both products on sustainable development of the society by a) use of biogas and b) use of biofertilisers.

Analysis of **energy, compounds and elements** will be provided on raw material and on products.

The **RTD approach** is multidisciplinary and contains both fundamental and applied research. As researchers and technicians come from various countries and do not have the same resources for doing experiments it is very important to build several **lines - that all are mobile** and can be moved to several places where the local environment and local circumstances are conclusive for the success.

“To be pioneer is interesting. The number of sceptics and prophets of doom is great.”
We want to face them by scientifically based programme of control and testing. During all steps we want to carry out analysis and use total transparency.

We would like to built
1) **Five Experimental lines** (EXP-LINEs)
2) **Three Demonstration lines** (DEMO-LINEs)

The technical hart - or engines - of these lines are batch bioreactors BioTransForm with volume of 20 L (BTF/20) in EXP-LINE and in the DEMO-LINE with volumes between 100 and 2000 L. All necessary equipment have been discussed with and calculated by subcontractor. Unfortunately we have no resources to do feasibility study and built complete line.

Both lines will be built step by step, first the EXP-LINE with two bioreactors BTF/20 and after three month, several experiments and required improvements next three bioreactors BTF/20 will be constructed. After another three month and several tests two novel bioreactors BTF/20 will be built and experience gathered from all partners will be used. In each EXP-LINE will be then available six bioreactors BTF/20 and experiments with high precision can be carried out. We are sure that in this is the way for the faster introduction of innovative and cost competitive renewable and energy efficiency technologies into the market.

EXP-LINE is needed for scaling up equipment and for possibility to verify results from EXP-LINE. Volume of bioreactors BTF will increase from 100 to 2000 L. Future full scale plant can use few large bioreactors or several small ones.

Using first small and then larger bioreactors BTF we attempt methods on different levels. As we cannot afford both lines at all places where partners works we decided to invite researchers, technicians and students to collaborate very close and share both success and disappointment. Valuable improvements can be made by enthusiastic and creative staff from one country in equipment in the other countries.

On the other side it is extremely important to build several lines and use many types of RB that are common in different countries. In the DEMO-LINE will be achieved a critical mass and first there we can measure the benefit. Similar thinking is presented in the Workprogramme of this call but in that case "it means that the aim is to assemble a *critical mass of resources*, to *integrate* research efforts by pulling them together and to make this research more *coherent* on the European scale".

Our aim is to use raw material of good quality – here it means that both the process and the solid product – biofertiliser - is in a great part determined by the material selected for microbial conversion. Microorganisms are very, very small "pigs" and cannot eat things that are not eatable! The **energy rich methane in biogas** is one of their excrements similar to energy rich liquid excrement alcohol. For good efficiency in recovery of biogas it is one great challenge to promote microbial activity and achieve sufficient yield of methane.

Clean environment and hygienic treatment

Not only amount of **recovered energy** but also **saved energy** and many other factors are important when we want to create **novel environmental technology** for better sustainability. Bioreactors BTF are always connected to biofilters. In the aerobic parts microbial conversion out coming air is wet and contains various compounds – often with characteristic not pleasant smell. This indicates that we loose nitrogen and sulphur in several combinations as emitting compounds.

All **emissions are both pollution and losses**. When nitrogen and sulphur disappear from the biofertiliser, **energy is needed to get them back** to the soils in one or other way. Therefore we use biofilters with the purpose to catch elements in dry and well disintegrated material. Then, when on the surface of small particles no more elements can be caught the contents of the biofilter go to next batch and are mixed with other types of renewable biomass. More of those important plant nutrients can be recycled and together with not digested structures they are of significant importance for fertility of cultivated soil, food quality, our health and in long run our survival.

Use of G&G-System is innovative, efficient and coherent holistic approach to waste management and sanitation , address socio-cultural, institutional, legal, economic, financial, environmental, sanitary and technical aspects of the problem , is alsoeconomically lucrative, ecologically correct and socially acceptable.

Our common activities are formulated in ten Workpackages
Details are available in WP tables below.

WP1 Management of consortium

- General management strategy
- establishing permanent communication between partners
- Contact and work with SMEs and decision making institution from Romania for their collaboration in experimental and implementation phases of ENEFBIOTRANS phases

Scientific management

- participation in the scientific network for the specific and general evaluation of the progress of the project

Technical management

- technical observations, difficulties and improvement proposals will be correlated and analysed in a periodic technical internal report

WP2 Design and construction of Experimental line (EXP-LINE) containing bioreactors BioTransForm, 20 litre of volume (BTF/20), biofilters and equipment for control of processes

- Feasibility study of Design and construction of the experimental bioreactors (step vice approach) and biofilters – all partners together with subcontractors (A and B);
- Instrumentation for the monitoring of bioreactors and biofilters;
- Construction of biogas collection system;
- Devices for flexible manipulation of input variables.

WP3 Experiments in EXP-LINE

- Production of biogas;
- Study of energy flows;
- Production of biofertilisers;
- Experiments on various substrates;
- Experiments on inactivation of pathogens;
- Experiments on inactivation of weeds;
- Analyses on effects of various additives;
- Analyses of compounds and elements;
- Bioassays - cultivation tests to verify quality of biofertilisers;
- Study of environmental impacts.

WP4 Modelling
In this WP partner who are experts on modelling will assist by modern methods to improvement of all technical parts of the G&G-System and creation of the best methods.

- Equipment;
- Optimisation of the process – various process parameters;
- Verification of the models.

WP5 Technical improvements of bioreactors and biofilters

- Appropriate model-based strategies for performance optimisation
- Automation of operation

WP6 Design and construction of DEMO-LINE

- Feasibility study for process up-scaling;
- Design of bioreactors of various volumes (step vice scaling up);
- Instrumentation for online monitoring of the bioreactors and biofilters;
- Technical implementation of devices for inputs manipulation;
- Design of tools implementing the automation of the process;
- Design of DEMO-LINE;
- Construction of all components of DEMO;
- Setting together the whole installation;
- Checking tests.

WP7 Experiments in DEMO-LINE will be carried out to verify results from EXP-LINE

- Experiments on precision in pre-processing;
- Production of biogas;
- Biogas collection, storage, conditioning and utilisation;
- Analyses of energy flows;
- Production of biofertilisers;
- Inactivation of pathogens;
- Inactivation of weeds;
- Effects of various additives;
- Analyses of elements;
- Post-treatment (storing) of biofertilisers;
- Bioassays - cultivation tests;
- Analysis of environmental impact.

WP8 Social aspects

- Acceptance;
- Employment;
- Analysis of the project influence on education and technical knowledge improvement;
- Analysis of all remarks and comments on project results coming from technology users;
- Diagnosis of future needs;

WP9 Meetings

- Internal workshops (scientific and technical);
- Conferences, seminars;
- Trainings.

WP10 Disseminations of results

- From EXP-LINE;

- From modelling;
- From DEMO-LINE;
- Create "European Bioenergy Pool" on Internet;
- Dissemination of technical information among potential customers;
- Analysis of the market;
- Final report.

BIOGAS – ***collection, storage and use***

INCT role in the project concerns biogas collection and utilisation both in EXP-LINE and DEMO-LINE. Biogas formed in biomass fermentation process is composed of methane (50-70%), carbon dioxide (30-40%), hydrogen (5-10%), nitrogen (1-2%), water (<0.3%) and trace amounts of sulphur hydrogen (<100ppm). To obtain the biogas composition related to standard gas characteristics (proper purity, calorific value, methane number), it is necessary to eliminate the water, lower the hydrogen, sulphur hydrogen and carbon dioxide concentration. Standard gas can be used in heat and electricity generation systems. For some other applications of biogas, e.g. as a fuel gas for cars, the other composition and characteristics are needed. Depending on future utilisation various gas composition are acceptable. INCT basing on the data collected in the project by other partners working on bioconversion system will elaborate the methods for biogas treatment. The aim of the research work is to adjust the biogas composition for further utilisation in the way that will fulfil the potential recipient expectations. The proposed method is based on membrane separation, which is environment friendly technology.

Energy in biogas

To obtain the biogas composition related to standard gas characteristics (proper purity, calorific value, methane number), it is necessary to eliminate the water, to lower the hydrogen, sulphur hydrogen and carbon dioxide concentration to the values described by standards. Standard gas of adjusted composition can be used in heat and electricity generation systems. For some other applications of biogas, e.g. as a fuel gas for cars and other machines, the other gas composition and characteristics are needed.

The proposed method of biogas treatment is based on membrane separation, which is environment friendly technology. The most often used and established technology for H_2S and CO_2 removal is amine absorption. It is an efficient method which adapts well to various gas compositions. However, there are several limitations which have enabled membrane gas permeation to be introduced into the market. Membrane units are more cost effective than absorption for smaller applications; they are easy in operation and do not cause additional emissions of toxic compounds into the atmosphere.

According the project schedule INCT will collect necessary data from experimental line operation concerning biogas parameters, composition and its calorific value. Basing on those data the methods of biogas collection and further treatment will be elaborated. Complementary study of the gas separation (GS) process employed for biogas composition adjustment will be done. The possibility of gas parameters adjustment according to some specific applications and customer needs will be investigated. The membranes, modules and other equipment for the biogas components separation basing on experimental data will be selected. Various possible methods of gas pre-treatment and conditioning will be studied and

appropriate technique will be selected. Selection of the analytical equipment and control system for the process will be done. Finally the procedures of biogas composition adjustments according to particular needs and further utilisation will be prepared.
After improvement of bioconversion system, which will be done (WP4) on the basis of experimental work, modelling and optimisation some parameters of the installation will be changed that will result in the change of biogas characteristics. Those supplementary data will be collected by INCT, who will do some corrections in the procedures of biogas conditioning. All of those procedures will be described in the report which will be deliverable from WP3.

ZWH research partner will be responsible for running WP 8 on Social Aspects.

B.4.1 Research, technological development and innovation activities

Experimental Line (EXP-LINE)
Research and innovation efforts in this EXP-LINE are focused
1) on the development of a novel approach to the management and operation of three-stage bioreactors and
2) on the radical improvement of methods by use of innovative equipment that makes possible increased precision in each step of conversion and thus retention time, losses of energy and elements will decrease while safety and productivity will increase.

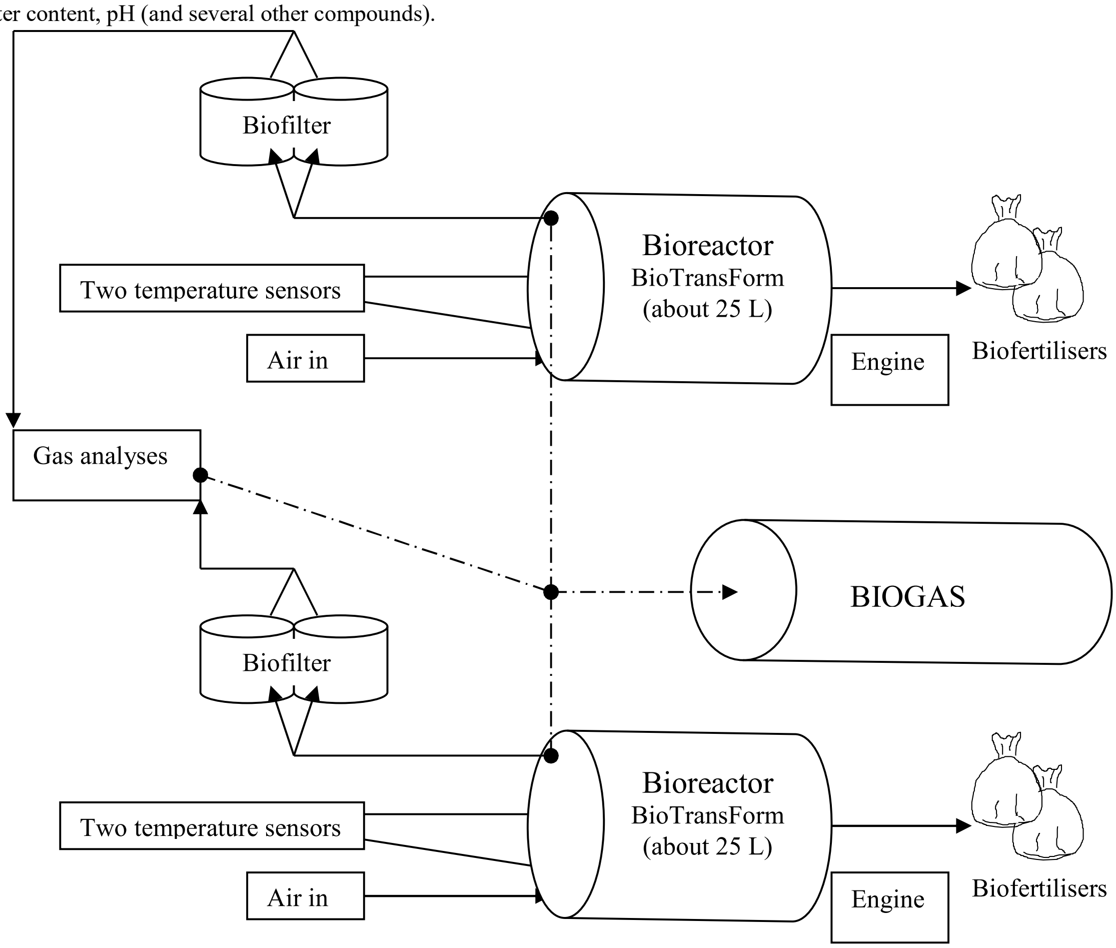
The main aim is optimal microbial conversion of raw material, containing various types of renewable biomass, into energy rich methane in biogas and biofertiliser containing energy rich compounds, beneficial microorganisms and most of the plant nutrients that were bound in the raw material.

These efforts can be subdivided in four strongly interconnected parts which will be performed in analogous ways on the bioreactors of both the experimental and demonstration line.

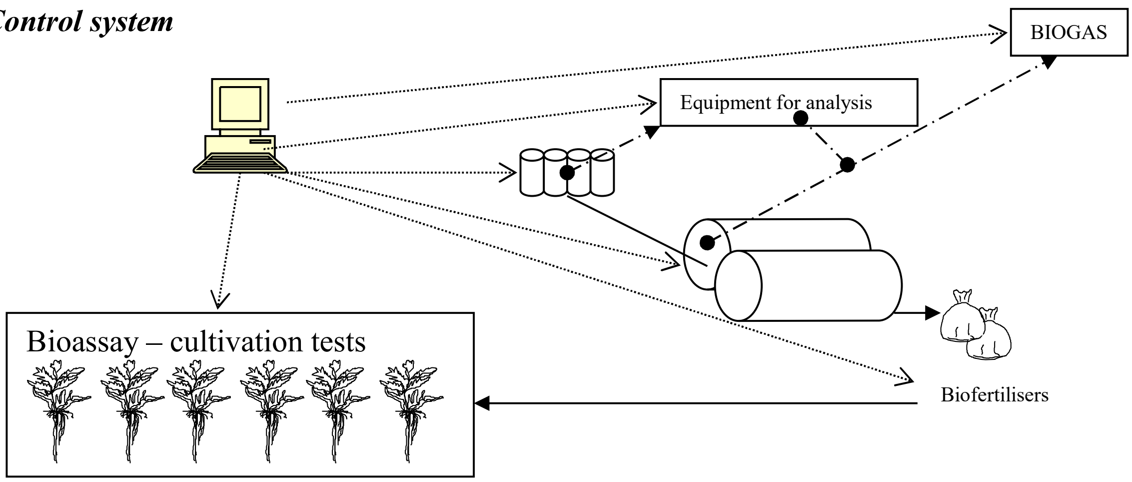
The first part aims at designing and scaling both an innovative knowledge-based bioreactor BTF and the equipment necessary for the exhaustive monitoring of the wide set of interrelated subprocesses occurring inside the bioreactor. During the design phase all partner will be involved in discussion on several technical improvements together with sub-contractor (Epsilon Technology AB, Sweden). Results of the feasibility study will lead to implementation by subcontractor in order to enable input and process variable manipulation, with the aim of reaching the maximum process flexibility and of allowing external interaction with it during various experiments.

The second part aims at reaching a deeper knowledge on the bioconversion process through the creation of a wide set of experimental data and the application of several multipurpose tools for their analysis. In this part are involved all partners. Partners that do not have EXP-LINE follow experiments during visits (weeks or month) are involved in analyses, cultivation tests, evaluations, modelling, discussions by e-mails, workshops, reporting, etc.

Figure B.4-1 **Experimental line**
Computer for control and for registration of all data.
Two well insulated bioreactors BioTransForm (BTF) connected to
GFC (mass flow controller) ; Two temperature sensores ; Two biofilters both connected to equipment for on-line analysis of gases in outlet air; Equipment for agitation of each bioreactor (engine and all necessary parts); Equipment for measurement of water content, pH (and several other compounds).



Control system



During the experimental phase the process will be fully monitored under several operating conditions in order to quantify its outputs not only under normal conditions but also under specified input and process variable manipulation. On the basis of experimental data, suggestions will be drawn in order to optimise the design phase assessing possible improvements. Moreover, the databases created during the experimental phase will be fundamental for the development of the following phases, aiming at the definition and validation of accurate models and at the realisation of appropriate strategy for process optimisation.

The third part aims at the definition and scaling of accurate modelling strategies in order to allow for the prediction of the process behaviour under the widest possible range of operating conditions and in response to possible variable manipulation. During this phase, different modelling techniques will be adopted and validated on the basis of the experimental data in order to exploit their potentiality, with the aim of choosing the most suitable for each of the various purposes that can be identified. Models defined in this phase will be fundamental for the following part.

In the fourth part, the optimisation of the process will be persecuted through the definition and scaling of both empirical and model-based rules aiming at manipulating the process. During this phase the aim will be the maximisation of biogas and/or biofertiliser production rates while achieving their optimal compositions. Experiments will be performed in order to assess the validity of proposed manipulation rules and will increase the experimental database constituting the aim of the second part of innovation related activities.

B.4.2 Demonstration activities

Demonstration lines (DEMO-LINE)
Here are all our activities concentrate on

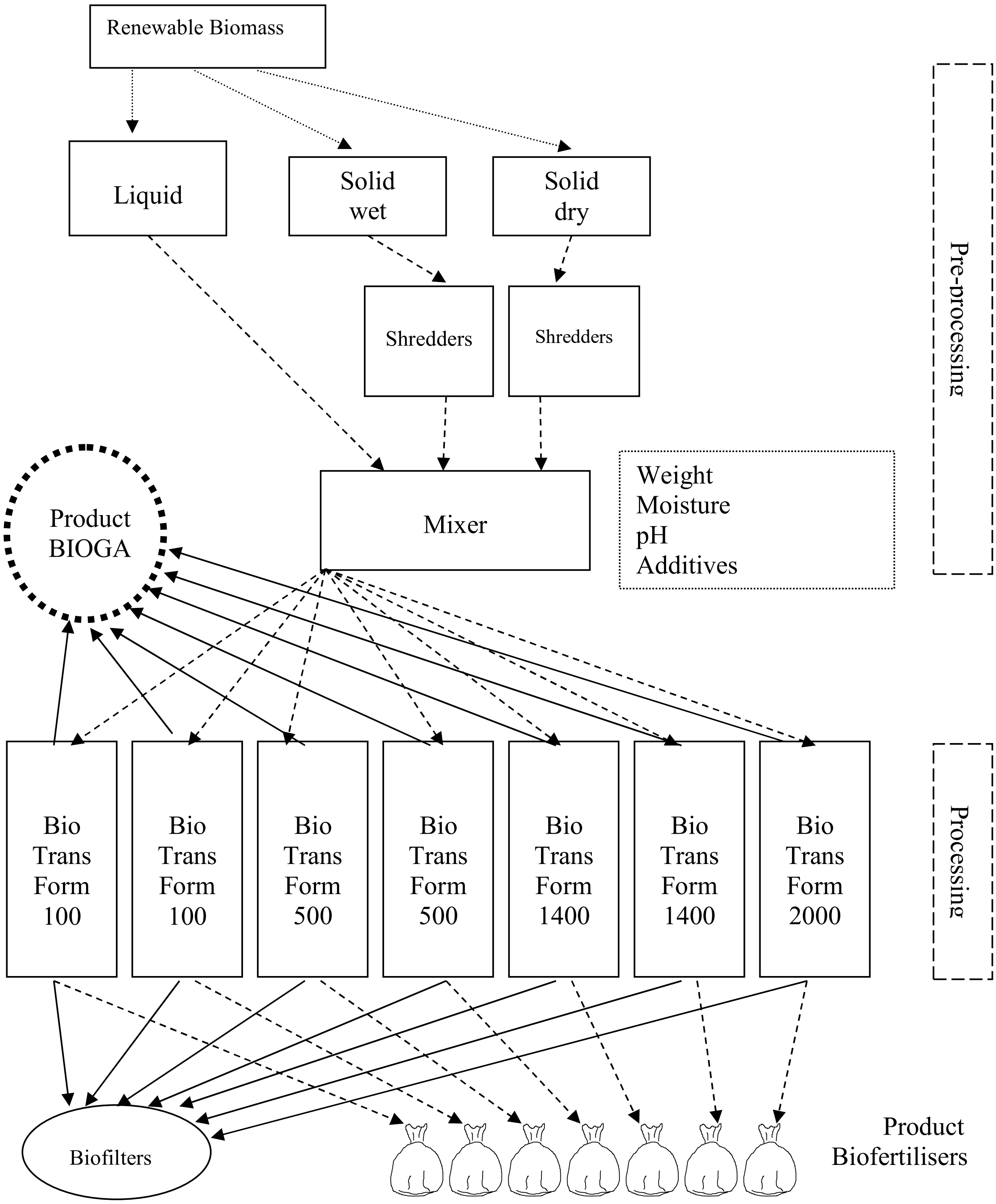
1) Step vice scaling up bioreactors BTF to verify results from EXP-LINE and to reach size that will be suitable for full scale facilities;
2) Further development and improvement both technology and methods;
3) Studies on energetic, environmental, economic and social impact.

Monitoring of DEMO-LINE will be performed in accordance with international standards and recognised practices and will ensure continuous performance optimisation on a long term basis.

Planning for unexpected outcomes of the research work:
As the bioreactors have been tested only as prototypes, the shape and size suitable for full scale performance have to be decided after the first or second step of scaling up.
Present a comprehensive description of the proposed demonstration action, including its scope, scale, objectives, validation methodology and success criteria. In the figure B.4-3 there are illustrate few gaps which may be filled by the implementation of ENEFBIOTRANS, the specificity for every sector and the potential contribution and task of every WP.

Collection and transportation of renewable biomass to local facility for production of biogas and biofertilisers in G6G-System has to be adjusted to modern logistic methods.

Raw material (renewable biomass) does not include compounds that disturb microbial activity in the process of bioconversion.



Gaps analyze.

Management of Renewable Biomass in Municipal Waste

The European Policy includes principles for reduction of the global volume and the maximum reuse of the reusable compounds. The actual problem is that in the western countries the incineration is preferred and in Eastern countries the waste is deposed practically only in landfills. ENEFBIOTRANS gives an alternative which is already studied but not enough, in the sense that the project will propose solution adapted to the concrete conditions from different participant country.

The EXP-LINE will adapt the condition to the effective structure of the organic waste, knowing, for example, the humidity in Romania is two times more important than in Sweden. The Experimental Line (**WP2**) Design and construction will use the specific information and experience from all partners and from European and International experience. More than that, one of the major European ISPA project (Management of Municipal Waste in Galati region) will be implemented in the region where one of the partners (**ECEE**) is from. The ECOSAL Prest SA, the company representing the City Council which will manage the project, accepted the collaboration (including the tests on the field). In the same region the Regional Environmental Protection Agency accepted to collaborate in the project. The technical improvements of bioreactors (**WP5**) will be realized taking into account the concrete structure and the seasonal variation of organic waste. The experiments in DEMO-LINE (**WP7**) will involve all the partners and the collaborators and, coupled with the dissemination activity (**WP9**) will create general model, usable in different conditions.

Management of Renewable Biomass in Farm Residues and Fuel Crops

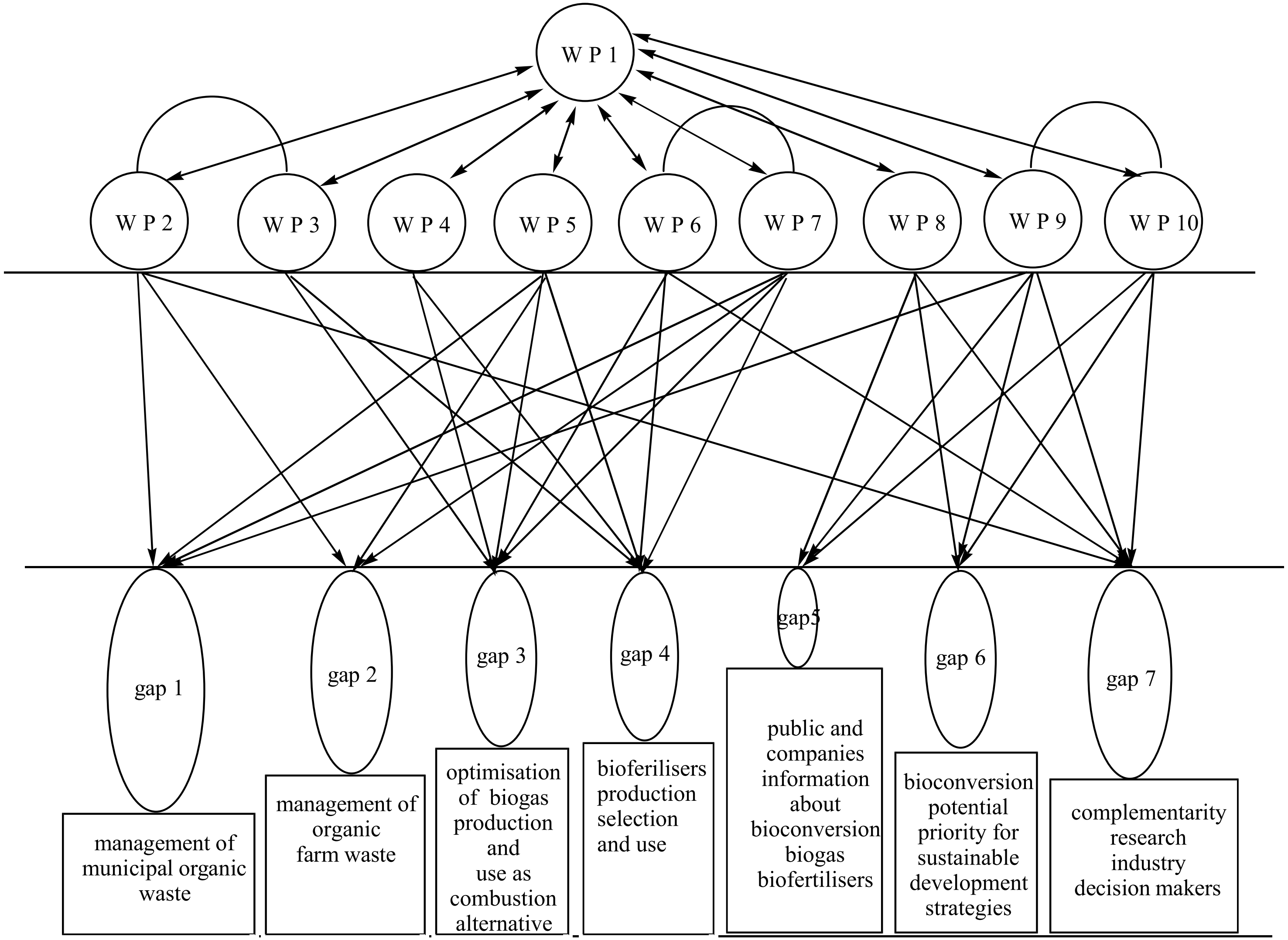
Quantities of renewable biomass that can be used as raw material for microbial conversion into biogas and biofertilisers are not so often discussed.

Beside production of biogas and biofertilisers for local use on the farm the G&G-System could have important environmental and health impact by: the minimisation of emissions to the air and water, inactivation of pathogens and weeds, etc.
The Experimental Line (**WP2**) will test:

- the optimum preparation and use of various types of renewable biomass
- the comparative study on different types of animal manure: from cows, pigs, chickens, etc.
- the experiments on mixtures of types of renewable biomass from municipalities and farms
- the use of various additives in order to improve process or biofertilisers or both
- the interaction between the use of biofertilisers and soil conditions (changes in temperature, moisture, protection against wind erosion, etc.)

After the technical improvements of bioreactors (**WP5**) and creation of some basic “recipes” adjusted for the local needs, the experiments will be continued in DEMO-LINE (**WP7**). A special attention will be accorded in Galati Region to the agricultural lands where the

Figure B.4-3 Specificity of WP to fill the gaps at European level in the optimization of biomass use



underground water is superficial and sensitive because the soil is permeable. In this case the biofertilisers have to be of quality that guarantee protection of groung water against pollution. In this region the implementation will be realized in collaboration with Regional EPA and the County Council.

Optimisation of Biogas Production, Storage and Use

One of the aims of **WP6** is to study the possibility of utilisation of biogas produced in technical scale by the bioconversion system constructed and demonstrated in the scope of the project (DEMO-LINE). Depending on future utilisation various gas compositions can be considered. INCT basing on the data collected in the project by other partners working on bioconversion system will elaborate the methods for the treatment of biogas produced in industrial systems. The aim of the research work is to adjust the biogas composition for further utilisation in the way that will fulfil the potential recipients' expectations.

All experiments performed with DEMO-LINE will provide INCT with additional data necessary for further work on biogas conditioning. The previous statements will be verified in pilot plant experiments. The complete methods of biogas parameters adjustment to standard gas parameters will be proposed and described in final report. The potential places of biogas utilisation will be identified.

If the theoretical principles of sustainable development have to be apply into the reality, it is necessary to analyse and compare economical, technical, environmental and social aspects (including jobs, health and education).

From the **economical** point of view, in all the step of the project it will be targeted the optimum taking into consideration: resources and their medium and long term utilization. The consortium created in ENEFBIOTRANS will collaborate with local, regional and national authorities in order to have a correct image on the opportunities for establishing a market for biomass in the short- and medium-term. It is necessary to find answer to following questions:

- How can short-term opportunities set the potential users on a pathway of biomass options meeting the requirements of future energy demands;
- What are the implications for biomass resources?

The **best available technology** will be used in all the phases of the project.

B.4.3 Training activities

The project is prepared by interdisciplinary team of the specialists from different branches for which common denominator are the term "bioconversion". To be more acquainted with each partner's role in the project and specific field of his competence the exchange of information by often meetings and seminars, will be important. The trainings in the institutions taking part in the project activities, especially for young research stuff, will be necessary. To gain the complete knowledge about all consortium members' expertise will be the aim of each project participant.

One of the most important goals of the project will be the knowledge transfer among all consortium members through bilateral meetings, workshops with participations of all partners, as well as trainings in partner institutions. The transfer of knowledge outside the consortium will be very important, too. The seminars and trainings for people interested in novel, developed in the project technology and potential users of bioconversion lines will be organized.

The examples of trainings:

1. **Design and functions of batch bioreactors BTF, biofilters and equipment for pre-processing:** responsible Ruzena, AS-M, Sweden

Programme

- Bioreactors for high-solid digestion compared with conventional ones
- Biofilters
- Equipment for pre-processing
- Control system (hard and software)
- Visits to related centres working on bioconversion in European countries

2. **Microbial conversion:** responsible Liliana, TU-Lodz, Poland

Programme

- Methods for pre-processing and processing
- Use of additives
- Analysis on energy flows, compounds and elements
- Inactivation of pathogens and weeds
- Visits to related centres working on bioconversion in European countries

3. **Modelling:** responsible Arturo, UINCT, Italy

Programme

- Visits to related centres working on bioconversion in European countries

4. **Storage and use of biofertilisers:** responsible Ruzena, AS-M, Sweden

Programme

- Analysis of plant nutrients in various biofertilisers
- Cultivation experiments – bioassays
- Visits to related centres working on bioconversion and cultivation experiments in European countries

5. **Training on novel technologies of biogas treatment:** responsible Grazyna, INCT, Poland

Programme

- State of the art: conventional biogas treatment techniques
- Membrane technology, membrane gas separation (GS) systems
- Biogas utilisation possibilities, analysis of the situation on the market
- Visits to INCT laboratory
- Visits to related centres working on bioconversion
- Discussion panel