Bioenergy from waste

A guide for European Union Municipalities
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1. Introduction

This booklet has been developed as a training booklet to provide an easy understanding and a review of the energy potential from waste resources of a municipality. It is designed to assist Local Authorities in the estimation of the amount of energy which can be generated from waste, using a calculating tool available online.

It has been created in collaboration with our partners under the INTERREG IVC, EBIMUN Project.

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2. EU Policy

During the past decades, the European Union has made many efforts for the development of a low carbon emission society. The Kyoto protocol was for example ratified in 2002 in order to cut carbon emissions, with specific targets for EU member states.

The Landfill Directive adopted by the EU in 1999, has an overall aim to reduce the pollution of surface water, soil, air and the global environment including greenhouse gases. The usage of organic waste for the generation of energy is an alternative way to its disposal in landfills.

The implementation of Animal Byproduct Regulations (EC) 1774/2002 and Nitrates Directive 91/676/EEC, has assisted in the development of bio-energy processes that are suited to the treatment of food waste and waste from agricultural sources.

3. The Carbon Cycle

How is it possible to reduce the emission of greenhouse gases?

Natural carbon emissions, such as animal or plant respiration are compensated by the natural absorbance of carbon. It is assimilated by plants and oceans, by photosynthesis or carbon exchange. This is a closed cycle and the amount of carbon in the atmosphere has been sustained for thousands of years within given levels.

The use of fossil fuels since industrialization has artificially inflated the levels of carbon emissions released into the atmosphere. These increased levels of carbon in the atmosphere cannot be quickly assimilated by nature and this accumulation in the atmosphere, causes global warming and climate change.

CO2 levels in the atmosphere have reached levels that have not existed for 400,000 years. The latest level recorded was 393 parts per million, while it was less than 300 ppm in 1950. CO2 concentration in the atmosphere is now at a critical point and action has to be taken by all to reduce the trend of increasing CO2 levels in the atmosphere.
Benefits from Bio Energy

- Using waste as a source of energy provides a good way to dispose or process it, producing energy on the way.
- As it is a renewable and abundant resource, waste is a very efficient way to provide a reliable source of energy.
- Using bioenergy is more environmentally friendly, as its carbon emission balance is near neutral.
- Setting up a bio energy facility can be a potential source of local employment.
- Bioenergy is one solution to the substitution of oil.
- The by-product of bioenergy production can sometimes be used, for example as a fertilizer.

Many processes are now available to produce energy from waste and biomass, so Local Authorities should be able to find a way to use its own resources to produce energy.

Although it represents quite a big starting investment, developing new sources of energy in a municipality is a safe way to help ensure energy supply in the future. Adopting a long term strategy is the best way to deliver a cost effective bio-energy facility.
The flow chart below has been designed to help assess and outline the different steps involved in developing a bio energy facility. It shows the process for setting up a bio energy facility, and outlines the process involved.
Biomass is biological material derived from living, or recently living organisms. In the context for energy this is often used to mean plant based material, but biomass can equally apply to both animal and vegetable derived material.

Biomass is the beginning of all fossil fuels. So there is no reason the amount of energy produced million years ago could not be reproduced now. Using modern skills and technologies, this energy can be produced more quickly than the millions of years it took for nature to do it.

Each EU member state will have to meet the challenge of gradually converting, renewing and modernising their former older energy systems to a sustainable and renewable way to produce and use energy.

This booklet has been designed, to provide Local Authorities with information and also review of what can currently be done to convert local biomass resources into energy. It includes for example, the processing of household waste, agricultural waste, and wood industry residues.

Finding out the type of waste available is the first item to complete. It will depend on the waste collecting system, the main industrial field in the concerned area, etc…

The previous flow chart shows that waste can be separated into two different categories:

- **wet material**
- **dry material**

Wet material is for example, produced by Local Authority sewage sludge and sludge from water treatment plants. Dry materials could be residues from wood industry.

In order to make the installation visable, it may be required for Local Authorities to join with others authorities or industries. In fact, sharing the installation will reduce the Local Authority expenditures. Plus, it can permit building a project that could not have been built without joining different municipalities, for example if the amount of waste is too low in each community.

The calculator available online will provide a quick way to make an approximate estimation of the bioenergy potential of a Local Authority. It is the first step in a bio energy project evaluation potential. This may also have to be carried out by a specialist company before the likelyhood of a project progressing.
Before deciding to develop a bioenergy project, it is imperative to provide an estimate of the energy potential from the bio energy resource of each municipality. Local Authorities will be able to therefore determine if a bioenergy project is economically viable or not.

The calculator is available online at www.bioenarea.eu/EBMVN Project

The calculator includes 7 work sheets, each of which covers a different range of biomass sources. A total calculation of energy potential can be achieved from each bio-energy product to the process. This yield, when available for a sustained period, can be included within a business plan where the feasibility of such a facility is known.

**Worksheet 1**  
Covers the organic waste produced by households

**Worksheet 2**  
Is designed to deal with the agricultural and food processing industry

**Worksheet 3**  
Is dedicated to the potential of sludges from water/waste water treatment plants or industrial sludges.

**Worksheet 4**  
Refers to energy crops which may be required to balance the process

**Worksheet 5**  
Deals with commercial activities residues

**Worksheet 6**  
Focuses on industrial processes residues

**Worksheet 7**  
Is exclusively dedicated to harvested biomass, such as wood

**Worksheet 8**  
Is a sum of the Bio Energy Potential
8. Types of Bio-Energy

Several ways are currently available to produce energy from biomass:

- 8.1 Direct combustion
- 8.2 Anaerobic digestion
- 8.3 Gasification
- Pyrolysis
- Fermentation
- Oil extraction

Each process can use different types of input material and produce different forms of energy.

<table>
<thead>
<tr>
<th>Technology</th>
<th>Energy Type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gas</td>
</tr>
<tr>
<td>Anaerobic digestion</td>
<td>X</td>
</tr>
<tr>
<td>Gasification</td>
<td>X</td>
</tr>
<tr>
<td>Pyrolysis</td>
<td>X</td>
</tr>
<tr>
<td>Fermentation</td>
<td></td>
</tr>
</tbody>
</table>

This table shows the different ways to create usable energy from biomass. Thus, direct combustion does not appear in it as it is a direct way to use the energy content of biomass.

Technologies such as pyrolysis, fermentation or oil extraction are not described in detail as these technologies, are generally not economically viable, however are expected to become viable in the coming decades due to the increasing cost of fossil fuel and security of supply issues.
Short description of each available technique

➢ **Direct Combustion** can be used for a thermal use of biomass, such as heating (personal or district), in predesigned boilers. It directly uses the energy content of biomass by burning it.

➢ **Anaerobic Digestion** process is composed of bacteria which has the ability to decompose organic waste, generating carbon dioxide (CO2) and methane (CH4). This is a chemical reaction, which brakes organic material to usable-sized molecules (sugar), then into acid and finally biogas.

➢ **Gasification** is an indirect way to use the energy potential of biomass. The principle is to convert biomass into Syngas, which is a mix between methane and other components. It is almost always used to produce electricity and heat energy as a by-product.

➢ **Pyrolysis** is a thermal decomposition of organic material without burning it, which means with a limited amount of oxygen. It produces gas, oil and charcoal. There are currently many innovative projects based on pyrolysis. The difference between these processes is mainly the nature of the final product. In fact, either oil or gas can be produced separately or both together by Pyrolysis.

➢ **Fermentation** is a technology to obtain liquid bio fuel from biomass. Several different techniques can be used for this process, with all processed from households waste.

➢ **Oil Extraction** is one of the most researched ways to create energy from solid biomass. It includes either a physical or chemical operation to extract the oil from the material. The most promising process is the creation of biofuel from microalgae. This process duplicates the creation of natural oil, by feeding microalgae with carbon dioxide. Grown in transparent tanks, the algae consume the carbon and multiply. Oil is finally extracted, and can be exploited like natural oil. The carbon balance is also neutral, with an emission during combustion equivalent at the amount of carbon absorbed during the growth.

This technology will provide in the future a widely used fossil fuel oil replacement product, but will not be able to reach the volumes needed for the current consumption.
8.1 Direct Combustion

Organic waste such as tree tinnings can be burned to generate for example, heat energy in many different forms in a predesigned boiler. The typical size of the installation will vary and can be used with other technologies in a hybrid system. However it is imperative to know the feed stock size and moisture levels prior to proceeding with a boiler installation.

*Different forms of combustible wood material can be produced, depending on the main available resource.*

**FIREWOOD** is often the by-product of tinning the tree stock belonging to municipalities and can be burned in stoves, gasification boilers and large automated boilers.

**CHIPS** can be obtained from tree tinnings or from processing timber waste. It can be used in many situations; because is a cheap source of energy and has a good calorific value. Typically boilers with a base load above 100kW use wood chips and require significant space to be allocated for the accommodation of boiler related equipment.

**PELLETS** are obtained by compressing little particles of sawdust. It will be essentially used in small or medium heating installations and where there is insufficient space to accommodate a wood pellet boiler.

It is advised for Local Authorities to have a study made on available combustible material in order to determine the most suitable type of boiler in their specific case. In fact, it can sometimes be quite convenient to benefit from the flexibility of a multi fuel boiler.

In general every part of wood resource can be used in boilers: residues are adapted to produce either chips or pellets, while the main part of the tree is used in a variety of bio-energy installations. Consideration will have to be given to the setting of a storage area, designed to ensure the availability of the combustible material at all times.
8.2 Anaerobic Digestion

Anaerobic digestion is a controlled process where biomass is broken down by micro organism to produce bio gas. An anaerobic facility can be fed with several types of material and is also available at different scales and types.

Another advantage of an anaerobic digester is the possibility to use the produced digestate as an agricultural fertilizer.
8.3 Gasification

Gasification is a process in which biomass is converted into Syngas. However gasification is not viable for all types of biomass. It has to contain specific components, and a minimum dry level of by-products can be guaranteed too.

The composition of the resulting Syngas will depend on the nature of the biomass, and the process employed. It will typically contain Nitrogen (50%), carbon monoxide (20%), carbon dioxide (12%), hydrogen (16%) and methane (2%).

This syngas has a typical calorific value of 5,000 kJ/Nm3, which is equivalent to 1.4kWh/Nm3. As a comparison, pure methane benefits with a calorific value of 11.1kWh/m3.

It can be either directly used onsite to produce energy in an internal combustion engine or a combustion turbine, or converted into high calorific valued fuel and used off site in a combined heat and power plant or even as a transport fuel. This process combines pyrolysis and partial combustion, and is divided into two main different techniques:

- Fixed bed
- Fluidized bed

The fixed bed process is the simplest to install but is quiet limited to installations of less than 1MW.

As opposed, fluidized bed installations are a little more complicated to build and run, but offer a larger range of power and a better tolerance to variation of biomass resource.

Different other parameters will also have to be chosen: leveling agent, operating pressure, heat supply, type of raw material etc...

Gasification technology is more appropriate if both electricity and thermal energy are produced, which will produce a high yield.
Bio energy can be used in different ways by a municipality.

It can be used for:

**HEATING** - is the main use of the biomass, especially the dry part. It is now quite easy to source high efficiency wood chips boilers, from a few kW to several MW. Biomass offers a real flexibility for heating projects: either a personal installation or a district heating scheme run by wood energy.

**TRANSPORT** - is a good solution to use the biogas waste which is produced. In fact, several municipalities of Sweden have for example already converted their own vehicles (council vehicles, waste collection vehicles and public transport) to this type of motorisation.

**ELECTRICITY** - can also be produced from waste. The most common way is to use an internal combustion engine or a turbine on a larger scale. Although the principle stays the same for every type of cogeneration, there are some technical differences between combustion cogeneration, steam cogeneration and combined cycle cogeneration.

*It might be viable for local authorities to produce both heat and electricity. In fact, the yield with cogeneration is better than a single energy source, and the installation is more flexible, as the production distribution can be modified.*

![Cogeneration principle](image)

The advantage of this modularity is the ability to adapt the production to the current demand in the close area of the cogeneration plant.
10. Case Study A: Waterford City Anaerobic Digester

Waterford City Council launched in June 2011 a tender on the construction and running of a new anaerobic digestion facility project at Kilbarry, Co. Waterford.

This plant is expected to process 22,000 tonnes of bio-waste per year. Methane will be produced from the Process and combusted on site providing heat and electricity equivalent to the electrical demand of 2000 homes.

The building of the plant will employ 50 people, and 5 full-time jobs are expected to be provided for the running of the installation which is due to be completed at the end of 2013.

This plant is the first one of this kind in Ireland and also provides a liquid fertiliser as a co-product, which can be spread on the land by local farmers.

This new plant will help Waterford city in meeting the demands under the new Landfill Directive.

From an educational aspect, it has been accorded that students from local schools and third level colleges will be able to visit the site, in order to provide information on the role of waste as a source of energy in the future.
Case Study B: 100% Biogas Urban Transport

The city of Linköping, in Sweden, started running its biogas plant in 1997. The idea was at that time to treat organic waste from agriculture, and use the biogas as a fuel for the urban city buses.

![Table]

<table>
<thead>
<tr>
<th>Linköping plant</th>
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<tr>
<td>100,000 t/year</td>
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<tr>
<td>2 X 3,700 m³</td>
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<tr>
<td>€ 14 million</td>
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This 140,000 inhabitant city is located in an agricultural district, so the manure from cattle and pigs could be co-digested with other waste from the food industry, such as abattoir or organic waste.

The city had a project to convert its buses to natural gas in the 90’s, in order to reduce the diesel-related pollution, but the Natural Gas Grid expansion was questioned, so the city of Linköping decided to use locally produced biogas. In fact, several organizations co-operated to set the Linköping Biogas AB in 1995. This company took the decision the same year to build a biogas plant to supply the city buses. It was put into operation in 1996 and was originally designed to handle 100,000 t/year of waste.
In 2005, there was a total input of 45,000t of waste, producing approximately 4.5 M Nm³ of biogas.

<table>
<thead>
<tr>
<th>Input (tonnes/year)</th>
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<tbody>
<tr>
<td>Manure</td>
<td>2,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Abattoir waste</td>
<td>30,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industrial organic</td>
<td>6,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>waste</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Household waste</td>
<td>250</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>7,000</td>
<td></td>
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Output (tonnes/year)

Certified bio-fertilizer to farming 52,000 (water is added)
12. Conclusion

Using biomass can be a very efficient way to reduce carbon emissions in the atmosphere, and is also a good way to have a sustainable source of energy for our municipalities. By building new infrastructures and developing new skills, viable plans can be delivered on.

For any further information or technical advice contact Waterford Energy Bureau or our project partners in the applicable jurisdiction.

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13. References

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- Biomass Technology Review: Processing for energy and materials, .. prepared by Crucible Carbon for Sustainability Victoria
- Biogas in the society, IEA Bioenergy
- La méthanisation, C Servais
- Wood chips picture front page and p11 by Tony Rowe, Arvada, Colorado USA
- Firewood picture p11 by photoXpress®

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