RURAL BIOENERGY

Training Plan on Bioenergy for the agri-food sector

2017-1-ES01-KA202-038057

DIDACTIC MATERIALS

"BIOENERGY IN RURAL AREAS"

MATERIAL FOR STUDENTS

(Complementary to teachers' material IO2)

INTELLECTUAL OUTPUT 3 (IO3)

2017-2019

Co-funded by the Erasmus+ Programme of the European Union

INDEX

INDEX

INDEX

This intellectual product (IO3) called "BIOENERGY IN RURAL AREAS" DIDACTIC MATERIALS, developed within the RURAL BIOENERGY project, includes materials created specifically for students, which are a fundamental part of the package of open educational materials (OER) resulting from the project (TRAINING PACKAGE IN RURAL BIOENERGY).

The educational materials for students have been developed following the structure of the MODULES established in the project, trying to explain the theoretical and practical contents related to Bioenergy and its different types of fuels, facilities and uses in rural areas and agricultural and agri-food sectors.

Although this material follows the same modular scheme of the material for teachers (IO2), as it cannot be otherwise since they are complementary materials, the present material destined for the student has a more didactic approach, trying to arouse interest in the subject, the critical sense, the relationships between different aspects, among other pedagogical objectives. **This material includes within each of the modules, the following parts specifically aimed at the student:**

> **Conceptual chart:** General conceptual scheme of the main contents of the module and their relationships between them. It is intended to provide a global vision of the different aspects developed in each unit, essential for the student to understand the subject. It is presented at the beginning of each module but its use is also recommended at the end as a support tool to review and correctly fix the main concepts and relationships.
>
> **Some previous questions:** As a way of making contact and with the aim of arousing curiosity and interest in the student in each subject some reflections or previous questions are raised, which will also help the final self-assessment after having gone through the content development.
>
> **Frequently asked questions:** A series of common questions and their answers are collected in order to make clear the frequent questions that anyone could ask and a professional or a bioenergy producer should know.
>
> **Worksheet:** With activities to awaken critical thinking, recapitulating the contents and sometimes deepening some of them.

Besides, in the part of the **contents development of each module, o**nly the main contents are included, in addition to doing it in a more didactic, simple and visual way than in the teacher's material, hence we have included many didactic graphics and diagrams.

Following the modular development, this didactic material includes a **GLOSSARY** with a brief definition of all those basic concepts and terms that the student should know.

In addition, this material provides a brief summary document with the main guidelines for the development of a **VIABILITY STUDY FOR THE IMPLEMENTATION PROJECT OF A BIOENERGY INSTALLATION**, which has also been considered very useful for the student.

1 INTRODUCTION TO BIOENERGY AND ITS USES IN RURAL AREAS

Conceptual chart

INTRODUCTION TO BIOENERGY AND ITS USES IN RURAL AREAS

CLIMATIE CHANGE

EXHAUSTION NATURAL RESOURCES AND FOSSIL FUELS	ENVIRONMENTAL PROBLEMS	POLLUTION

CIRCUAR ECONOMY
RENEWABLE ENERGIES
NEW POLITICS
about energy, economic and rural development, agriculture, energy efficiency, etc.

BIOENERGY

RAW MATERIALS OF BIOMASS (Crops and residues)	TRANSFORMATION PROCESSES AND TECHNOLOGIES	USES OF THE BIOENERGY
FOREST AGRICULTURE LIVESTOCK AGRICULTURAL INDUSTRIES FOREST INDUSTRIES MUNICIPALITIES	**Biofuels** SOLID GASEOUS LIQUIDS	**THERMAL** (Heating, hot running water, hot for processes…) **ELECTRICITY** **BIOFUELS FOR TRANSPORT** (Biodiesel, Bioethanol)

A NEW OPORTUNITY IN RURAL AREAS

(Economic diversification, new economic income, fixing of population)

EXAMPLES OF RURAL USES

1.1. NEED FOR A NEW ENERGY AND ECONOMIC DEVELOPMENT MODEL

Some previous questions

*The following images show some of the consequences or impacts of one of the most serious environmental problems we face today globally: **climate change**.*




What is climate change? What causes it? What does it mean to you? How do you feel it in your daily life? Do you think it is so serious as to endanger the future of the planet we live in?

1.1.1. SOME IMPORTANT CONCEPTS REGARDIND THE GLOBAL PROBLEM OF CLIMATE CHANGE AND ITS SOLUTIONS

GREENHOUSE EFFECT GASES AND CLIMATE CHANGE

Greenhouse gases exist naturally in the atmosphere but the rapid increase in their concentration due to anthropogenic activity has made them a threat to the climate. The greenhouse gases are carbon dioxide (CO_2), methane (CH_4), N_2O, HFCs, perfluorocarbons (PFCs) and SF_6. CO_2 contributes the most to climate change, given that it represents approximately 80% of total emissions.

The main source of CO_2 emission is the combustion of fossil fuels. This is mainly done to obtain energy, either electric power in power plants or mechanical or thermal energy, such as internal combustion engines of vehicles or heating boilers of buildings.

The increase in CO_2 and other greenhouse gas emissions due to the combustion of fossil fuels for different human activities (transport, industry, domestic use, electricity production, etc.) has caused global warming and climate change. If we add to this the loss of natural resources in general and fossil fuel deposits such as oil, natural gas and coal, in particular, has led to new long-term policies and strategies, both of the EU as worldwide, to change the energy model, introducing new renewable and cleaner sources of energy, among which is bioenergy, and emerging new economic development models in which the bioeconomy and circular economy takes a great importance.

Photo: Pixabay. We take the environment for granted but we are subjecting the planet to irreversible processes that can turn "our home" into a desert.

BIOECONOMY

The bioeconomy promotes a smarter way of using and conceiving biological resources, converting renewable resources from land or sea into other products or bioenergy, for example by giving waste a "second life" by converting them into valuable resources by generating this way economic resources with the closing of the production cycle. It is a way of preserving nature and biodiversity while generating new economic activities and income for farmers, forest entrepreneurs, fishermen, ... promoting employment, economic growth and therefore local development in rural areas.

CIRCULAR ECONOMY

Taking as an example the cyclical model of nature, the circular economy is presented as a system of resource utilization where the reduction of the elements prevails: minimize production to the indispensable minimum and bet on the reuse of the elements that due to their properties can't go back to the environment. That is, the circular economy advocates the use of most biodegradable materials possible in the manufacture of consumer goods so that they can return to nature without causing environmental damage after their useful life. In cases where it is not possible to use "eco-friendly" materials, the objective will be to give it a new life by bringing them back to the production cycle and composing a new piece. The circular economy aims to change the paradigm of producing, using and pulling the current linear economic model that could be coming to an end.

Some of the important principles of the circular economy are:

1. Waste becomes resources. All biodegradable material returns to nature and that which is not biodegradable is reused or recycled. Those products or residues that no longer correspond to the initial needs are reintroduced into the economic circuit and use energy that can't be recycled).

2. Establishment of a mode of industrial organization in the same territory characterized by optimized management of stocks and flows of materials, energy and services.

3. Energy from renewable sources and elimination of fossil fuels to produce the product or to recycle.

RENEWABLE AND NON-RENEWABLE ENERGIES

We call **non-renewable energies** to those of limited quantity in nature. These types of energies fall into two categories, according to their extraction: fossil fuels and nuclear fuels. Although they are usually the ones that pollute the most, since they are the ones that are classically used and all their mechanisms are already built, they represent around 80% of the world's energy. They generate high emissions of greenhouse gases (GHG) and harmful gases (SO_2, NO_x) in addition to waste. Energy sources are only found in certain areas of the planet, so their extraction and use has historically depended on international trade and collaboration, and that is why it has been the origin of many war conflicts and is subject to great price instability.

Renewable energies are of more recent use, they take as their source infinite materials in nature -because they are inexhaustible or because of their rapid regeneration-, polluting less in the process. Renewable energy is energy from non-fossil renewable sources, that is: oceanic, wind, geothermal, solar, hydraulic, aerothermal and hydrothermal energy, in addition to **bioenergy.**

COMMON ADVANTAGES TO ALL RENEWABLE ENERGIES
Autonomous character
Greater respect for the environment
Creation of a greater number of jobs than conventional sources
Contribution to energy diversification
Strengthening the regional balance due to the geographical breadth of its distribution

SPECIFIC ADVANTAGES OF BIOENERGY
Contribution to forest cleaning, reduction of fire damage and erosion prevention
Use and recovery of waste
Solution to waste disposal problems and prevention of possible contamination
Rural economic diversification, job creation and population fixing
It generates a neutral balance in CO_2 emissions, and less SO_2 and NO_x emissions compared to fossil fuels
It generates less energy consumption in transport when generated and consumed in nearby areas
It has a lower potential danger to possible accidents during transport
It prevents the erosion of “retired” or deforested land that goes to energy crops/plantations

1.1.2. EUROPEAN FRAMEWORK

The new energy production model, the prospects for energy savings and the promotion of new energy sources are related to the new economic models, focused on sustainable local development. A new energy production model must meet the following objectives: **economic sustainability, environmental sustainability and the importance of local development.**

The promotion of renewable energy sources as part of the local development policy requires significant financial support in addition to legal norms, explicit strategies and political objectives that support its development. It is essential to take coordinated measures between the production sectors and institutions (in the field of agriculture, the environment, land use, transport).

Between 2005 and 2016, the consumption of renewable energy in the EU increased by 78.6%. Some renewable energy sources grew exponentially. Among renewable energy sources, total biomass or bioenergy (i.e. wood and coal, biogas and biofuels and municipal waste) plays an important role, since it accounted for two thirds (65%) of gross energy consumption of internal energy renewable in the EU-28 in 2016.

Below we collect some of the existing Policies, Strategies and Directives in Europe to promote the use of renewable energy and a new energy model with less carbon emissions in addition to promoting a more environmentally friendly economic development.

EUROPE 2020 STRATEGY

The Europe 2020 initiative is the EU's growth and employment strategy in the present decade and insists on the need to make an urgent transition to effective ways of using natural resources. This affects consumers and producers in areas such as energy, transport, climate, environment, agriculture, fisheries and regional policy.

The European Commission has presented a proposal to revise obsolete rules on the taxation of energy products in the European Union. With the proposed new norms, it is intended to restructure the modalities of taxation of energy products, in order to eliminate the current imbalances and take into account their CO_2 emissions and their energy content.

The new standards also aim to promote energy efficiency and encourage the consumption of more environmentally friendly products.

COMMON AGRICULTURAL POLICY AND FOREST STRATEGY OF THE EU

The EU Common Agricultural Policy (CAP) was created in 1962 to improve agricultural productivity, so that consumers have a stable supply of food at affordable prices, while ensuring that EU farmers are guaranteed a life reasonable.

Currently, it must face more challenges, among others:

- Climate change and sustainable management of natural resources.
- Landscape conservation throughout the EU and the maintenance of a lively rural economy.

The CAP has two pillars: support for the agricultural products market and the income of farmers and rural development policy. **Among the EU priorities for rural development policy is promoting the efficiency of resources and encouraging the transition to a low carbon economy, capable of adapting to climate change in the agricultural, food and forestry sectors.**

The European Commission presented a new EU forestry strategy (COM (2013) 659) for forests and the forestry sector in 2013, in response to the increasing demands placed on forests and the important social and political changes that have affected forests during the last 15 years.

The strategy is a framework for forest-related measures and is used to coordinate EU initiatives with the forest policies of the Member States.

In March 2010, the European Commission adopted a Green Paper on forest protection and information in the EU: preparing forests for climate change (COM 2010, 66 final). The document was intended to stimulate debate about how climate change modifies the terms of forest management and protection, and how EU policy should be developed as a consequence.

Forestry, together with agriculture, remains crucial for land use and natural resource management in rural areas of the EU, and as a basis for economic diversification in rural communities.

The rural development policy is part of the common agricultural policy (CAP) of the EU, which has been the main instrument for implementing forestry measures in recent years. In this context, it is estimated that spending on forest-related measures, through the European Agricultural Fund for Rural Development, amounted to between 9 and 10 billion euros during the 2007-2013 period.

DIRECTIVES ABOUT RENEWABLE ENERGIES

Directive 2009/28/EC, of the European Parliament and of the Council of 23 April 2009, on the promotion of the use of energy from renewable sources, establishes a common framework and sets mandatory national targets in relation to the share of energy coming from renewable sources in the final gross consumption of energy (minimum quota of 20%) and with the share of energy from renewable sources in transport (minimum quota of 10%).

As of 2014, each member state has been obliged to demand the use of minimum levels of energy from renewable sources in new and existing buildings that make a major renovation, as well as in public buildings; and to encourage the use of heating and cooling systems and equipment from renewable sources. In the case of biomass, it was forced to promote conversion technologies that allow a conversion efficiency of at least 85% in residential and commercial applications and at least 70% in industry.

The Commission will monitor the origin of the biofuels and bioliquids consumed and the effects of their production (especially if the production of biofuels has an increase in food products). The Directive indicates that the production of biofuels must be sustainable. The biofuels used to meet the objectives set out in the Directive and those that benefit from the national support systems must therefore necessarily comply with sustainability criteria. Articles 17, 18 and 19 include the sustainability requirements for biofuels and bioliquids as well as the reduction of greenhouse gas emissions. For the consumption of biofuels to be taken into account in meeting the objectives, **it must provide at least a 35% reduction of greenhouse gases (GHG) with respect to fossil fuels**. The minimum emission savings is 60% after 2018.

Biofuels and bioliquids will not be produced from raw materials of **high biodiversity value (**p**rimary forests and other wooded areas, protected areas, meadows or pastures with a rich biodiversity, land with high carbon reserves).** To demonstrate compliance with the obligations imposed on operators in the field of renewable energy and the objective established for the use of energy from renewable sources in all forms of transport the contribution of biofuels obtained from **waste, materials non-food cellulosics and lignocellulosic material** will be considered to be **twice** the equivalent of other biofuels. The sustainability requirements of the biofuels established in the Renewable Energy Directive have been modified through the approval of Directive (EU) 2015/1513 of the European Parliament and of the Council, of September 9, 2015, by which the Directive is modified 98/70/EC, on the quality of gasoline and diesel, and Directive 2009/28/EC, on the promotion of the use of energy from renewable sources.

STRATEGIC FRAMEWORK ON CLIMATE AND ENERGY FOR THE PERIOD 2030

The fundamental objectives of the climate and energy framework for 2030 are three:

- at least 40% **reduction of greenhouse gas emissions** (relative to 1990 levels).
- at least 27% share of **renewable energy.**
- at least 27% improvement in **energy efficiency.**

This framework - adopted by the EU leaders in October 2014 - is based on the climate and energy package until 2020. In addition, it conforms to the long-term perspective contemplated in the Roadmap to a competitive low carbon economy in 2050, the Energy Roadmap for 2050 and the White Paper on Transport.

This framework establishes a binding objective to reduce EU emissions of at least 40% in relation to 1990 levels, which will allow measures to reduce emissions by 80-95% in 2050, in the context of reductions that countries must do to contribute to the Paris Agreement. Based on the Energy Efficiency Directive, the European Council approved by 2030 an indicative energy saving target of 27% but this will be reviewed in 2020 taking into account another 30%.

Significant investments will be necessary that would be largely offset by fuel savings. More than half of the investments should go to the residential and tertiary sectors. Countries with lower levels of income would have to make a relatively greater effort compared to their GDP (however, the conclusions of the European Council address the issue of distribution and include measures of equity and solidarity, which also try to ensure overall efficiency).

REINDUSTRIALIZATION OF THE EU 2030: CIRCULAR ECONOMY BASED ON THE RURAL ENVIRONMENT

With regard to sustainability in agriculture, livestock and rural development, as well as in terms of food security, the policy established in the European Union marks the orientation and strategy in most aspects that has to do with production agricultural and livestock, the transformation of agricultural products, and the sustainable supply in sufficient quantity of safe food to the inhabitants of the EU, through the common agricultural policy (CAP).

Within the framework of the New European Consensus for Development, regarding Agriculture, objectives are focused on the sustainability of water resources, agriculture, fisheries and sustainable livestock and sustainable food systems. After a radical reform in 2013 in order to be more fair, greener, more efficient and more innovative, it now contemplates among its main objectives, with funding at European level (with 38% of the European budget): it protects farmers from excessive price volatility and market crises; helps to invest in the modernization of farms; it maintains viable rural communities, with diversified economies; it protects the environment; etc.

ENERGY ROUTE MAP FOR 2050

The European Commission has established a **Roadmap towards a low-carbon economy**, with a series of measures for this viable and economically feasible transition. By 2050, the EU should have reduced its greenhouse gas emissions by 80% in relation to 1990 levels, exclusively through internal reductions (ie without recourse to international credits). This objective is in line with the European commitment to reduce emissions by 80-95% in 2050, in the context of the reductions that must be made by developed countries.

To achieve this, you will first have to achieve a reduction of 40% in 2030 and 60% in 2040. To save costs later, it is advisable to act soon. If we postpone the measures, we will have to reduce emissions much more drastically at a later stage. Therefore, the previous stages established are:

- A reduction of 40% in 2030 compared to 1990 levels (this goal is already part of the framework for 2030)
- A reduction of 60% in 2040.

It is necessary that all sectors contribute to the transition towards a low carbon economy: the sector of <u>production and distribution of electricity</u> (has the greatest reduction potential, could almost completely eliminate CO_2 emissions by 2050); <u>transport</u> (emissions from transport could be reduced by more than 60%); <u>buildings</u> (around 90% in 2050, improving energy, though the application of passive housing technologies and the replacement of fossil fuels with electricity and renewable energies); <u>industry</u> (energy-intensive industries could have reduced their emissions by more than 80%) and <u>agriculture</u> (it will have to reduce emissions from fertilizers, manure and livestock and can contribute to the storage of CO_2 in soils and forests).

The roadmap concludes that the transition towards a low carbon society is viable and economically possible, but requires innovation and investments. To make this transition, the EU would have to invest an additional 270.000 million euros (that is, an average of 1.5% of its annual GDP) over the next forty years.

Work sheet 1.1.

NEED FOR A NEW ENERGY AND ECONOMIC DEVELOPMENT MODEL

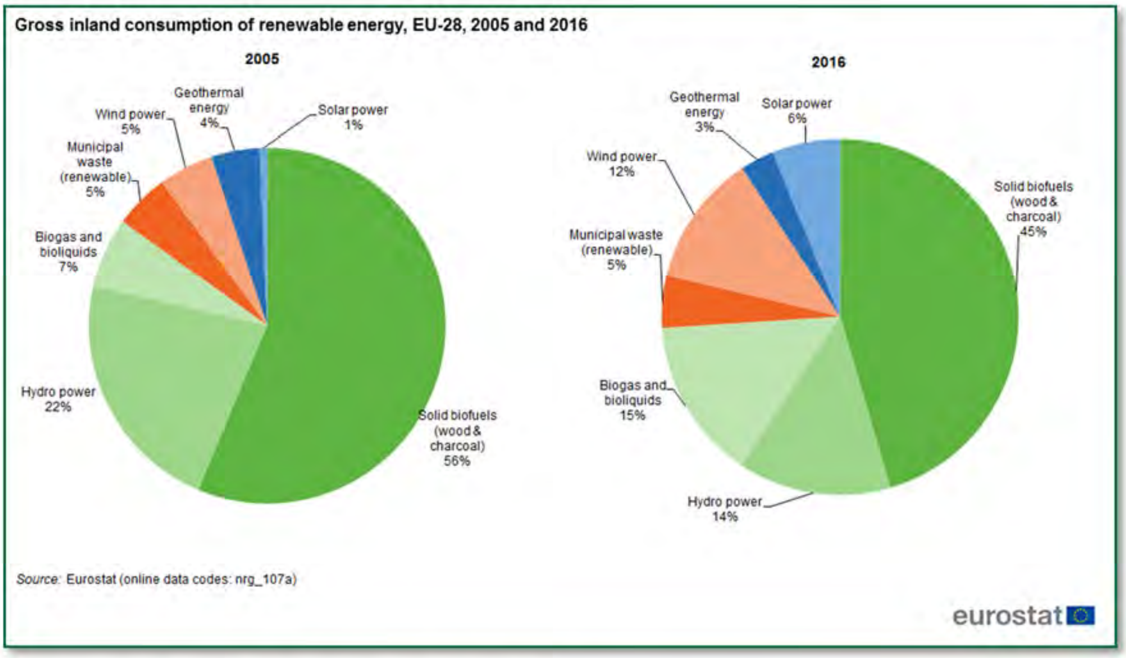
EXERCISE 1.1.1. *What is the main greenhouse gas and what is its main source of emission?*

EXERCISE 1.1.2. *Biomass or bioenergy is a form of renewable energy. Could you explain why?*

EXERCISE 1.1.3. *Mark with an X in one or another column as you consider that a common advantage is listed for all renewable energies or it is a specific one of bioenergy.*

	ALL RENEWABLE ENERGIES	*BIOENERGY*
Autonomous character		
Respect for the environment		
Contribution to forest cleaning and fire and erosion prevention		
Contribution to energy diversification		
Fixing population in rural areas		
Strengthening the regional balance		
Solution to waste disposal problems and prevention of possible contamination derived from them		
Creation of a greater number of jobs than conventional sources		

EXERCISE 1.1.4. *Analyse the following graph and draw conclusions about the evolution of renewable energies in Europe between 2005 and 2016.*



What types of renewable energy have grown?
Which ones correspond to bioenergy? How has each one evolved?

1.2. INTRODUCTION TO BIOENERGY AND ITS USES

Some previous questions

What do bioenergy or biomass mean? Try to say what the following photographs represent. How do you think that these natural resources can be transformed into usable energy?



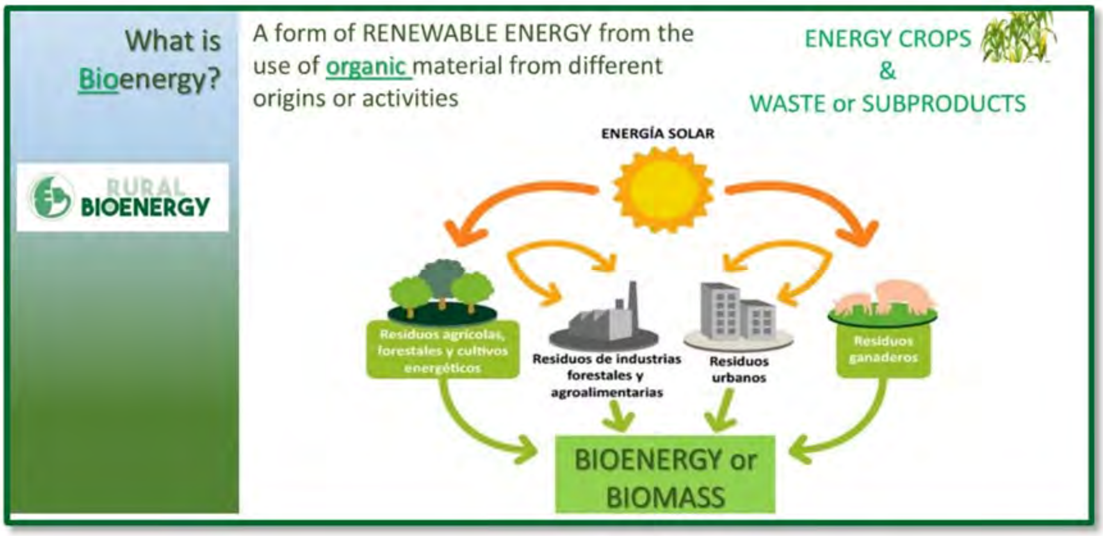

It is not easy to understand that bioenergy is considered a clean energy that does not contribute to climate change. Can you find any explanation?

What advantages and disadvantages does the use of bioenergy have compared to fossil fuels?

1.2.1. WHAT IS BIOENERGY? BIOENERGY AS A RENEWABLE ENERGY THAT DOES NOT CONTRIBUTE TO CLIMATE CHANGE.

BIOENERGY, BIOMASS AND BIOFUELS

Bioenergy is the transformation of organic matter or biomass from different sources or activities for the generation of energy (electricity, thermal energy or transport fuels).

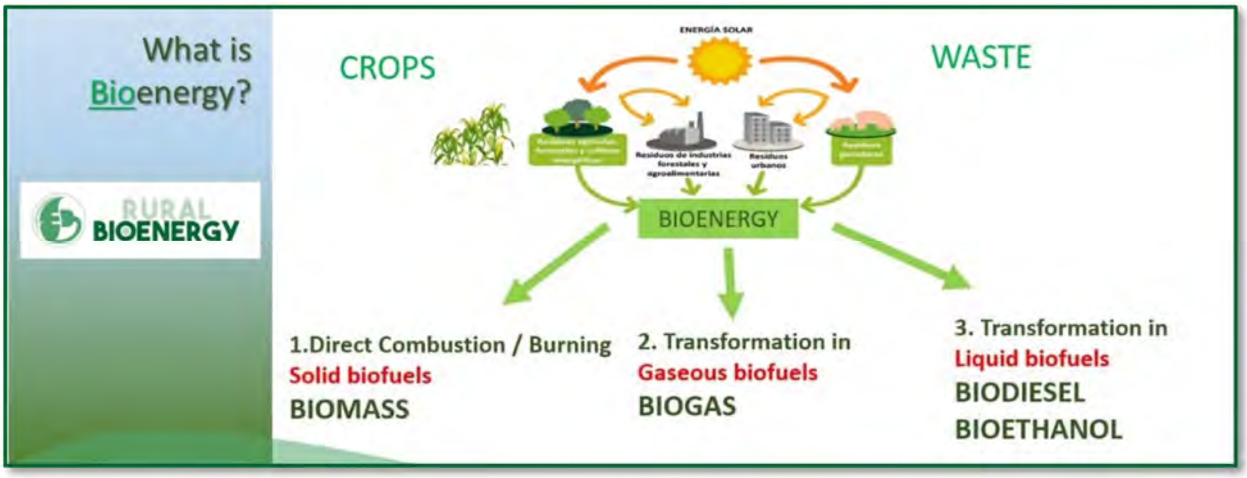


Biomass is any organic matter (wood, crops, algae, animal waste) that can be used as an energy source. It is probably our oldest source of energy after the sun. For thousands of years, people have burned wood to heat homes and cook their food.

Biomass gets its energy from the sun because all organic matter contains stored energy from the sun. During a process called photosynthesis, sunlight provides plants with the energy they need to convert water and carbon dioxide into oxygen and sugars. These sugars or carbohydrates, provide energy to plants and animals that eat them. Biomass is a renewable energy source because its supplies are not limited.

Biomass exists in the thin surface of our planet called biosphere. **It represents only a small fraction of the total land mass, but it is a huge energy reserve, like a continually replenished warehouse.** Biomass mainly includes trees and plant residues (wood, leaves, straw, shells...) and animal waste.

Bioenergy is the energy produced from the conversion of biomass, where it can be used directly as a **solid biofuel** or transformed into **liquid biofuel** and/or **gases**.



BIOENERGY AND NEUTRAL BALANCE IN CO_2 EMISSIONS

To understand that bioenergy is a clean energy that is considered not to interfere with climate change, it is necessary to know that there is a balance of the carbon cycle on the planet. Through photosynthesis, plants absorb CO_2 and accumulate it in plant tissues. Subsequently, herbivorous animals feed on these vegetables, from which they obtain energy for later, following the trophic chains, transfer it to the other levels of the food chain; on the one hand, it is returned to the atmosphere as carbon dioxide by breathing, on the other, it is drifted into the aquatic environment, where it can remain as organic sediments or carbonates and bicarbonates. In addition to the activity carried out by the plant and animal kingdoms in the carbon cycle, carbon released through rot and combustion also enters. Precisely this natural balance is breaking because human activity has raised the level of carbon in the atmosphere, especially by burning fossil fuels (coal, oil or natural gas) to produce energy. As result, we emit more carbon dioxide than the planet can absorb.

Biomass is considered to have a **neutral balance in CO_2 emissions** and its combustion does not contribute to increase the greenhouse effect, since the emitted CO_2 has been previously captured from the atmosphere by plants through photosynthesis.

1.2.2. WHERE IS BIOMASS OBTAINED?

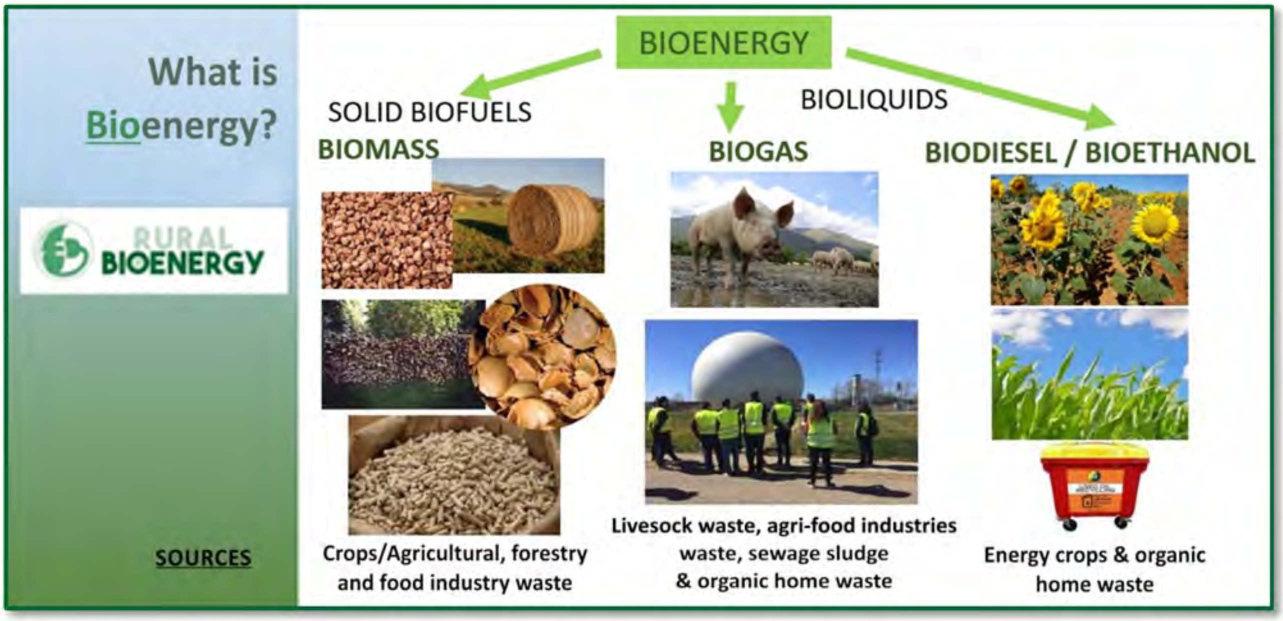
RAW MATERIALS AND BIOMASS SOURCES

The base of the biomass resource comes from forestry, agricultural, livestock and related industries; It is usually classified as a primary resource when its origin is the direct harvest of forests or crops; as a secondary resource, when it comes to waste from forest, agricultural or livestock industries; and as a tertiary, when its origin is urban waste.

Bioenergy can be obtained from agricultural or forestry crops produced specifically for this purpose or from residues derived from agricultural, livestock, forestry, industrial and municipal activities.

The advantages of using waste for bioenergy production in rural areas are:

- Reduce environmental problems (for example, emissions from open burning).
- They are an additional source of income for farmers - income generation.
- They represent an alternative for rural development.
- Represent a community-based energy system.
- Faced with what can happen in the case of the use of crops, there is no competition with food production and the change of use of the farmland is avoided by offering many resources of biomass residues of existing agricultural land.



CLASSIFICATION OF BIOENERGY RAW MATERIALS ACCORDING TO THEIR ORIGIN

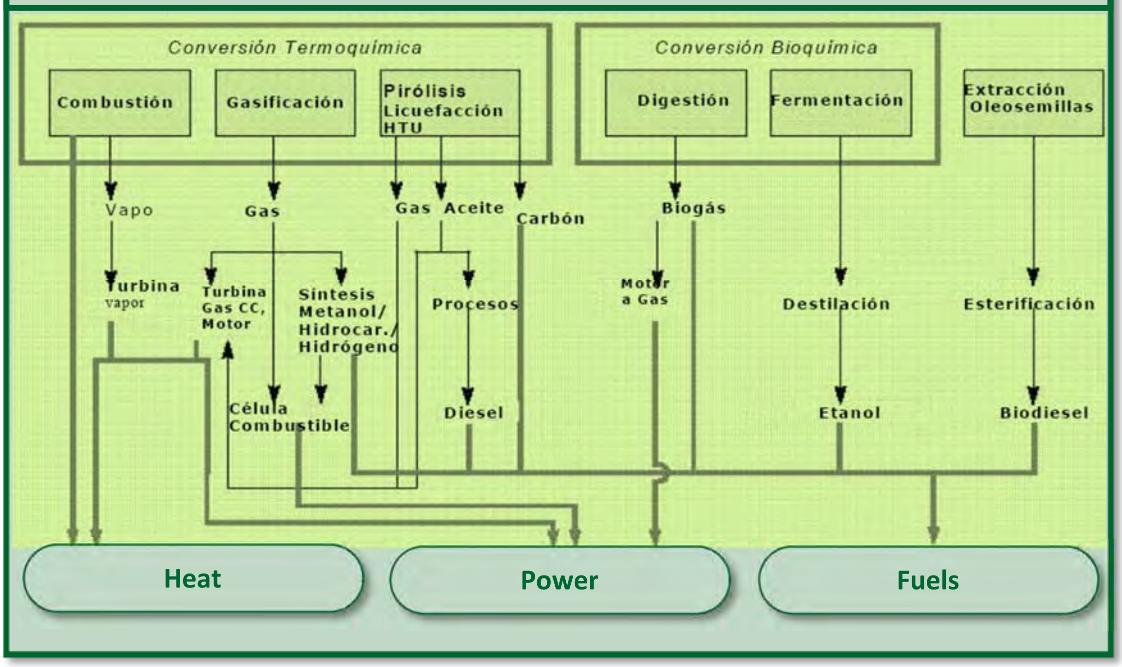
FOREST ORIGIN		
	**Forest crops**: species mainly woody cultivated in forest land.	Poplars, pines and other conifers, etc.
	Forest exploitation: biomass originated as a product of forestry operations where management plan for their extraction is necessary.	Cups, branches, etc.
	Forest residues: residual biomass generated in the cleaning and maintenance of forests and green spaces.	Remains of pruning, thinning, felling and thinning: bark, branches, leaves, treetops, etc.
AGRICULTURAL ORIGIN		
	**Agricultural crops:** herbaceous or woody species produced through farming activities on agricultural land.	Soy, sunflower, cereals, rapeseed, beets, etc.
	Agricultural residues: residual biomass originated during the cultivation and first transformation of agricultural products.	Remains of pruning of fruit trees and vineyards, cereal straw, etc.
LIVESTOCK ORIGIN		
	**Organic waste** from livestock farms. It is mainly the mixture of droppings and the cattle bed.	Manure, slurry, chicken manure, etc.
INDUSTRIAL ORIGIN		
	**Byproducts and residues from agrifood industries**: Olive or seed oil production, citrus processing, wine and alcohol industry, sugar, canning, brewery, slaughterhouses, meat and dairy industries, etc.	Nuts, seeds, olive bones, pomace, serums, meat remains, brewery residues, pomace, apricots, etc.
	By-products and waste from industrial facilities in the forestry sector: first and second processing forest industries (sawmills, carpentry, etc.), by-products from the pulp industry (bleach), from the recovery of lignocellulosic materials.	Barks, chips, sawdust, pallets, building materials, etc. black bleach, brown bleach, fiber sludge, lignin, resin oil, etc.
MUNICIPALITIES		
	The **biodegradable fraction** of urban solid waste that is generated daily in all locations. This category also includes waste from sewage treatment plants and hotels, restaurants, coffee shops, etc.	Organic solid waste from household waste, sewage sludge sludge, frying oils, etc.

1.2.3. PROCESSES OF TRANSFORMATION AND USES OF BIOMASS

The energy obtained from biomass can be used for different purposes:

- Heat production, mainly heating or running hot water, used in the facilities themselves (agro-livestock or in industrial processes) or in heating networks (district heating) providing heating and hot water to housing units and buildings, neighbourhoods or even entire towns and cities.
- Electricity generation (on a small scale for self-consumption but more commonly in large power plants to discharge to the grid).
- Production of liquid biofuels, such as biodiesel and bioethanol, which could cover a large part of our transportation fuel needs in the future for cars, trucks, buses, airplanes and trains.

Different processes of transformation of biomass for the production of heat, electricity or fuels



Apart from the **mechanical processes** that consist of the physical transformation of biomass, in order to produce homogeneous or higher density fuels (such as pellets) there are three main types of processes that allow obtaining from biomass and through Different technologies, biofuels in either solid, liquid or gaseous state (from which they finally get heat, electricity or transport fuels):

1. **Thermochemical processes**
2. **Biochemical or biological processes**
3. **Chemical processes**

1.- Thermochemical processes.

Thermochemical conversion processes use heat as the main mechanism to convert biomass into another chemical form. They are based on the thermal decomposition of biomass, in the absence or lack of oxygen, through processes such as combustion, pyrolysis or gasification.

COMBUSTION

Biomass burning is the most developed and most frequently applied process for obtaining **heat, mechanical energy or electricity**. It is the oxidation process at temperatures between 600°C and 1.300°C that generates CO_2, water and ash. A moisture content of biomass <50% is required. They are used as process equipment stoves, ovens, boilers, steam turbines, turbogenerators and the net conversion of bioenergy has an efficiency of 20% to 40%.

COGENERATION – COMBINED HEAT AND POWER (CHP): Some of the applications of thermal conversion are combined heat and power (CHP), which integrates the production of usable heat and power (electricity). This technology is highly efficient – provides increased levels of energy services per unit of biomass consumed compared to facilities that generate power only.

Comparison of standard power plant energy production and CHP energy production

GASIFICATION

Conversion of the solid raw material of biomass into combustible gas or chemical feed gas (synthesis gas). The biomass is subjected to temperatures between 600°C and 1.500°C in the absence of oxygen. Gaseous products originate that constitute a mixture known as synthesis gas, syngas or poor gas (mainly composed of nitrogen, carbon monoxide, carbon dioxide, methane and hydrogen in varying proportions.

PYROLYSIS

Pyrolysis is the thermal decomposition of materials at elevated temperatures in an inert atmosphere: conversion of organic material into a carbon-rich solid and volatile matter by heating in the absence of oxygen. In general, pyrolysis of organic substances produces volatile products and leaves a solid residue enriched in carbon, char. Pyrolysis is the basis of several methods for producing fuel from biomass, i.e. lignocelluloses biomass.

2.- Biological or biochemical processes.

The biochemical conversion uses the enzymes of bacteria and other microorganisms to break down biomass into gaseous or liquid fuels, such as biogas or bioethanol. In most cases, microorganisms are used to perform the conversion process: anaerobic digestion and fermentation and composting.

ANAEROBIC DIGESTION

Anaerobic digestion is a natural process and is the microbiological conversion of organic matter to methane in the absence of oxygen.

The decomposition is caused by the natural bacterial action in several stages. It is carried out in a variety of natural anaerobic environments, which include water sediments, soils with water accumulation, natural hot springs, oceanic thermal vents and the stomach of several animals (for example, cows). The digested organic matter that results from the anaerobic digestion process is usually called digested.

Anaerobic digestion is used as part of the process to treat biodegradable waste and sewage sludge. As part of an integrated waste management system, anaerobic digestion reduces the emission of landfill gases into the atmosphere. Anaerobic digesters can also be fed with specific energy crops, such as corn. The process produces a biogas, which consists of methane, carbon dioxide and traces of other polluting gases. This process takes place in a digester (an anaerobic, heated, sealed container). The digestion tank is heated and mixed well to create the ideal conditions for the conversion of biogas. This biogas can be used directly as fuel, in combined heat and energy (CHP) engines or can be upgraded to biomethane with natural gas quality. The nutrient-rich digestate also produced can be used as a soil fertilizer.

FERMENTATION

Fermentation is an anaerobic process (occurs in the absence of oxygen) that breaks down the glucose within organic materials. It is a series of chemical reactions that convert sugars to ethanol.

The basic fermentation process involves the conversion of a plant's glucose (or carbohydrate) into an alcohol or acid. Yeast or bacteria are added to the biomass material, which feed on the sugars to produce ethanol (an alcohol) and carbon dioxide. The ethanol is distilled and dehydrated to obtain a higher concentration of alcohol to achieve the required purity for the use as automotive fuel. The solid residue from the fermentation process can be used as cattle-feed and in the case of sugar cane; the bagasse can be used as a fuel for boilers or for subsequent gasification.

The future belongs to bioethanol produced from lignocellulosic biomass, not from corn starch or sugar cane.

3.- Chemical processes.

A variety of chemical processes can be used to convert biomass into other forms, such as producing a fuel that is used, transported or stored more conveniently, or to exploit some property of the process itself. Basic operations for the transformation of the material through chemical reactions and chemically catalysed conversions. Currently, the chemical process used for the production of biodiesel (methyl esters of fatty acids) is transesterification.

TRANSESTERIFICATION

Conventionally, biodiesel is produced from oil through the process of transesterification or alcoholysis. This process consists of combining the oil, usually vegetable oil (rape, soy, mustard, flax, sunflower, canola, palm oil, hemp, jatropha), with a light alcohol, usually methanol, obtaining as the main by-product glycerin, which It can be used in various applications.

TYPES OF BIOMASS ORIGINS	TECHNOLOGIES				
	TERMOCHEMICAL P.		BIOCHEMICAL P.		CHEMICAL P.
	COMBUSTION	GASIFICATION ▪ PYROLYSIS	ANAEROBIC DIGESTION	FERMENTATION	TRANS-ESTERIFICATION
FORESTAL	X	X			
AGRÍCOLA	X	X			X
GANADERA			X	X	
INDUSTRIAL	X		X	X	X
URBANA	X		X	X	X

Type of technology to be used in the use of biomass according to its origin.

1.2.4. USES OF THE BIOENERGY IN RURAL AREAS

Bioenergy can represent a new engine of the rural economy due to its capacity to generate jobs that has this use. It is estimated that 135 direct jobs can be created for every 10,000 biomass users, compared to 9 created using oil or natural gas (Miguel Trossero, FAO). In other words, the capacity for generating bioenergy employment is 14 times higher than fossil fuels.

In the forestry sector, the use of bioenergy contributes to sustainable forest management, being perfectly compatible with other industrial uses. The use of forest residues after logging improves the problem of forest underutilization and reduces the risk of fire. A greater use of the forest masses would increase the productivity of the mountains and improve the socio-economic conditions of the territory. In Europe, 61% of the annual growth of the masses is used on average, and in the Nordic countries, almost 90% thanks to which it has been possible to boost the economy by retaining population in rural areas. This gives an idea of the enormous possibilities in the countries of southern Europe where the potential productivity of forests is much higher, as the long vegetative period in these latitudes is up to 3 times longer.

But also in the rural environment there is an enormous potential for the **use of different wastes from various agricultural, livestock and agro-food processing industries**. There are many examples of waste and by-products with energy potential: **pomace and olive bones as remains of the olive industry; fruit pruning remains; vine shoots, leftover skin and grape grains, scrapes and grape brooms as remnants of winemaking activity; sera of milk and other remains and sludge of the wine, beer and agri-food industry in general; slurry and other cattle manure; cereal straws and other traces of agricultural activities; residues of the meat industry; mushroom growing substrate remains,** and many more.

Finally, there is also the possible agricultural economic activity destined to exploited crops with the sole objective of obtaining biomass: energy crops, agricultural or forestry crops of fast-growing plant species that are planted for the purpose of harvesting them to obtain energy or as Raw material for obtaining other combustible substances.

As we have already seen, the use of agricultural, livestock, forestry and agri-food waste as bioenergy apart from solving the problem of the disposal of these wastes (because it is not known what to do with them on some occasions the waste is discharged and piled up indiscriminately, what produces bad smells and contamination of the soil, air and water) **implies the economic valuation of a new resource that can mean an important economic income or saving if it is used for self-consumption.**

These challenges, among others, could become opportunities using waste to generate various products for their own use or for sales, which also offers farmers a way to cushion the possible price fluctuation. Where there are price declines, revenue from waste could provide additional interesting support.

Another aspect that deserves attention refers to the possible **organizational models of energy chains**, their effect on the conditions of new opportunities for the development of agricultural farms, as well as their role in separate models. To do this, we will describe three basic models, revealed in recent years:

1. **The model of energy production of closed-loop type (i.e. for satisfying the needs of the family/the farm).** The agricultural company produces itself the necessary energy and consumes it entirely. The thermal energy, required for heating of residential and company premises can be produced, for example, by small boilers using waste wood, fragmented wood or pellets. (Besides the need of electricity could be satisfied by photovoltaic roofs or wind-power mini installations). In this case, the entrepreneur will achieve considerable energy economy since he uses products or sub-products from the farm or natural energy sources. Obviously, careful evaluation should be made of the installation costs, of the achieved economy and of the respective terms for investment pay-back.

2. **The model of selling waste materials for energy production.** An entrepreneur activity, whose characteristics differ, depending on the organization type of the production chain. As we have already mentioned, in the case of industrial energy production in large power stations which, in most cases are far away from the facilities for waste material production, the agricultural companies will be seriously harmed since the cost for processing and transportation of the waste materials will considerably decrease the added value for the producer.

   Different is the situation with the small and medium-scale installations, implemented on local level and characterized by a short production chain, in which the producers also participate. This both decreases the negative environmental effect and ensures larger income for the farmers. This is the case, for example, with the heating networks, fired with fragmented wood, used for heating of small municipalities, public structures or residential areas. In this case the local origin of the waste material and the direct negotiation of the price between the participants in the production chain ensures a higher added value for the producer.

3. **The model of energy sale.** In the last years, predominantly in some countries, the model of selling energy from the agricultural farms was set up. In this case we have more or less complex types of organization. The simplest case, which we'll call "warm up your neighbour" is the case with businesses, constructing small heating networks which both satisfy the needs of the business and deliver heat to the closest neighbours as well. In other cases the entrepreneurs create small closed-loop production chains, thus providing their clients with an installation, waste material and installation maintenance. Another type of energy sale is the supply of electric energy for the grid, produced by photovoltaic panels or by wind power installations.

   State-of-the-art experience has been accumulated of associations or agricultural cooperatives, devoted to energy production. These are really existing agroenergy businesses where the farmers both supply waste material for the business and possess a share in its profit – either directly or, through energy recovery (for example, biofuels).

In conclusion, we can say that the energy production from renewable sources is a good opportunity for the agricultural companies. The profitability and gain of this activity depend on how successfully the farm manages the separate phases of the production chain.

Work sheet 1.2.

INTRODUCTION TO BIOENERGY AND ITS USES IN RURAL AREAS 1/5

EXERCISE 1.2.1. *Complete the following table with 5 examples of raw materials of each origin from which bioenergy can be obtained.*

ORIGIN OF BIOMASS	EXAMPLES OF RAW MATERIALS				
FORESTRY					
AGRICULTURE					
LIVESOCK					
INDUSTRIES					
VILLAGES AND CITIES					

EXERCISE 1.2.2. *Indicate which of the following wastes are susceptible to thermochemical transformation processes and which are more appropriate for biological processes:*

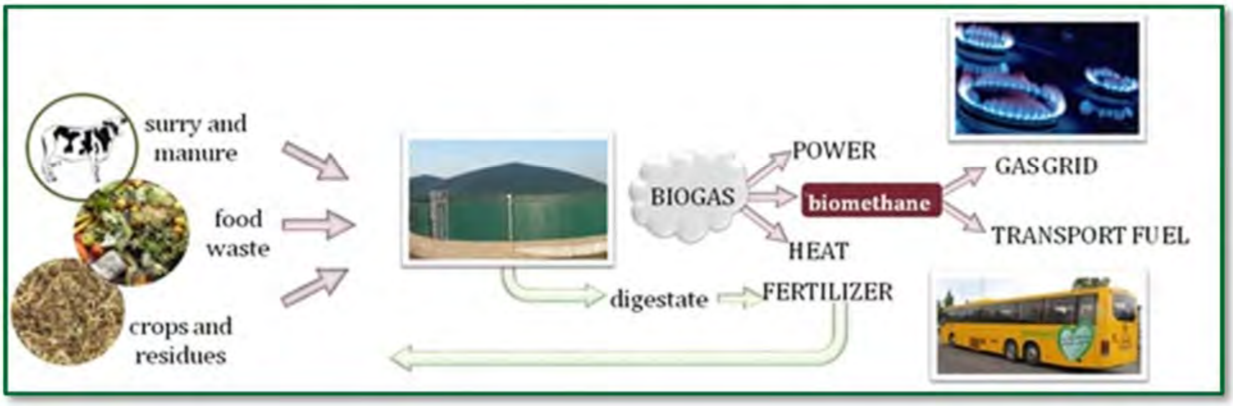
Work sheet 1.2. INTRODUCTION TO BIOENERGY AND ITS USES RURAL AREAS 2/5

EXERCISE 1.2.3. *Complete the following text with* ***DRY biomass*** *or* ***HUMID biomass****:*

"……………………………… can be burned to produce heat or electricity. It can also be gasified to produce methane, hydrogen and carbon monoxide, or it can be converted into a liquid fuel.

……………………………. such as cattle manure, sewage sludge or food industry waste, can be fermented to produce biogas".

EXERCISE 1.2.4. *Explain the following scheme of production and use of bioenergy.*



a) What are the raw materials?
b) What is the transformation process?
c) What kind of biofuel is obtained?
d) Is any other product obtained from the process?
e) What are the final uses of energy?

Work sheet 1.2. INTRODUCTION TO BIOENERGY AND ITS USES IN RURAL AREAS 3/5

EXERCISE 1.2.5. *Read the following text that includes some concrete examples of bioenergy use in rural areas. Indicate the example of use* *<u>that you think is more</u>*.... *(Indicate the reason).*

Innovative	***Economic profitable***	***Applicable to your region***

EXAMPLES OF USES OF BIOENERGY IN RURAL AREAS

We describe as follows some exploitations in more detail, classifying biofuels according to whether they are solid or liquid-gaseous, and some examples of applications in the agri-food sectors are included.

SOLID BIOFUELS

Solid fuels obtained from biomass that can be used for the production of heat are not only the forest crops or the rest of forest activities; there is a great diversity of remains and byproducts of agricultural activities and the agro-food industry with great potential such as firewood and pruning remains (with their possible transformation into chips, pellets, etc.), olive bones, husks of nuts, cereals straw and many others.

- **<u>For thermal use:</u>** The **thermal applications** of the biomass can be carried out mainly through boilers, stoves or fireplaces. The boilers are the only equipment capable of heating and hot water at the same time, while the stoves and fireplaces allow to heat the room in which they are located.

  These solid fuels can also be used within the agri-food sector to produce the heating and hot water needed in the production processes of farms and livestock farms, wine industries, food industries, etc. Here are some examples:

  - ✓ **Use of waste from the process of production of wine as solid biofuels in Cellars.** The waste used are the branches of the wine pruning, the barrels in disuse and remains of grapes after pressing. Through the combustion of biomass in the boiler, the heating of the installations is obtained, as well as the hot water and the water used in the industrial processes of the cellars.
  - ✓ **Use of biomass in pig farms, poultry farms, etc.** The boilers of conventional fuels like diesel fuel can be replaced by biomass boilers (of pellets or polyvalent that allow different solid biofuels) to produce the necessary heating in some types of farms (maternity areas). It can be done through a contract with an Energy Services Company that deals with installation and maintenance).
  - ✓ **Use of olive seeds as a solid biofuel**. The olive seed is a fuel with excellent characteristics: high density, humidity around 15%, very uniform granulometry and calorific value around 4.500 kcal/kg in dry basis. It is very suitable for thermal uses, both in the industrial sector as domestic and residential. Traditionally it has been used in boilers of olive grove industries, both oil mills and extractors. It has also been used in other sectors such as the ceramic industry, farms, etc. Nowadays its uses in the domestic and residential sector for the supply of hot water and heating are becoming increasingly important.

Work sheet 1.2. INTRODUCTION TO BIOENERGY AND ITS USES IN RURAL AREAS 4/5

The technology has experienced a great advance, currently importing equipment with very high performance and low emission levels. To facilitate the collection of fuel, olive seeds are being sold in 15 kg bags, easy to distribute and handle, optimal for use in the domestic sector, and with a considerably lower price than other fuels with similar benefits, such as wood pellets.

- ✓ An especially interesting option are the **district heating**, which due to their greater energy efficiency and the use of economies of scale, allows reaching a greater number of users. There are examples of these district heating, from installations of 400 kW of power and several hundred meters of pipes that provide service to several municipal and private buildings, to installations of around 15 MW and more than 10 km of network.

- **For electricity generation.** The production of electricity requires even more complex systems given the low calorific value of biomass, its high percentage of moisture and its high volatile content. This requires specific thermal power plants with large boilers, with larger household volumes than if using a conventional fuel, which involve high investments.

  The great demand for fuel from these electric plants requires ensuring a continuous supply, which has the duality of increasing its price by the distance at which the supply must be sought, but can also reduce it by acquiring large quantities. There are few electricity production plants that exist in Spain and most of the installed power comes from installations located in industries that have their own production assured. This is the case of the paper industry and, to a lesser extent, of other forest and agro-food industries, which take advantage of the waste generated in their manufacturing processes to reuse them as fuels.

  One of the explanations for this limited progress is the lack of energy crops that supply fuel continuously to certain plants.

  In order to improve the performance of the facilities and therefore their economic profitability, technological innovation in this field is oriented towards the development of **biomass gasification and subsequent conversion into electricity through motor generators or other gas combustion systems**. The immediate future will be the promotion of biomass co-combustion, that is, the joint combustion of biomass and other fuel in thermal power plants already installed.

  - ✓ Among the fuels most used in electrical applications are the residues of the olive oil industry such as the pomace (olive residues called in Spanish “orujo” and “orujillo”, that is, grape skin and other waste after squeezed or pressed). There are large plants in the south of Spain that feed on these fuels:
    - *Orujo:* The process of obtaining olive oil in the mills, mainly by centrifugation and in a small number by pressing, generates as by-product this. For every ton of processed olives, approximately 0,8 tons of pomace are obtained, which has an approximate humidity of 60% -65%. The pomace generated in the oil mills is stored in rafts for further processing, which can be a physical process of second centrifugation or a chemical process in the extractors, obtaining olive residue oil, but it can also be subsequently used for the production of electricity, previous drying up to an approximate humidity of 40% to facilitate its combustion.
    - *Orujillo:* The pomace, once dried and subjected to the process of oil extraction, is transformed into orujillo. It is a by-product with a humidity of around 10% that has good properties as a fuel, with a calorific value of around 4.200 kcal/kg on a dry basis, and which can be used both for generating thermal energy in industries and for generation of electric power.
  - ✓ Forest industries and other agri-food industries (such as corn industries and alcohol industries) also have their share of importance in producing electricity with their own waste (chips, sawdust, rice husk, grape pomace...). One of the largest biomass power plants in Spain is located in Sangüesa (Navarra-Spain), in this case supplied with cereal straw. Another example is in Biomass of Cantabria (Spain), where biomass is used mainly as forest biomass from the remains of eucalyptus felling and other fast-growing forest species. Biomass of Cantabria (Spain).

Work sheet 1.2. INTRODUCTION TO BIOENERGY AND ITS USES IN RURAL AREAS 5/5

LIQUID (OR GASEOUS) BIOFUELS

Generically called liquid biofuels refer to all fuels, both liquid and gaseous, which are obtained from biomass and can be used for any energy application, whether thermal, electrical or mechanical, to feed boilers and internal combustion engines. However, the terms commonly used for its definition are: **biofuels** (liquid or gaseous biofuel used for transport) and **bioliquids** (liquid or gaseous biofuels intended for **energy uses other than transport**, including electricity and the production of heat and cold).

- **Biogas for thermal and electrical use.** Biogas is a gas composed mainly of methane (CH_4) and carbon dioxide (CO_2), in varying proportions depending on the composition of the organic matter from which it was generated. It has enormous potential in the agri-food sector because the main sources of biogas are livestock and agro-industrial waste, but also sludge from urban wastewater treatment plants and the organic fraction of household waste.

  Biogas is the only renewable energy that can be used for any of the major energy applications: **electric, thermal or as fuel**.

  It can be sent for direct use in a boiler adapted for combustion and thus produce heat in industrial processes or for homes. It can be injected after purification to bio-methane in existing natural gas infrastructures, both transport and distribution.

  Biogas can be used as fuel in **a cogeneration facility for electrical and thermal energy**. Basically it is a gasoline engine connected to a generator. The engine activates the generator which in turn produces the electricity. As a result of internal combustion, the gas engine also generates heat. The engine releases this heat through the exhaust gases and the cooling water. The exchangers allow to capture and use this thermal energy in a productive way since the water temperature reaches 90ºC.

  The agri-food industry needs a large amount of electrical and thermal energy that biogas production can satisfy. Examples in the agri-food and forestry sector:

  - Use of biogas in small agrifood small-scale companies for self-consumption, for example for the production of heat needed in the maternity areas of the farms, in addition to the production of electrical energy. The problem is that small and medium enterprises (SMEs) have a small production of waste or by-products susceptible to produce biogas. This requires the adaptation of technology to small-scale plants or the association of several farms or agro-food industries for joint production. It has the advantage that the fertilizer obtained is also very interesting for agricultural operations. There are many examples of successful cases of small-scale plants for self-consumption.
  - There are biogas plants adaptable to small livestock farms (compact, modular, easy to install and simple operation for small and medium sized livestock farms, which would allow organic waste to be valued through the production of biogas and a fertilizer that can be used in situ in the farms, which allows obtaining biogas with a methane content of up to 64% that can be used as fuel in engines for heat and electricity generation, and the resulting liquid digestate shows better fertilizer capacities than the manure.
  - Production of biogas to produce electricity from waste and by-products with high water content: sera (by-product of the dairy industry) manures and slurry from the pig sector and other by-products of agri-food origin (remnants of the wine and beer industry).

2 WOOD-ENERGY. SOLID BIOFUELS INSTALATIONS

RURAL BIOENERGY

Conceptual chart

WOOD-ENERGY. SOLID BIOFUELS INSTALATIONS

FORESTRY
AGRICULTURE
INDUSTRY

WOOD

SOLID BIOFUELS

WOOD LOGS **WOOD CHIPS** **PELLET** **MICRO-WOOD CHIPS**

Biofuels quality systems

THERMICAL OR ELECTRICAL CONVERSION. COGENERATION
SMALL AND MEDIUM FACILITIES

COMBUSTION PROCESS

Drying Thermal descomposition Combustion

STORAGE DEPOSITS

BOILERS
(bottom or reverse combustion boilers, with inclined grate or travelling grate, de rejilla inclinada o móvil, with automaticfeeding…)

HEAT

COGENERATION APLICATIONS

HEAT & POWER

Some previous questions

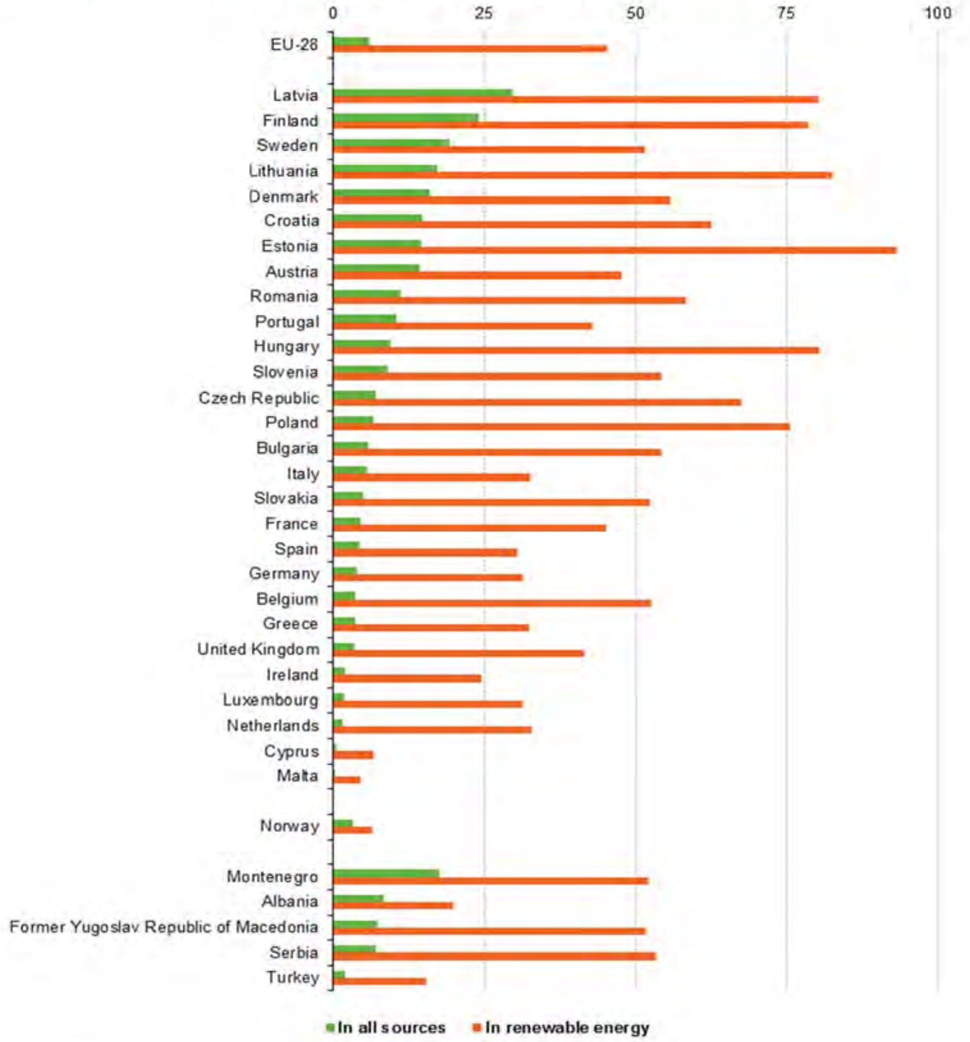
When we talk about wood energy, what type of solid fuels most common in the market we mean? Where do they get from? For what specific energy uses can they be used?

In many EU Member States, wood is the most important source of renewable energy. In your opinion, what could be 6 European countries with the highest consumption of this energy?

Check if you are right. Analyze the following graph that represents the percentage of wood and wood products in energy consumption in different countries of Europe (within the total energy and within renewable energy).

Wood as a source of energy, 2016.

(% share of wood and wood products in gross inland energy consumption, in toe)



Source: Eurostat (online data codes: nrg_100a and nrg_107a)

According to the previous data:

What are the 6 countries that consume the most wood energy?

What is the percentage of energy from wood consumed by your country?

- *Within total energy sources*
- *Within the energy from renewable sources*

2.1. ENERGY FROM WOOD AND SOLID BIOFUELS

2.1.1. INTRODUCTION

With the terms “solid biofuels” we refer to wood and products derived from it but also to plant biomass from lignocellulosic crops used for energy production.

The sources of this energy are very important and are obtained from:

1. **Forestry activities** (energy crops and forest residues such as stumps, waste, small dry branches...).

2. **Agriculture** (waste products from tree pruning, young branches of felling, agricultural product wastes, lignocellulosic plant crops ...) or human activities (wood for recycling...).

3. **Industrial activities** (chips, sawdust, shavings, pellets, briquettes...).

Wood is the third most used energy source in the world after oil and coal. In general, it is accepted that its use in a reasonable way contributes to the maintenance of the biochemical balance on the planet (as we have seen in the first module renewable carbon does not contribute to the greenhouse effect, the sulfur content is insignificant, etc.).

The interest in wood energy has been encouraging the development of new technologies that integrate fuel load automation and combustion management for several decades. These new technologies are characterized by their very good parameters for both the energy industry and the environment.

The role of wood energy is very important in the scenario of renewable energy sources in Europe since forest areas cover approximately one third of its surface, especially in some European states (for example, more than 45% of the Austrian, Swedish and Finnish territories are occupied by forests). In addition, the European forest area is growing through the afforestation of abandoned agricultural land.

The political interest in energy security and renewable energy sources has led in recent years to a reassessment of the possible use of wood as a source of energy. In many European countries, wood is the most important source of renewable energy.

In this total computation of biomass, wood and agglomerated wood products, such as pellets and briquettes, provided the highest proportion of energy of biological origin, representing almost half (45%) of the gross consumption of renewable energy inside the EU-28 in 2016.

The EU promotes sustainable forest management, with the following objectives:

- create and preserve jobs and otherwise contribute to the maintenance of the rural environment.
- protect the environment by preserving the soil, minimizing erosion, purifying water, protecting aquifers, improving air quality, absorbing carbon, mitigating climate change and preserving biodiversity.
- monitor the state of forests to comply with environmental agreements.
- improve the competitiveness of forest industries in the domestic market.

Wood is a source of energy that regenerates through photosynthesis. Its reasonable use will not harm energy reserves and the environment for future generations. It saves fossil energy sources (oil, natural gas, coal, uranium) that are of finite quantities and of non-uniform distribution.

Wood regeneration time is much shorter compared to other energy sources. However, the main advantage of wood energy is that it does not contribute to the greenhouse effect. The amount of CO_2 that is released in the combustion of wood is comparable to the amount produced during its natural formation. This amount of CO_2 corresponds to the amount absorbed through photosynthesis in the growth process. In this way, the balance is maintained and, therefore, the CO_2 balance is zero.

2.1.2. TYPES OF SOLID BIOFUELS

Within the framework of increasing the importance of renewable energy and wood energy, in recent years there has been a continuous technological evolution in the process of producing wood fuels. In the context of forestry activities, new products adapted to different needs have been developed.

The boilers used in industries and in biomass power plants for electricity generation admit a great variety of fuels, since they do not need to be fed with biomass of the quality of domestic boilers. However, in the case of domestic thermal applications, a quality fuel compatible with the boiler is required. It will be the distributor of the boiler who indicates the types of biomass to be used, existing specific boilers for a type of fuel or biomass, as well as multi-fuel boilers that admit any type of biomass: wood pellets, dried olive bone, shell crushed almond, etc. In general, the boilers work with dry biomass of granulometry not exceeding 8 mm, the pellets being an ideal fuel due to the ease of transport, storage and handling.

The main wood fuels available in the market are:

Wooden logs

Wood chips

Pellets

Wooden microchips

Wooden logs

The production of wood logs involves the following phases: Forestry, harvesting and log preparation.

There is an immediate need to improve product quality and minimize production costs to develop this market. Harvesting and preparation of firewood must be improved, moving from conventional means traditionally used to modernization through extensive mechanization. There is a tendency to move from conventional wood production methods to permanent site production. Logistics for firewood production are often not covered by the process specifications, since firewood is still considered only as a byproduct of wood production for industrial applications.

In the last ten years, the new equipment for the entire firewood production process (for example, cutting machines, combined cutting and cutting machines, machines for measuring the volume of wood, etc.) made it possible to improve and provide joint specifications for logistic production of firewood and its preparation for immediate use.

Wood chips

Las astillas son un combustible de madera muy interesante, se adapta para ser utilizado en una amplia gama de plantas de calefacción, desde las domésticas hasta las redes de calefacción de comunidad. The production of wood chips is a fairly simple forestry or agricultural activity, which includes the following phases:

- Forestry
- Harvest
- Preparation of logs
- Division of wood chips
- Storage and drying

In fact, difficulties in producing quality chips at competitive prices come from the planning of operations and the logistics of delivery:

- There is a wide range of alternatives for the division of wood, both in terms of organization and productivity.
- There is a good selection of high quality machinery from different manufacturers available in the market.
- The normal operation of heating systems requires the composition of the chips be very uniform in size.

There are five types of splitting machines: small splitters transported by agricultural tractors, splitters connected to the tractor, mobile or self-propelled splitters, heavy-duty stationary dividers mounted on a truck or semi-trailer and stationary dividers.

Pellets

The consumption of this type of wood-fuel, have strength increased in the last years, for many reasons:

- High caloric power
- Easiness of management (packaging and transport)
- Easiness of use at domestic level in little stuffs

The production of pellet can be a forestry or agricultural activity, but requires a more complex production process, including these phases:

- Forestry
- Harvesting
- Preparation of logs
- First splitting of logs in chips
- Milling aimed to obtain a fine chip
- Drying until a 8-12% of humidity
- Storage
- Refinement finalized to obtain sawdust
- Pelletisation

Wooden microchips

In the last years some farmers began the production of this new wood-fuel, a wood-chip very little and dry, that put together the advantages of wood chip with those of pellet:

- The production process is the same of the traditional wood-chip
- The use of micro wood chips is the same of pellet, as wood-fuel for domestic pellet-stuffs
- The micro wood chip is more adapt in a short chain, based on the use of local forestry production
- The cost of micro wood chip is lower than pellet
- Wood energy production cycle

	Wooden pellet	Wooden chips
Calorific value (kWh/kg)	4,7	2,7
Humidity (%)	8	50
Densidad (kg/m³)	700	250
Content of ashes (%)	0,5	1

Comparative analysis between wooden pellet and chips

QUALITY OF SOLID BIOFUELS

A very important step of the recent evolution towards the specialization of wood-fuel production, has been the adoption of a quality system through the certification schemes UNI-EN-ISO.

The rules concerned with the certification of solid biofuels from wood are the following: UNI EN ISO 17225:2014 – Solid biofuels - Specifications and classification of the fuel (Part 1: General requirements; part 2: wood pellets; part 3: wooden briquettes; part 4: chips; Part 5: Wood).

The main quality factors defined from the certification scheme, for each type of wood biofuel, are:

• **Origin of the product:** this parameter is very important because it allows to know if the product come effectively from forestry and agricultural activity, and the area of origin.

• **Dimension:** is an essential evaluation element, because this parameter is a straightly connected with the correct running of the heating/power plant. The optimal dimension of wood biofuel depends from the type of heating/power plant.

• **Water content:** this parameter is connected both with efficiency of the energy conversion and calorific value. Some type of heating/power plants requires a low water content (i.e. pellet stuffs or heating plants using wood chips).

• **Calorific value:** is a very important economic parameter: the higher calorific value (MJ/Kg or kWh/Kg) is the main element for setting the price of wood biofuel.

• **Content of ashes:** is a very important environmental parameter, because the ash is a potential pollution factor.

2.2. ENERGY PRODUCTION FROM SOLID BIOFUELS

2.2.1. STRATEGIES FOR PRODUCTION OF ENERGY FROM WOOD

A correct and integrated strategy for production of energy from wood, must consider the whole production chain, involving many subjects, many professional figures. Each step along the chain, needs a deep analysis considering:

- Technological aspects
- Models of management
- Economical analysis, evaluating the relationship costs/benefits
- Contractual aspects

The main steps to consider are the following:

SUPPLY OF FUEL	• Type and characteristics of fuel • Harvesting management • Storage management
TYPES AND CHARACTERISTICS OF PLANTS	• Technology of combustion • Correct dimension of plants, in relation to the energy needs • Logistic aspects • Environmental impact • Financial aspects
CHAIN MANAGEMENT	• Involvement of professional and business figures • Definition of tasks and relevant benefit • Definition of contractual agreements

2.2.2. COMBUSTION PROCESS

The wood combustion process takes place generally in three stages which are depending on temperature of the process: 1. Drying, 2. Decomposition, 3. Combustion.

From the point of space inside boilers running on wood logs, these stages run separately, while especially in boilers of larger size with automatic feeding for the travelling grate, these processes take place in separate sections of the grate.

1. Drying

Water contained in wood starts to evaporate even at temperatures below 100°C. as evaporation is a process which uses the energy released during the combustion process, temperature in the combustion chamber decreases and slows down the combustion process.

In fact, "fresh" wood requires such quantity of energy to evaporate the water contained in it that the temperature in the combustion chamber drops under the minimum level required for maintenance of combustion. For this reason, water content of wood fuel is among the most important quality parameters.

2. Thermal decomposition (pyrolysis /gas generation)

After the drying process at a temperature of about 200°C the wood undergoes thermal decomposition which leads to evaporation of the volatile matter contained in it. Volatile substances make up over 75% by weight of wood and because of this it can be asserted that their burning will mean basically burning of the gases included in their composition.

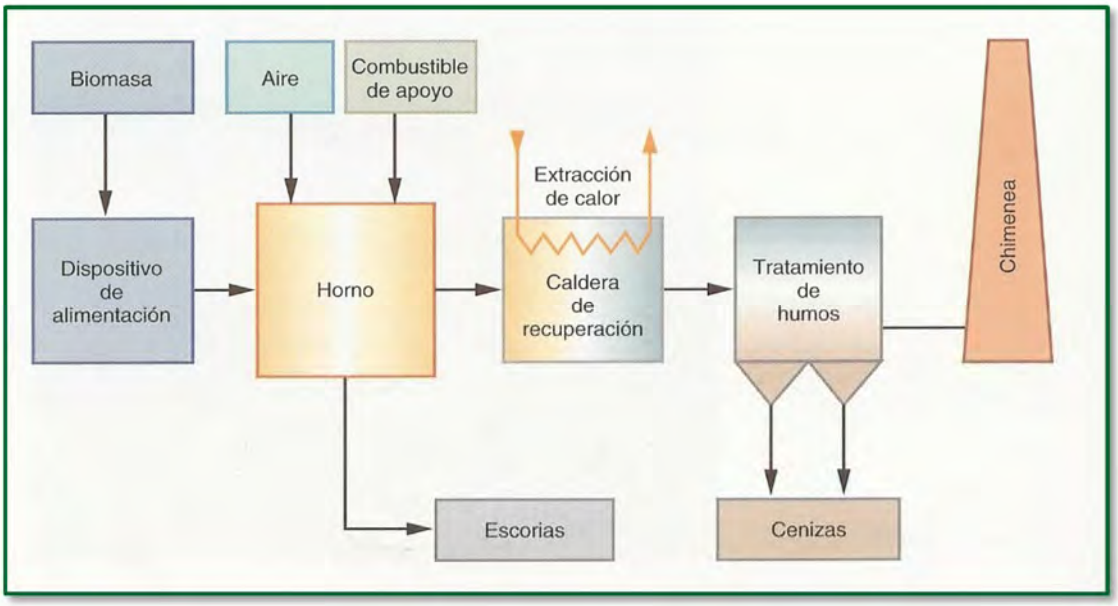
3. Combustion

It is complete oxidation of gases and this is a phase that starts at 500°C and 600°C, and continues at temperatures up to about 1.000°C. Within the range of 800°C - 900°C fixed carbon burns and also resin burns together with it.

"The rule of the three T" demonstrate that the lack of suitable conditions will lead to incomplete combustion of wood and consequently to an increase of noxious emissions. The main causes for incomplete combustion are the following negative conditions:

- ✓ Unsuitable air-fuel mixture inside combustion chamber and general shortage of oxygen.
- ✓ Low temperature of combustion.
- ✓ Short time of combustion.

Therefore, quality of combustion depends on three main factors: Time, Temperature and Turbulence.



Scheme of a combustión plant

2.2.3. THERMAL, ELECTRICAL AND COGENERATION CONVERSION. SMALL AND MEDIUM FACILITIES

Wood fired boiler systems can be divided in the following categories depending on the type of the wood fuel used, generating capacity and boiler feeding system:

- Boilers fired on wood logs, manual feeding.
- Small boilers fired on wood pellets, automatic feeding.
- Small and medium sized boilers fired on wood chips, with inclined (i.e. fixed) grate and automatic feeding with a feed screw.
- Medium and large sized boilers with travelling grate and automatic feeding with a feed screw or a pusher.

WOOD LOG FIRED BOILERS

Wood log fired boilers can be divided in two categories depending on the combustion principle: bottom combustion and reverse combustion.

Bottom combustion boilers normally use natural draught and pressure drop requires to feed primary air from outside which is then transferred to the combustion chamber; flue gases are transferred to the bottom part of the furnace (secondary air) and after it to the second combustion chamber. As the air flow passes under the furnace, it is very important to have the wood arranged in the proper way so that air could move uniformly to the combustion zone.

The reverse combustion boilers with induced draught are the most innovative solutions for boilers in terms of technology. Gases are discharged through a hole under the furnace into the second refractory lined combustion chamber as a result of a forced pressure drop created by a fan located at the bottom. The resistance of the flue gas flow is high and it requires an ID fan with electronic controls. The fan allows for precise modulation of the primary flow air (normally, preheated) and secondary air flow inside the combustion chambers. Normally, there is a lambda probe in the first section of the flue stack for continuous measurement of o2 concentration in the flue gases and regulation of the fan, and in boilers with automaticfeeding - the rate of fuel feeding. This oxygen concentration sensor is exceptionally useful in wood log and wood chip boilers since these fuels have typically variable water and energy content. Also, the lambda probe helps to obtain a continuous maintenance of a combustion process of high performance and consequently minimize harmful emissions. Wood fired boilers are normally ignited manually, however, more advanced models have also automatic ignition.

In wood log fired boilers it is very important to provide energy storage through Hot Water Accumulator (known also as buffer tank), that is adequately sized depending on a number of heat engineering parameters.

WOOD PELLET FIRED BOILERS

The wood pellet boilers can fully meet the annual heat needs of a single or double-family house. In general, there is an option to have either a compact semi-automatic or fully automatic system. The compact semi-automatic system consists of a boiler with a fuel tank next to it (this can be a tank for daily or weekly needs), normally with manual feed. A large quantity of fuel (for example, packed in bags) have to be kept in stock in another place.

Pellet fuel is automatically fed to the combustion chamber by the feed screw. The fuel tank has to be of a volume at least 400 litre. Then the fuel can be sufficient for up to one month depending on the dwelling area to be heated and outside temperature. In an ideal case, the owner will be informed about reaching of the lower level of the fuel charge by an indicator fitted either on the boiler or in a remote place, and then the system should remain in operating mode to control the shut down temperature.

In the fully automatic system a hopper is located near the weekly fuel tank and is automatically loaded with larger quantities of fuel (for example, for one year; feeding is by means of a feed screw or a pneumatic extraction system. In an ideal case, the hopper is loaded, for example, by a tank.

WOOD CHIP FIRED BOILERS

The wood chip boilers are divided in two categories:

1. Boilers with inclined grate
2. Boilers with travelling grate

Boilers with inclined grate these are small to medium-sized boilers rated from 25 kW up to some 400-500 kW suitable for domestic applications in small heat transfer systems. They have a fixed combustion chamber with different types of feeding. The most widespread boilers are these with grates with bottom feeding by means of a pusher where primary air is active under the grate and contributes to drying of the wood and gas production, while the secondary air is active under the grate and contributes to efficient oxidation of released gases.

COMBINED PRODUCTION OF HEAT AND ELECTRICAL ENERGY. SMALL-SCALE APPLICATIONS

The combined production of heat and electric energy (CHP, combined Heat and Power or cogeneration) from wood biomass is by means of closed thermal processes in which the combustion cycle of the biomass and production cycle of electric energy are separated by the phase of heat transfer from the combustion gases to the transfer medium used in the second production. This is done so to avoid damaging of the internal combustion engines by the aerosols, metals and chlorine compounds contained in the gases released in the combustion process. to achieve steady energy development and environmental protection, the production of electric energy from biomass fuel shall involve also production of heat energy according to the following principle: "Production of kWel only when there is a need also of its heat equivalent!" otherwise, the process will lead to waste of resources and therefore loss of huge quantities of energy. And so, cogeneration requires use of heat and electric energy at the same time, something which is not easy.

SOLID BIOFUEL STORAGE DEPOSITS

Depending on existing facilities or space availability, the alternatives for biomass storage are several:

A. **Storage container:** This system is the most reasonable option for users with limited space. Thanks to the size of the container (up to 300 kg) long periods of boiler autonomy can be achieved.

B. **Textile silo:** This system is optimal in places where there is enough space for its installation. The canvas silo is supported by a metal structure, is permeable to air but not to dust, and is antistatic. It can be installed both inside and outside the building; It is filled with biomass from the top and the boiler feed is from the bottom by means of an auger. The capacity of these silos is between 2 and 5 tons of fuel.

C. **Underground tank:** When there is not enough space for fuel storage, this type of tank can be used outside the house, which by means of a pneumatic system transports the pellets to the boiler.

D. **Work storage silo:** In this system there are two different cases: silo with sloping ground with an auger that carries the fuel to the boiler, or silo with a pneumatic feeding system that allows the silo to be located up to 30 m from the boiler.

The storage system has a direct influence on the type of transport and supply systems. Silos on the ground need supply vehicles that can be discharged by throwing fuel on the battery. Underground silos can be filled with any type of dump vehicle or tilting box.

The fuel can be transported from the place of storage to the boiler in different ways:

- ✓ **Floor with hydraulic horizontal scrapers:** it is a good option when there is little space available or the fuel has low density. Although it has a higher cost, it optimizes the volume of the silo. Rotary scrapers (steel slats) are cheaper and can be used with a wide variety of fuels (chopped pineapple, wood chips, etc.). The storage silo must be round or square to avoid spaces.

- ✓ **Combination of inclined floor and auger:** the biomass is sliding until it ends in the channel where the screw that carries it to the boiler room is located. The inclination and height of the ramps is very important, because the biomass can get stuck if the design is not adequate.

- ✓ **Sloping ground with a pneumatic feeding system:** it is the cheapest but only admits pellets or fuels of a very homogeneous size and shape. The pneumatic supply allows the storage or storage silo to be located at a distance of up to 15 m from the boiler room, thanks to a hose. The storage place must be narrow and long, to avoid possible dead spots.

- ✓ **Flexible auger screws**: operation similar to the tire and very useful for fuels with impurities that can bind a rigid screw.

Frequently asked questions

1) Can heating installations with another type of boiler (diesel/propane) be used when replacing it with a biomass boiler?

The change of boiler only implies the acquisition of the boiler and the new fuel, maintaining the rest of the facilities: radiators, underfloor heating, domestic hot water tank (DHW), etc.

2) Which is better a boiler or a pellet stove?

A stove usually does not reach the heat output needed by a home and therefore will not serve as a heat generator for a building, centre or large house. The stoves usually have powers between 5-12 kW, which limits their use to heat small weekend houses, concrete rooms of a house or centre, or to replace an old wood burning fireplace in the living room. The boilers instead, with powers between 50-500 kW, can provide it.

3) Which biomass boiler is better?

Currently there are many boiler brands that differ in technology and power and, therefore, in cost, robustness and automation. The most common are the following types:

a. Compact equipment: they are designed for domestic and non-industrial use, include all automatic cleaning systems, electric ignition, etc.
b. Boilers with lower feeder: boilers are very well adapted for fuels with low ash content (pellets, chips).
c. Boilers with mobile grill: they are more expensive but have the advantage of being able to use biomass with a high moisture and ash content. It is generally used with higher powers (1,000 kW).
d. Diesel boilers with pellet combustion system: they have a lower price but present some inconvenience, as the power is reduced by around 30% and the cleaning of the boiler cannot be automatic.
e. Boilers adapted with cascade combustion systems: the combustion system is located outside the boiler. Due to its design, the flame generated for the combustion of biomass is similar to that of a traditional boiler, such as coal or natural gas.

4) What is the best fuel for solid biofuel boilers?

Boilers for industrial use and for electricity production admit a wide variety of fuels, but those for domestic thermal use need to be fed with quality biomass and compatible with the boiler. It will be the distributor of the boiler who indicates the types of fuels to be used, existing specific boilers for a type of fuel or biomass, as well as poly-fuel boilers that admit any type: wood pellets, dried olive bone, shell crushed almond, etc.

In general, the boilers work with dry biomass of granulometry not exceeding 8 mm, the pellets being an ideal fuel due to the ease of transport, storage and handling.

5) What price do solid biofuels have?

In domestic uses, the difference of price depends on the degree of processing in the case of less elaborated biofuels or used in large heating networks and € 200/Tm for pellets packed for boiler or stove of single-family homes. Specifically, the price of pellets can vary from 120 to 350€/Tm depending on the country, tax rates and the purchase system. In Spain, around 150-350€/Tm according to the quantity purchased, the raw material of the pellet, the distance to the consumer and the form of supply (in bulk: € 150/Tm, bagged: € 350/Tm).

6) What autonomy does biomass have as fuel?

Approximately 1 kg of pellet has half the calorific value of a litre of diesel, so it takes two kilos of pellets or other types of biomass to produce the same energy as a litre of diesel. If in one year a boiler consumes 2.000 litres of diesel fuel, 4.000 kg of pellets will be needed, occupying a volume of 6 m^3 (approximate data).

7) How much space does a "biomass boiler" need?

Biomass boilers are generally very compact: about 140 cm high by about 40 cm wide with a depth of about 70 cm, although their dimensions depend on the model. However, the boiler requires a large and dry place for fuel storage, which can be a problem in buildings with small boiler rooms and little usable space. Therefore, it is necessary to look for other storage facilities such as deposits inside the building, a closed room next to the boiler or in a warehouse separate from the building.

8) What daily maintenance does the biomass boiler require?

Biomass boilers are automatic but some models require the user to put the fuel in the tank, while if a silo is available, a manual refill is no longer necessary. On the other hand, when burning biomass a certain amount of ash is produced that is collected in an ashtray to be emptied (approximately one kg of ash is produced for every 100 kg of biomass combustion). Besides it is necessary to keep the storage place ventilated to avoid that the humidity causes the appearance of moulds and a lower performance of the boiler.

9) Is there any danger associated with a biomass boiler?

There is no danger. The only problem that could cause biomass is the dust produced in its discharge to the silo that can be avoided by installing an air extraction system and a dust filter driven by a small electric motor.

10) When is it recommendable to install a "biomass boiler"?

The cases in which it is advisable to install a biomass boiler are the following:

- On farms, livestock, forestry or agri-food industries or other related industries where the waste from the activity can be used.
- In installations with large fuel consumption.
- In buildings, facilities or homes that need to replace the existing boiler.
- In installations where they cannot be adapted to the regulations of gas or diesel boiler rooms, after the life cycle of the current boiler has elapsed or for the conversion of the old coal or diesel C heating.
- In a new project or rehabilitation, where the use of renewable energy is necessary.

Work sheet 2.

WOOD-ENERGY. SOLID BIOFUELS INSTALATIONS

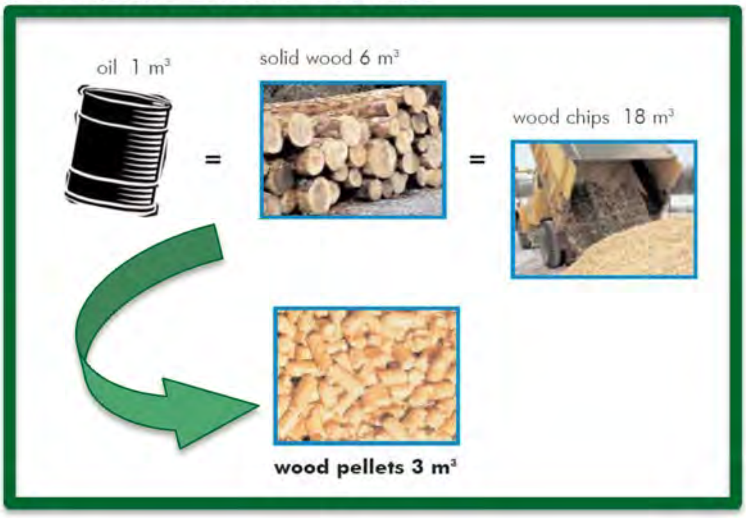
EXERCISE 2.1. *What conclusion do you draw by observing the data collected in the following table about the regeneration period of different types of energy?*

Energy	*Regeneration period*
Wood	*15-200 years*
Coal	*250- 300 million years*
Oil	*100- 450 million years*

Source: Eurofor, Inestene

EXERCISE 2.2. *Equivalence of the necessary volume of different types of wood fuels **(wood logs, wood chips and pellets)** for the same energy content as 1 m³ of oil). Order them from higher to lower energy content:*

VOLUMETRIC ENERGY CONTENT



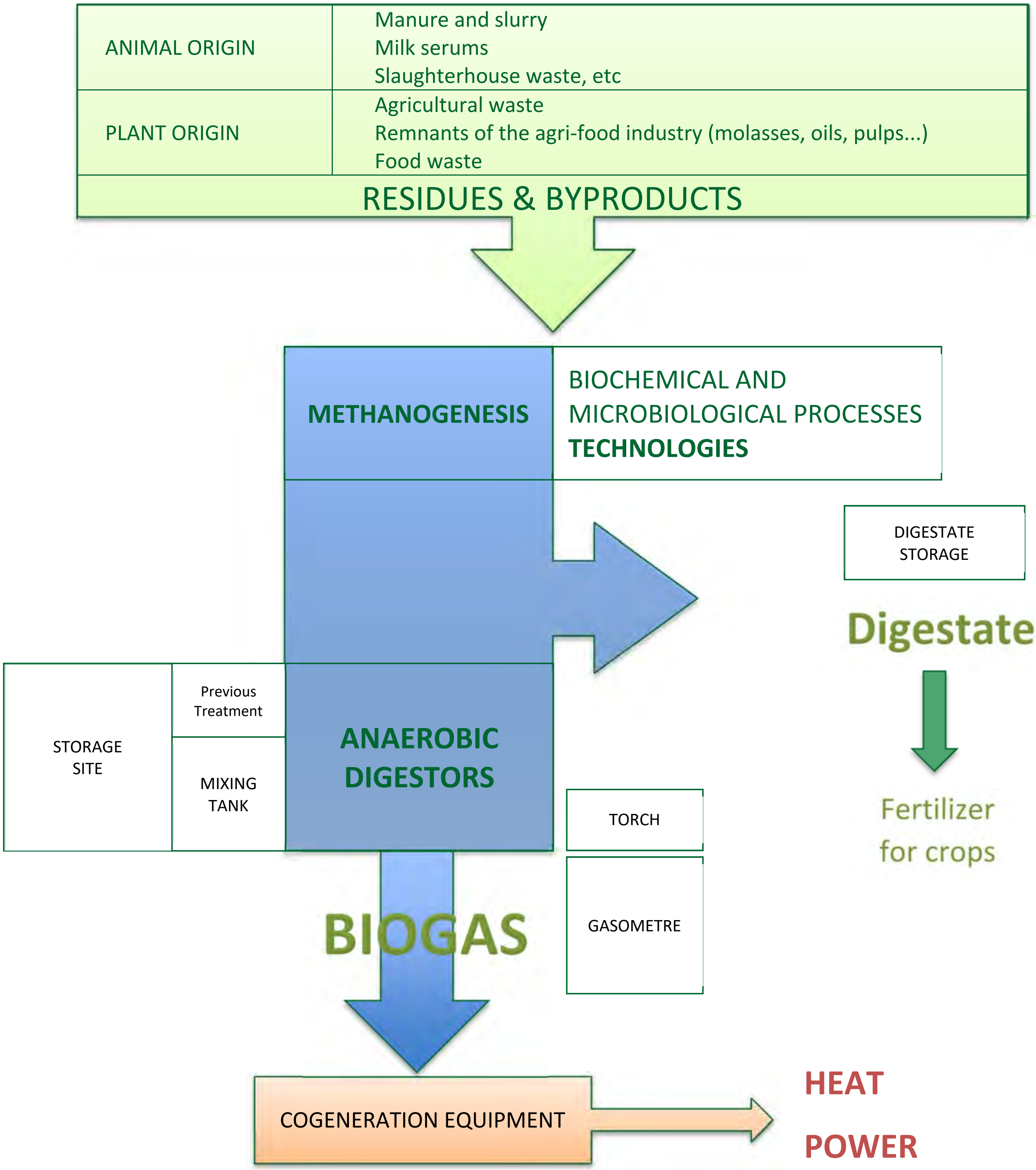
EXERCISE 2.3. *Explain the different types of solid biofuel boilers that exist.*

3 | BIOGAS INSTALATIONS

RURAL BIOENERGY

Conceptual chart

BIOGAS INSTALATIONS



Some previous questions

This module tries to publicize the origin and formation of biogas from different organic waste from various activities in the agri-food sectors.

What waste do you think are more interesting for biogas production? Order the following wastes from best (1) to worse (4) for this bioenergy use: **agricultural, livestock, forestry and agri-food industries**.

1	2
3	4

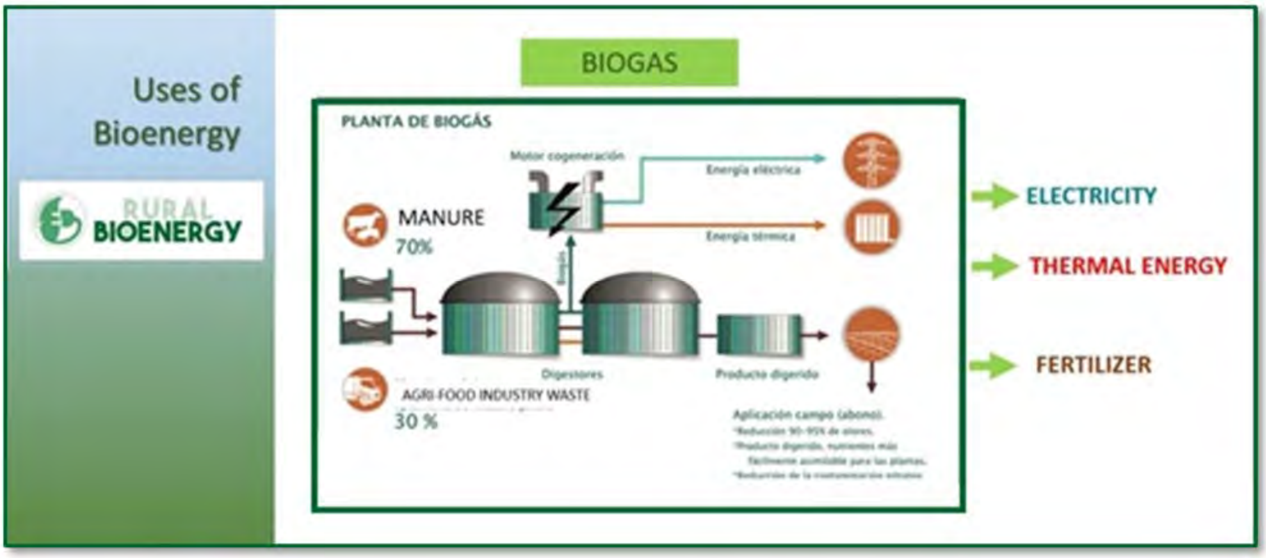
It is also about knowing the technologies and processes that take place for the production of biogas and how are the biogas energy use facilities. Could you say what essential part of biogas facilities the image represents and what is it for? What uses can be made of biogas?

3.1. WHAT IS BIOGAS AND FROM WHAT IS IT OBTAINED?

Biogas is one of the main forms of bioenergy, along with solid biomass and other biofuels. It is a by-product of the decomposition of biomass in the absence of oxygen, a process also known as anaerobic digestion.

Biogas, also known as renewable gas, is very similar to what we know as natural gas in the sense that its main chemical element is methane or CH_4. While natural gas is artificially extracted from natural underground deposits and supplied to the consumer through a complex pipeline infrastructure, biogas is generated naturally on the earth's surface in natural environments such as marshes, manure dumps or in human-controlled environments called anaerobic digesters.

The chemical composition, as well as the quality and quantity of biogas produced in biogas plants (anaerobic digesters) depend on the quantity and type of their raw materials and the design of the biogas plant. The available raw materials are tested in specialized laboratories, which then recommend the best "recipe", that is, the best combination of raw materials and their proportions to achieve the best biogas production. In general, the main component of biogas is methane (CH_4) whose concentration is 40% to 60%, followed by carbon dioxide (CO_2) - 40% to 20%, water (H_2O) and small amounts of other chemical components as nitrous oxide (N_2O), sulfides, etc.



There are three main ways in which biogas can be used:

- **Heat.** Biogas as a source of heat can function in several ways. The first and simpler one is when biogas is burnt as fuel in a gas boiler at the same place where it is produced, for example in a farm. There is also a centralized and more complex way for use of biogas as heat source. The biogas produced in a larger biogas installation undergoes purification and treatment in order to meet specific quality standards and is then injected in the centralized natural gas distribution pipeline.

- **Electricity.** Biogas for electricity is probably the most efficient way to use biogas. In the most efficient installations, the generation of electricity is combined also with recovery of the waste heat which is created in the process.

This technology, known as **combined heat and power generation (*cogeneration*)**, can be based on an internal combustion engine or a steam turbine, and can serve both large-scale and small-scale projects. Large-scale projects can range from thermal power plants and district heating utilities of 10 GW for example, whereas small-scale projects can be from 20 kW (serving a house) to several hundred kilowatts (serving a hotel, hospital, factory, etc.). The energy efficiency which can be achieved in this combined generation process is up to 96%, compared to approximately only 40% when heat and electricity are generated separately by a boiler and a power plant.

In addition to electricity and heat, cogeneration plants can be upgraded to provide also cooling energy. It can provide the air-conditioning of a whole building, or can ensure the cooling needed in an industrial process. This upgraded technology is called **trigeneration**, after the three types of energy – combined cooling, heat and powerAdemás de la electricidad y el calor, las plantas de cogeneración se pueden actualizar para proporcionar también energía de enfriamiento. Puede proporcionar el aire acondicionado de todo un edificio, o puede garantizar la refrigeración necesaria en un proceso industrial. Esta tecnología mejorada se llama **trigeneración**, después de los tres tipos de energía: enfriamiento combinado, calor y energía.

Photo: Work in progress for the construction of a small-scale cogeneration plant.

- **Transport fuel**. Biogas in its role as fuel for vehicles such as buses in the public transport network will be explored in more detail in the next module dedicated to biofuels. Similar to the scenario of centralized biogas supply for heat purposes, in this case biogas is again upgraded to biomethane and supplied through the filling stations or as compressed gas in bottles (like the compressed natural gas – CNG).

RAW MATERIALS FOR BIOGAS

The agri-food sector is rich in waste and residues which are valuable sources of energy – raw materials for biogas production. Here are the main sources, but they often have to be combined to give good results.

Animal origin wastes.

There are numerous possible places for generating animal waste in rural areas:

- **Animal breeding farms – manure**. In the design of biogas systems it should be considered that the manure from different animals has quite different contents and potential for biogas production. Consider pigs and chicken for example.
- **Dairy farms – milk whey**. It is often used as a raw material for biogas production in combination with other feedstocks (straw, corn silage, etc.).
- **Slaughterhouses – liquid waste (waste waters and blood) and solid waste (edible and non-edible offal, hide and skin, hairs, bristles etc.).** Slaughterhouse waste is a significant environmental challenge. Anaerobic digestion is one of the best options for managing this waste. The biogas potential of slaughterhouse wastes is greater than animal manure, and is reported to be in the range of 120-160 m^3 of biogas per tonne of waste. However, the C:N ratio of slaughterhouse wastes is quite low (4:1), which requires co-digestion with high C:N substrates such as animal manure, food waste, crop residues, bird litter, etc.

Vegetable origin wastes.

Some points of generation of plant waste are the following:

- **Plant growing estates**: sunflower stems, heads and husks, stems and husks of cereals, bagasse, corn stems and leaves.
- **Food and beverage production** pressed olive seeds after olive oil production, pressed grapes after wine production, fruit peels and seeds, wastes from breweries and distilleries, etc.

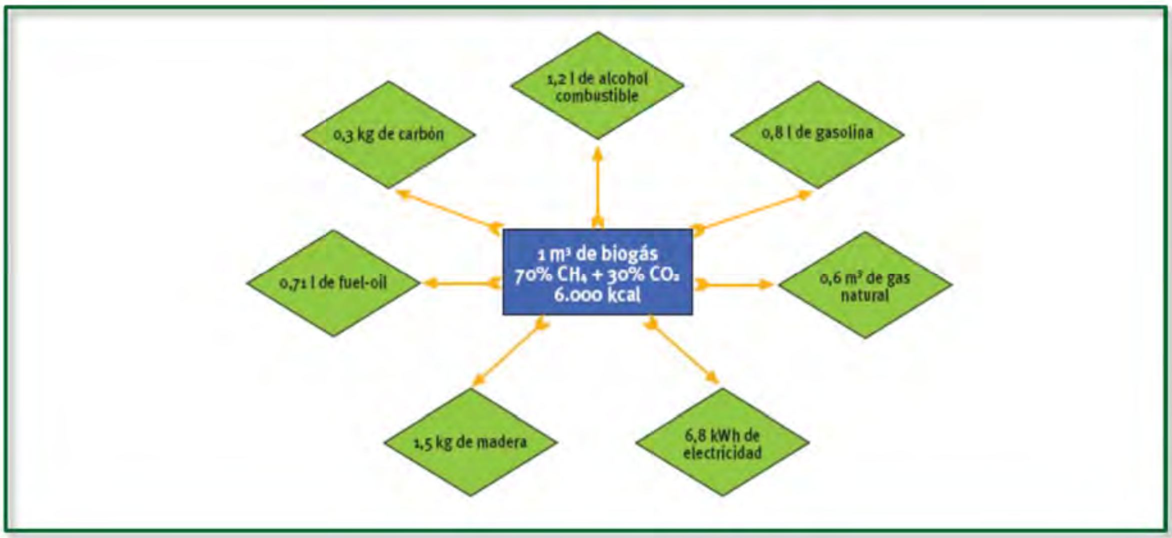
- **Food waste:** incredible quantities of food are discarded every day from restaurants, supermarkets, and households. Few countries have centralized systems for food waste management.
- **Forest waste (dendromass):** in general, forest waste is not suitable for biogas production because of the lignin component in wood, which cannot be digested by the methanogenic bacteria.

Organic waste is characterized above all by its composition of dry matter (MD) and volatile matter (MV). The Methane Potential is the volume of methane biogas produced during anaerobic degradation in the presence of bacteria of a sample initially introduced, expressed under Normal conditions of Temperature and Pressure (CNTP: 0°C, 1013 hPa).

You will find in this table for some waste its potential of methane production (in m^3 of methane per ton of raw material):

Raw material	Methane potential (m^3 CH_4/Ton of raw material)
Liquid bovine manure	20
Contents of paunch	30
Bovine manure	40
Potatoes pulps	50
Brewery waste	75
Shearing of lawn	125
Corn residues	150
Lubricate from slaugtherhouse	180
Molasses	230
Used grasses	250
Cereal waste	300

Potential for methane production by biodegradation of waste



Equivalences of biogás with other energy sources. Source: CIEMAT

Although apparently a huge amount of biogas is necessary compared to other fuels to obtain the same energy, we must take into account the physical state in the form of gas that makes it occupy a larger volume, so the one that most closely approximates is the natural gas case.

3.2. BIOCHEMICAL AND MICROBIAL PROCESSES FOR BIOGAS PRODUCTION. TECHNOLOGIES

The different biological processes that take place in the production of biogas and the associated technologies are reviewed below.

METHANOGENESIS

When biomass is decomposed by microorganisms in the presence of oxygen (aerobic environment), we witness a process called composting which gives us a rich soil fertilizer. When there is no oxygen, this process is called anaerobic digestion and in addition to the fertilizer (called digestate) it gives also biogas.

The formation of biogas is called methanogenesis (its main component) and it happens in the final step in the biological decomposition of biomass in the absence of oxygen. It is the biological production of methane mediated by anaerobic microorganisms from the Archaea domain commonly called methanogens.

Over the years, people have learned how to create the necessary environment in order to produce biogas through this process and have engineered biogas plants involving anaerobic digestion.

There are **different types of anaerobic digestion systems** (AD) depending on the temperature they maintain, the percentage of dry matter in the biomass, the rate at which biomass is fed into the digester, and others. Below is a description and comparison of the main categories of anaerobic digestors.

Mesophilic or Thermophilic: Mesophilic systems operate at 25-45°C and thermophilic systems operate at 50-60°C or above. Thermophilic systems have a faster throughput with faster biogas production per unit of feedstock and m³ digester and there is greater pathogen kill. However, the capital costs of thermophilic systems are higher, more energy is needed to heat them and they generally require more management.

Wet or Dry: The difference between what is considered a wet process and a dry process is quite small. Effectively, in wet AD the feedstock is pumped and stirred (5-15% DM) and in dry AD it can be stacked (over 15% DM). Dry AD tends to be cheaper to run as there is less water to heat and there is more gas production per unit feedstock. However, wet AD has a lower set-up capital cost.

Continuous or Batch Flow: Most digesters are continuous flow as opening the digester and restarting the system from cold every few weeks is a management challenge. They also generally give more biogas per unit feedstock and their operating costs are lower. Some dry systems are batch flow, however. To overcome peaks and troughs in gas production there is usually multiple batch digesters with staggered changeover times.

Single, Double or Multiple Digesters: As explained above, AD occurs in several stages. Some systems have multiple digesters to ensure each stage occurs sequentially and is as efficient as possible. Multiple digesters can give you more biogas per unit feedstock but at a higher capital cost, higher operating cost and greater management requirement. Most digesters in the UK are single or double digesters.

Vertical Tank or Horizontal Plug Flow: Vertical tanks simply take feedstock in a pipe on one side whilst digestate overflows through a pipe on the other. In horizontal plug-flow systems a more solid feedstock is used as a 'plug' that flows through a horizontal digester at the rate it is fed in. Vertical tanks are simple and cheaper to operate, but the feedstock may not reside in the digester for the optimum period of time. Horizontal tanks are more expensive to build and operate, but the feedstock will neither leave the digester too early nor stay in it for an uneconomically long period.

The best system for you will be determined by what feedstocks are available, what output you want to maximise (e.g. is the goal energy production or waste mitigation?), space and infrastructure.

3.3. MAIN COMPONENTS OF A BIOGAS INSTALLATION

These are the main components of a biogas installation that includes anaerobic digestion and cogeneration.

RAW MATERIALS UNLOADING AND STORAGE SITE

There are separate storage facilities for liquid raw materials (tanks) and solid raw materials (silos). The storage compensates for the seasonal fluctuations in the supply of raw materials.

PRETREATMENT EQUIPMENT

Animal by-products (blood and slaughterhouse wastes) might contain pathogens of animal diseases which might spread through the digestate if such materials are used in anaerobic digestion. In order to avoid that risk, animal by-products must be thermally treated before they are loaded in the mixing tank and the anaerobic digestion system, in order to destroy possible pathogens.

FEEDING LINE AND MIXING TANK

An automatic feeding line ensures the proper supply of raw materials in the digestor. For liquids it consists of pipes and pumps while for solid raw materials it might be a vertical mixer feeder. Depending on the type of raw materials, there might be need for an area (a receiving tank) dedicated to mixing and homogenising them before entering the anaerobic digestor.

ANAEROBIC DIGESTOR

The heart of the process, a gas-resistent reactor where the raw materials decomposition takes place in the absence of oxygen, and the biogas is produced. In the European climate conditions the anaerobic digestors must have thermal insulation and must be heated.

GAS HOLDER (GASOMETER)

This is an airtight and watertight membrane, resistant to pressure, atmospheric agents, meteorological conditions and ultraviolet radiation. It serves as a storage of the produced biogas and also as a cover of the anaerobic digestor.

SAFETY FLARE

When there is excessive biogas which cannot be stored or used, combustion is the last possible solution to prevent risks for the security and to protect the environment. This is ensured by a safety flare.

PUMPS AND PIPES

The separate components of the biogas plant are interconnected through pipes and the circulation in them is ensured by pumps.

DIGESTATE STORAGE

The residuals from the digestion are pumped outside the digestor and transported through ducts to a separator where the solid and liquid digestates are separated. The liquid digestate is transported through channels to temporary storage ponds - artificial lagoons equipped with membranes.

BIOGAS TREATMENT EQUIPMENT

In addition to the methane (CH_4), the biogas exits the digestor with water vapor, carbon dioxide (CO_2), and a certain quantity of hydrogen sulfide (H_2S). When combined with the water vapor in the biogas, it creates sulfuric acid (H_2SO_4). Hydrogen sulfide is toxic, corrosive and has a specific unpleasant smell, and can damage the cogeneration engine. To prevent such damage, it is necessary to include equipment for desulphurization and drying of the biogas.

CHP UNIT

This is the area where the biogas is transformed into energy. It consists of an internal combustion engine with pistons whose shafts are connected to electric generators. The cooling water and the exhaust gases of the internal combustion engine are directed to heat exchangers for production of hot water. The generated heat covers the needs of the anaerobic digestion process.

TRANSFORMER / CONNECTION TO THE GRID

The complex must include also a step-up transformer (from low to medium voltage), if the electricity is going to be sold to the grid.

REMOTE MONITORING AND CONTROL SOFTWARE

As already illustrated, biogas plants are complex installations where all components are interdependent. Their proper functioning and efficiency are best ensured by a centralized and automated monitoring and control. This software records vital parameters (temperatures, energy consumptions, biogas production rates, etc.) to allow continuous monitoring and adjustment of the system's performance, as well as preventive maintenance.

Some of the collected data are:

• The type and quantity of the loaded raw materials	• The quantity and composition of the gas
• The process temperature	• How full are the tanks, digestors and the gas storage tanks
• The pH value	

Frequently asked questions

1) What is the Hydraulic Retention Time?

It is a term which is often mentioned in relation to anaerobic digestion systems which determines how much raw material should enter the anaerobic digester and how long it should stay inside in order to obtain optimal biogas output.

2) What is the digestate? Can it be used as a fertilizer?

Digestate is the waste that is obtained after biogas production as a byproduct of anaerobic digestion plants. It serves as a fertilizer that can be used in agricultural or forestry crops because in the process it has been stabilized and disinfected, eliminating pathogenic microorganisms. It is a rich fertilizer that replaces chemical fertilizers produced by chemical industries with intensive energy consumption.

3) Can the CO_2 (produced together with the CH_4 in the biogas) be used?

Modern facilities can capture CO_2 and deliver it to the greenhouses that need it for the photosynthesis of vegetables or to the industries that use it in the manufacturing process (soft drinks, medicinal gases). This process is called **quad generation**: heat, energy, cooling and CO_2 combined.

4) Are biogas plants economically viable?

The sustainability and long life of biogas plants are guaranteed with a good design and careful calculation in the conceptual phase of the project and good maintenance after installation. First, biogas projects must be evaluated in terms of their total energy efficiency, which means that all the energy they will produce (electricity, heat and/or refrigeration) must be fully utilized, either on site or sold to the network or nearby end users. The recovery period, the investment will depend on the choice of technology and the different existing raw materials.

5) Does a biogas installation need a lot of maintenance?

Maintenance is essential for the sustainability of biogas plants. Maintenance activities include scheduled and ad hoc preventive maintenance and repairs, replacement of spare parts and consumables, as well as a review (an important repair) of the cogeneration engine when a certain number of hours of operation is reached. A review can double the life of the system. An important part of maintenance activities that ensures reliability and rapid intervention is real-time remote monitoring and control software.

6) Does biogas smell?

The old biogas plants caused discomfort from the bad smell (although the biomass not treated at its origin, for example, manure dumps, causes the same bad odours) but this is already easily corrected with modern technologies (biological filters, treatment of the air for ventilation, discharge and storage of raw materials in enclosed spaces and sealed and impermeable membranes that do not allow smells or gases to escape, although the digestate emits some smell is much smaller than that of untreated manure. You can receive additional treatment for a greater reduction of any remaining odour (the longer the retention time, that is, the longer the biomass remains in the anaerobic digester, the less smell it will have.

Work sheet 3.

BIOGAS INSTALATIONS 1/2

EXERCISE 3.1. *Check your knowledge about biogas with the following practical* ***example of one practical example of a combined 2 MW biogas plant.*** *Answer the final questions.*

2 MW BIOGAS COMBINED HEAT AND POWER PLANT
Biogas combined heat and power plant which generates slightly over 2.000 kW of electrical power and almost 2.300 kW of thermal power. The total energy efficiency of the system is 89,3%, the sum total of 41,9% electrical efficiency and 47,4% thermal efficiency. The thermal energy is delivered in the form of hot water, which is then used in the biogas production process, for the sanitation of the animal wastes before they enter the anaerobic digester, and also for hot water and space heating of the nearby buildings. The electricity is used on site, and the excess quantity is sold to the grid.
Raw materials
The raw materials in this biogas plant are the following agri-food wastes: pig manure, slaughterhouse wastes, blood, sugar beet by-products, and corn silage. The animal origin wastes are thermally treated before they are loaded in the anaerobic digestion system in order to destroy possible pathogens.
Chemical composition of the biogas obtained
Around 55% CH_4 content, slightly less than 45% CO_2 content and small quantities of other compounds such as H_2S.
Technical and performance parameters
Electric power: 2.000 kW // Thermal energy: 2.300 kW HRT (Hydraulic retention time): 50 days Operating hours per year: around 8.000 h Electricity produced: more than 16.000.000 kWh/year Self-consumption percentage: 8-10% Electric efficiency: 41,9% // Thermal efficiency: 47,4%

What does ***combined plant*** *mean? What else can we call it?*

What kind of ***raw materials*** *does it use* ***from animal and plant origin****?*

What does it mean that it has a ***hydraulic retention time of 50 days****?*

Work sheet 3. BIOGAS INSTALATIONS 2/2

*It is an **anaerobic, mesophilic, single stage, continuous flow and simple digester process**. Explain what it means.*

*Why is it necessary to thermally treat animal wastes before loading them into the **anaerobic digestion system**?*

What gases are part of the chemical composition of the resulting biogas? Which is the most abundant?

***EXERCISE 3.2.** Look for information on the impact of food waste, good management practices and how it is used in anaerobic digestion in the report prepared by the World Biogas Association in 2018 – "Global Food Waste Management – An Implementation Guide for Cities", available at http://www.worldbiogasassociation.org/food-waste-management-report*

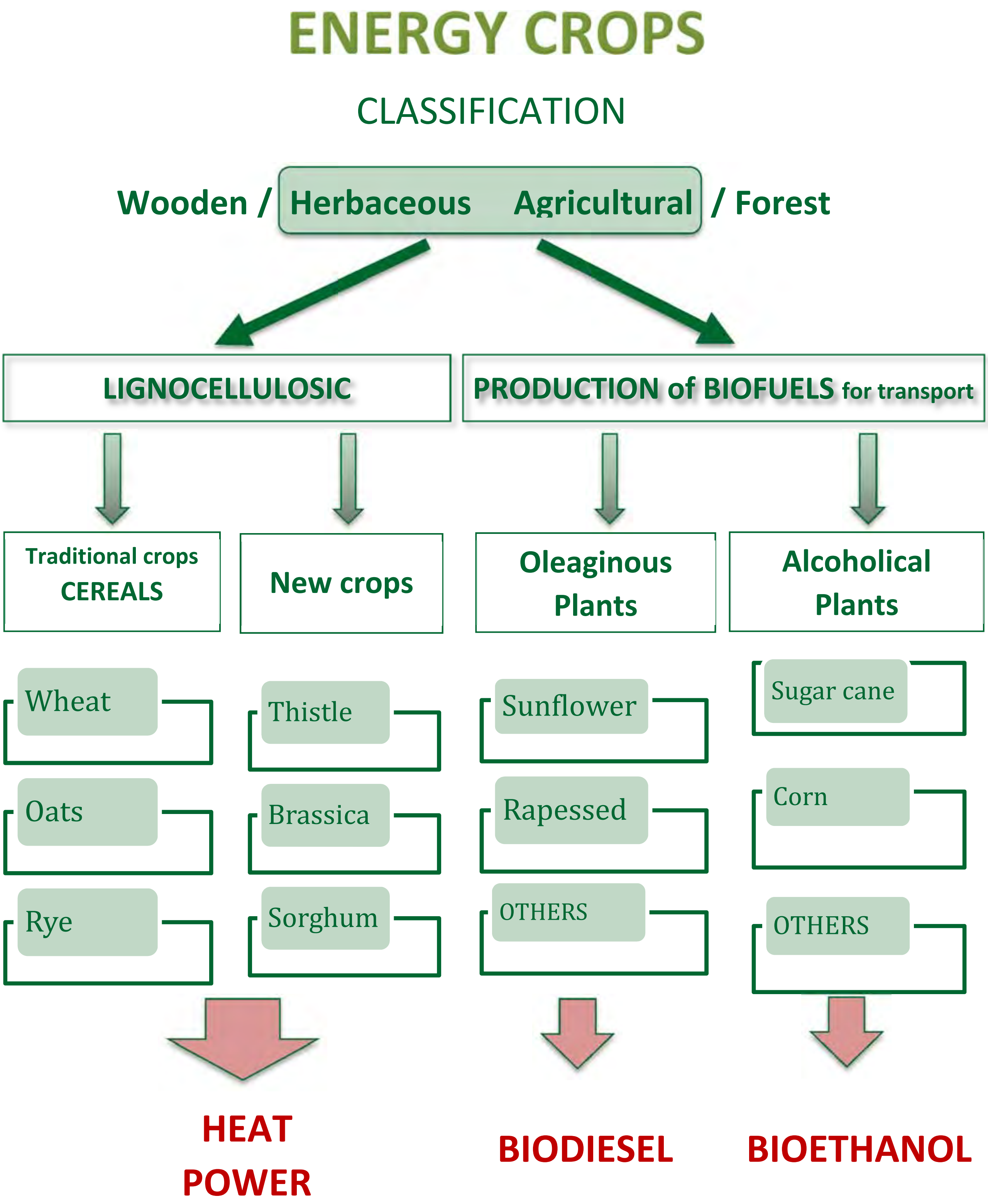
Summarize your own conclusions

4 ENERGY CROPS

RURAL BIOENERGY

Conceptual crops

ENERGY CROPS



Some previous questions

As we have seen so far, bioenergy can be obtained from residues of different activities (agricultural, livestock, forestry and industrial activities) but it is also obtained from exploited crops with the only objective of obtaining biomass which are called energy crops.

Could you give an example of plants that can be grown for energy purposes? Indicates the specific final energy uses that can be made of them.

Energy crops are an interesting option as alternative energy sources to oil that can, in addition to reducing dependence on conventional fuels, represent a potential opportunity for the agricultural sector contributing to the rural development of marginalized areas, motivating investment, revaluing land and avoiding rural emigration and abandonment of land.

What conditions do you think energy crops must meet to really be a new opportunity?

4.1. WHAT ARE ENERGY CROPS?

They are agricultural or forestry crops of fast-growing plant species that are planted for the purpose of harvesting for energy or as raw material for obtaining other combustible substances.

Energy crops, like any other, should respond as much as possible to criteria of sustainability and environmental respect as well as be economically profitable for producers.

CHARACTERISTICS OF ENERGY CROPS

Trying to obtain the highest economic and energy profitability and environmental sustainability, crops for energy purposes must respond to the following characteristics:

- **Adapt to the climatic and soil conditions of the place where they are grown:** it is important to look for the type of crop that best suits the characteristics of the soil and the conditions of the place.
- **Have high levels of productivity in biomass and low production costs:** these are usually fast growing crops and short rotations, with high annual production and that do not require much work to save on operating costs.
- **Have an easy handling:** with requirements and operating conditions as similar as possible to any other agricultural crop; require conventional techniques, work and machinery without the need for large investments for their cultivation.
- **Have a positive energy balance:** the energy they produce must be greater than the energy invested in their cultivation and subsequent transport to the transformation plant.
- **Be sustainable and not contribute to the degradation of the environment:** for biomass to be effective in reducing greenhouse gas emissions, it must be produced sustainably. The production of biomass implies a chain of activities that range from the cultivation of raw materials to the conversion of final energy.

  Specifically, crops must meet the following requirements:

  - Do not impoverish the soil and allow easy recovery of the soil, to subsequently implant other crops.
  - The edaphic and climatic requirements must be similar to the crops in retreat so that they can be cultivated in the land previously used by them.
  - Low fertilizer, phytosanitary, irrigation water and fuel needs to perform the necessary agricultural work.
  - Do not pose a danger to the rest of the flora, its propagation being outside the crop area, void due to its dissemination or easily controllable.

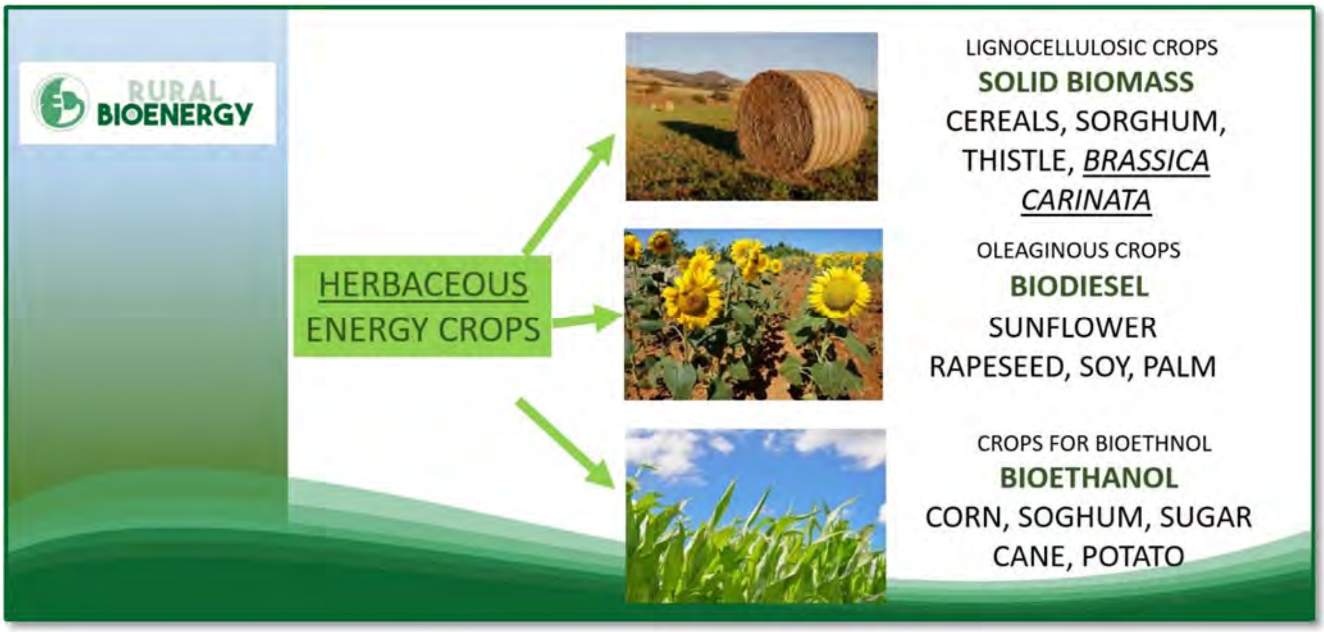
CLASSIFICATION OF ENERGY CROPS

They can be classified according to several criteria.

<table>
<tr><td rowspan="2">Depending on the type of biomass</td><td colspan="2">Herbaceous crops: those in which their crop cycle develops for less than a year.</td><td>Wheat, barley, thistle, etc.</td></tr>
<tr><td colspan="2">Woody crops: with a slower growth than arable crops, their cultivation cycle develops over several years.</td><td>Poplar, eucalyptus, pine, etc.</td></tr>
<tr><td rowspan="2">Depending on the knowledge about the plant or its tradition as crop in the region</td><td colspan="2">Traditional crops: those plant species that are historically grown in a particular region for food or obtaining raw materials of interest to the industry.</td><td>Wheat, sunflower, corn, poplar, etc. (in Spain)</td></tr>
<tr><td colspan="2">Alternative crops: those species that, despite having aptitudes for their development for energy purposes, or are not known in a certain place or are known, but are not cultivated.</td><td>Thistle, sorghum, etc. (in Spain)</td></tr>
<tr><td rowspan="2">Depending on the environment where crops live</td><td colspan="2">Terrestrial crops: those that live in land.</td><td>Rapeseed, thistle, poplar, etc.</td></tr>
<tr><td colspan="2">Water crops: plant species that necessarily live in places where water is present.</td><td>Chlorella sp., Alaria sp., etc.</td></tr>
<tr><td rowspan="3">Depending on the kind of biomass that they produce and its final use</td><td colspan="2">Lignocellulosic biomass producing crops: those that have an important cellulose content that makes them especially suitable for direct combustion in boilers for electric or thermal energy production, with or without transformation, and can be used for different applications (thermal, fuel manufacturing more elaborated, obtaining second generation biofuels).</td><td>Woody plants cultivated in short shifts (poplar, eucalyptus, etc.) or crops of herbaceous species (thistle).</td></tr>
<tr><td rowspan="2">Crops for biofuel production. Crops destined to biofuels or liquid fuels obtained from agricultural products; they are classified into two groups:</td><td>Crops of oleaginous plants: those from which oil is obtained, and through a series of chemical processes that oil is transformed into biodiesel.</td><td>Girasol, colza, cardo, Jatrofa, soja, palma, etc.</td></tr>
<tr><td>Crops of alcoholic plants: those from which bioethanol is generated and through a series of chemical reactions in which said bioethanol participates, ETBE (ethyl-tert-butyl ether) is obtained, used as a gasoline additive.</td><td>Trigo, cebada, patata, maíz, remolacha, sorgo, etc.</td></tr>
</table>

Herbaceous crops and forest crops. We will focus on the main species for agricultural arable crops.

4.2. MAIN ENERGY CROPS



What is sought is the type of crop that best suits the characteristics of the soil and the conditions of the place, trying to obtain the highest profitability.

4.2.1. LIGNOCELLULOSIC AGRICULTURAL CROPS

SPECIES OF TRADITIONAL AGRICULTURE

Among these species are the annual plants that have traditionally been cultivated with the objective of using their fruits and seeds for other purposes (human or animal feed, industry, etc.) such as cereals or rapeseed, among others.

It is important to distinguish between winter and summer crops as their characteristics and especially the irrigation requirements will be important when assessing the suitability and profitability of crops. In certain places where water is available and the climate is adequate, the most promising summer species are corn and sorghum.

Cereals

Although there is a wide range of possibilities for new crops to produce biomass, cereals are one of the most appropriate for the production of biomass (for the production of heat or both heat and electricity) given the existing cultivation tradition.

All species of winter cereals are susceptible to be used in the production of energy (wheats, barley, triticales, oats and ryes mainly), although some will be more favourable than others for energy use. The triticales, oats and ryes are the best ones for the use of their integral biomass to produce energy because they are the species with the lowest harvest index (grain biomass/total biomass). The oats and the ryes have the advantage of being less demanding of nitrogen and, therefore, less expensive to produce.

Although it should not be forgotten that they are also more sensitive to bedding and less advisable in high productivity areas.

The cultivation system is the same if we talk about a grain production that if we speak of a biomass production, the collection being the only different element to take into account (harvest of the whole plant and subsequent packing). In this way, the production costs are similar to the traditional costs of producing cereals, although the harvesting of the biomass is more economically costly than the harvesting of the grain.

In a simple way it can be estimated that the prices of biomass of cereals should be close to half the price of grain of the same cereal. Cereals also have energy possibilities although they are cultivated for other uses because the waste such as cereal straws can be a supplement of income for farmers because they can be burned as solid biomass.

NEW SPECIES

Among the so-called new species for the production of lignocellulosic biomass are *Cynara cardunculus*, *Brassica carinata* and *Sorghum bicolor*.

THISTLE (*Cynara cardunculus*)

The thistle is a lively species very well adapted to the Mediterranean climate of dry and hot summers that can reach good productions for biomass: when the crop is established it can reach total productions superior to 18-20 Tm of dry matter per Ha and year.

The cultivation of thistle we can say that it enters into production from the second year, being able to remain in the same terrain an unlimited number of years, provided that a minimum of care necessary for its maintenance is carried out. In the cultivation of thistle one must bear in mind the consideration that the first year is of implantation, with a slow development since it comes from seed. Subsequent years later the plant re-springs from the remaining buds of the root neck and quickly forms a rosette of basal leaves thanks to the reserves accumulated in the root.

Brassica carinata

The *Brassica carinata* is a cruciferous plant although this one unlike others is not cultivated as an oilseed because the cake of the grain is toxic, and that loses much value to the seed. But it is an interesting plant for the production of biomass due to its high productivity, being less demanding than *Brassica napus* and integrating very well in the rotations, being more profitable than a year of fallow which makes it economically sustainable, since it has been shown that produces yield increases in subsequent crops, for example cereal.

Brassica carinata as a crop for the use of its biomass is well suited to fresh and intermediate dry land, with productions that are around 6-8 Tm/Ha of biomass. As for the cost of production, including harvesting and transport to the factory, it is around 50-70 €/Tm.

The cultivation of brassicas is perfectly integrated into the cereal rotation, improving the yields in the following cereals and allowing the reduction of the use of nitrogen fertilizers and phytosanitary products.

Scheme of rotation of crops for production of herbaceous biomass.

1 HEAD CULTIVATION FOR BIOMASS (BRASICAS) 1/6 year, 1/6 surface	2 CEREALS Humid weather: Wheat, barley Dry weather: barley, barley	LEGUMINOUS Plant

The harvest involves a series of different tasks: mowing, swathing, packing and handling. Different solutions have been studied regarding the collection method so that the biomass losses in the different operations are as low as possible and the mass yield is greater.

The harvest is made when the siliques begin to form and before the grain has been completely formed, since what is intended is a greater development of the vegetative part than of the reproductive part. It is important an adequate adaptation of the machinery for the collection of the vegetative part to achieve a maximum amount of biomass collected.

The mown biomass has an initial moisture content of 60-80% that can be reduced in the field up to 15% before being swarmed and packed.

The yields of *Brassica carinata* vary greatly depending on the collection technique with the following yields (source: ITGA Navarra): 7.000 kg biomass/Ha with mower, 4.000 kg biomass/Ha with mower-harvester (more approximately 1.100 kg grain/Ha) and about 2.200 kg biomass/Ha with harvester (and about 1.900 kg grain/Ha).

SORGHUM (*Sorghum bicolor*)

Sorghum is an annual species of the family of grasses of tropical origin. Among the varieties for crops for the production of lignocellulosic biomass, the most important is sorghum for fiber. The sorghum for fiber, with the limitations of temperature and need for irrigation, is one of the most interesting crops in terms of bioenergy production due to its possible double use: the production of the grain to obtain biofuels, and the rest of the plant (which can grow up to 4 m in height) for the use of biomass for thermal or electrical purposes.

The yields are very variable depending on the growing area; in the Mediterranean area very positive data can be obtained regarding the production of dry matter under demanding cultivation conditions (fertility, water availability and mild temperatures).

To obtain good yields, medium to good quality soils are needed, sowing to obtain 150.000 to 200.000 plants/Ha and irrigation of 7.000 m^3/Ha and year. Some studies carried out in Spain point to a productivity of 80 Tm/Ha and about 10 kg of sugar and 17 Tm of dry matter per Ha.

OTHER SPECIES WITH POSSIBILITIES

There are others rapidly growing energy herbaceous plants can be directly burned to produce heat and electricity. The most commonly used species are *Miscanthus spp.* and *Arundo donax* because, besides the high productivity, they are not demanding in edaphoclimatic conditions. Staiss and Pereira (2002) indicate that, in regions with good water conditions and solar radiation and high temperatures, yields of 32 t dry matter/ha/year of *Miscanthus* and up to 40 t dry matter/ha/year of *Arundo donax*. Brás et al. (2006) adds that the demonstrated high productivity of *Miscanthus* announces an increase in the area devoted to its production, especially in fallow land. On the other hand, despite the potential of *Arundo donax*, both productive and end-use, prudence in its adoption is necessary since this species reveals invading behavior in different circumstances, as it is mentioned in the literature.

4.2.2. CROPS FOR OBTAINING BIOFUEL

Globally, two classes of biofuels can be distinguished:

1. biofuels for compression ignition or diesel engines. The oil plants are used for the production of biodiesel, extracting the oil from their seeds, with the objective of replacing the diesel that is consumed in the transport sector.
2. biofuels for spark ignition engines. Bioalcohols are an alternative to gasoline, either as a total replacement element or as an element that improves their octane number.

OLEAGINOUS PLANT CROPS

A large number of plants can be used to produce biofuels provided that good agricultural and environmental practices are observed during their cultivation and that they do not compete with food.

With respect to biodiesel, although initially it was produced largely from sunflower oil and rapeseed oil, other crops were also adopted as raw materials, such as soybeans and palm (Rosa, 2008), although some showed higher productivity than others. However, other oil plants, less demanding in soil, humidity and climate, have proven to be better solutions for the use of poorer soils, such as jatropha curcas and castor oil. In addition, they have better productivity indexes than the first generation ctionalrops used for the production of biodiesel (Marques, 2008).

Rapeseed or sunflower are the traditional crops for obtaining biodiesel, although there are new crops that are being rapidly implemented.

CROPS FOR BIODIESEL (Ecas Project 2007)			
Conventional	Rape Sunflower Soy Palm	Alternative	Jatropha Thistle Castor *Brassica carinata*

SUNFLOWER

The most traditional crop is sunflower. Staiss and Pereira (2002) indicate that the new varieties of sunflower can reach yields of 2,5 to 4,0 Tm of seeds/Ha with an oil content of 40 to 50%.

The deeper the soil, the more development capacity the plant will have given that the sunflower has a pivoting root, which can reach up to 2 meters under favorable conditions, although most of the secondary roots develop between 5 and 30 cm deep. It will also depend on the management: in direct sowing, in strong lands or if the soil is compacted and root development is difficult, although the soil is deep the crop may have problems of implantation. In irrigation, it can be cultivated in first sowings or as second crop after a winter crop (barley, rapeseed, fodder, etc.). For these second harvests, sprinkler irrigation and direct sowing will favor that the crop can be implanted in the shortest possible time after the previous harvest.

The sunflower can start its germination when the temperature of the soil reaches 5 to 7ºC, but then the germination is slow, so it is considered that at least the temperature should be 10ºC. At higher temperature in the soil, the germination is faster and the loss of seeds is smaller. The proper planting depth is 3 to 6 centimeters. When deeper the number of plants that emerge is lower.

In rainfed crops, with water as one of its limiting factors, we must try that the planting is done in the first days in which its surfacing is feasible, to achieve the greatest possible development when the heats reach the strongest and the humidity is insufficient.

The usual sowing density is 150.000 seeds to sow 2 Ha in irrigated land and 3 Ha in dry land (84.000 plows/Ha in irrigated land and between 40-60.000 pts Ha in dry land).

The sunflower is a demanding crop in nutritious principles and thus, with extractions of nitrogen of 50 kg/Tm. 70-90% nitrogen is absorbed from 3-4 leaves until full bloom.

RAPESEED

The rapeseed is a plant of the cruciferous family that has traditionally been used for oilseed production. It is sown in fresh and fertile soils in climates not excessively cold and with a reasonable rainfall.

Rapeseed oil, which produces a high production of grain and produces an oil of excellent quality, is the most cultivated oilseed in the EU, with Germany being the main producer.

Rapeseed is a crop that can be planted both in dry and irrigated areas. In dry land you can have productions of 2.200 kg/ha while in irrigation you can reach 4.500 kg/ha. For these productions the key is a good implantation and reach the winter with some plants of good size (usually about 8 leaves) and a root length of 15 to 20 cm so that it can withstand low temperatures of up to -17ºC.

Rapeseed requires deep, well-drained soils with good structure. The preparation of the soil is similar to that of cereals. The main difference is that rapeseed by having a pivot root is more sensitive to deep compaction. It is also sensitive to crusting but planting with moisture avoids this problem.

The needs of fertilizer in rapeseed will depend on the productive potential of the land and its level of fertilizers, so it is recommended to perform a soil analysis of the plots and know the level of nutrients of these. As a general rule, we will apply to rainfed on 80-90 UF of nitrogen (30-40% in the bottom), 60 UF of phosphorus (in the bottom) and 60 UF of potassium (in the bottom). In irrigation, it will be necessary to increase these contributions by 15-20%.

A background fertilizer is a good help for the establishment of rapeseed, a very demanding crop with respect to phosphorus. Therefore it is recommended to make a fertilizer with a fertilizer NPK that provides the three macronutrients (for example, an 8-15-15) since rapeseed does not need much nitrogen for implantation, but needs it at winter.

Sulfur is an essential element for rapeseed, which we will apply in coverage along with nitrogen in quantities of 60-65 UF per hectare.

The first weeks of October would mark the limit for winter rapeseed plantings in Atlantic areas taking advantage of the first autumn rains in the spring to reach the rosette state before the first frosts. It is therefore possible to plant in these areas from the beginning of September to mid-October, but the sooner the better to ensure a good-sized plant at the beginning of winter and in any case ensuring the necessary humidity in the soil to facilitate its emergence.

In Mediterranean areas, autumnal rapeseed sowing begins in September and lasts until the last week of November, as there is no winter stop or risk of frost.

Sowing is one of the most critical times for cultivation, it is very important to get the soil right and apply the appropriate seed dose as the critical factor for a good development of the crop is a good installation of it (with a population of sufficient plant and distributed homogeneously). The seed dose to be used should guarantee a final population of plants between 30 and 40 per square meter, that is, in normal or poor dry land, densities of 4 kilograms of seed per hectare (between 65 and 75 seed /m^2) and in fresh dry and irrigation of 2,5-3 kilograms of seed per hectare (between 45 and 55 seeds/m^2).

In addition, the cost of seeds is high, especially in the case of hybrid varieties. Thus, the recommended dose of seed for non-hybrid varieties is 50 to 100 seeds/m^2 and hybrid varieties of 40 to 60 seeds/m^2 (the latter require lower doses because they have greater branching capacity). If there were problems with snails, this planting density could be slightly increased to offset the losses caused by these.

The distance between lines should be between 20 and 45 cm, while the ideal planting depth will be about 2 centimetres due to the small size of the seed.

To achieve maximum performance it is important that at the end of winter there is a maximum of 40 plant seed/m^2 distributed evenly in the field, because if there are more plants, they compete with themselves and the yield is significantly reduced.

Rapeseed is a very versatile crop compared to the planter to be used, being able to use both conventional cereal seeders or precision, which allow a reduction in the dose. It is types you can get a good implantation of the crop if the depth of planting is respected.

It can even be sown with a precision planter like the one used in corn. With this type of precision planter the maximum homogeneity of the crop is achieved and can reach high yields, of up to 5.500 kg/ha in irrigation of aspersion.

Within the varieties of rapeseed we find hybrids and no, more and less rustic, more and less precocious, of more and less high size, etc. It is important to analyse the specific needs before choosing the variety.

OTHER CROPS

Crops such as thistles or jatropha have been tried to replace sunflower crops, especially in soils with less water retention.

Thistle is a perennial plant with an active growth phase in autumn and spring and can produce 20 Tm of dry matter per hectare per year and approximately 2 to 3 Tm of seeds per hectare per year, with an oil content of 25% (Staiss and Pereira, 2002). In addition, as already mentioned, thistle can be cultivated with the dual capacity of, in addition to seed oil, it can also supply solid biomass as a raw material for energy production (Brás et al., 2006; Lourenço and Januário, 2008), giving interesting returns when compared to the cellulose plants.

Of the less studied oilseeds, **Jatropha** is the one that has generated more expectations due to the success obtained in countries such as India or China. However in Europe it is difficult to keep the plants viable during the winter, mainly due to frost.

As in any other crop, climate will influence the development of crops, for example, from one hectare of palm in tropical regions you get between 3.700 and 5.400 L of biodiesel, while if the crop is thistle in dry regions of Mediterranean climate is between 150 and 360 L and also between 9 and 13,5 Ton of dry matter.

CROPS FOR BIOALCOHOLES OR BIOETHANOL

Ethyl alcohol of vegetable origin or bioethanol is a chemical product obtained from the fermentation of sugars found in plant products (such as cereals, beet, sugar cane or biomass). It is obtained by fermentation of sugary raw materials with an initial alcoholic strength of 10 to 15%, being able to concentrate later by distillation until obtaining the so-called hydrated alcohol, 4-5% of water, or reaching the absolute alcohol after a specific process of dehydration.

Hydrated ethanol can be used directly in conventional combustion engines with slight modifications, and performance similar to that obtained in gasoline, if they are well regulated.

Absolute ethanol can be used in a mixture with normal gasoline to increase the octane number and eliminate the additives of lead in the super fuels. These fuels are known as "gaso-holes". Ethanol is used in mixtures with gasoline in concentrations of 5, 10%, and even 85%, E5, E10 and E85 respectively, which do not require modifications in current engines.

The raw materials used to produce this type of alcohol should be low-cost hydrocarbon products, either sugary or starchy type, susceptible to undergo a fermentation process directly, such as fructose, glucose or sucrose, or after a process of hydrolysis, as is the case with starch or inulin.

Crops such as **SUGAR CANE**, **SUGAR SORGHUM OR BEET AMONG** those of the first group and **CEREALS, CASSAVA, POTATOES,** among those of the second group, may be economically interesting in some circumstances for the production of fuel ethanol.

Approximately one litre of ethanol can be obtained from 2,5-3 kg of cereal grains, 10 kg of beet roots or 15-20 kg of sugarcane.

Through the cultivation of one hectare of irrigated beet 6.000 litre of ethanol can be produced, while if corn or sweet sorghum is grown only 3.700 litres are obtained, or if the crop is sugarcane, up to 10.000 litres are produced.

If the crop is dry land, one hectare of wheat would produce 880 litres, while the sweet sorghum would produce 700 litres (Project ECAS 2007).

As in biodiesel, production with traditional crops such as **CORN** is giving way to the emergence of new species with higher yields.

CROPS FOR BIOETHANOL (Ecas Project 2007)	
Conventional	Cereals (wheat, corn, barley ...) Beet Sugar cane
Alternative	Potato Sorghum saccharine Prickly pear

Frequently asked questions

1) Is it necessary to make important economic investments in a farm to produce energy crops?

No technological reconversion or economic investment is necessary for the start-up of energy crops. Although some have their own requirements and operating conditions, in general they constitute agricultural products that require common agricultural techniques and work among farmers as well as the use of conventional machinery existing in the vast majority of farms, without the need for large investments in specific machinery for cultivation.

2) Do energy crops impoverish the soil? Are they compatible with conventional crops previously in the agricultural fields or their subsequent planting again?

There are many species whose edaphic and climatic requirements are similar to the crops in retreat so that they can be grown on the land previously used by them.

In general, these are species that do not impoverish the soil more than other crops and allow easy recovery of the land to subsequently implant other crops.

3) Can they have a sustainable economic profitability?

Yes, provided that the farmer can obtain a long-term contract at a certain price and species compatible with the type of soil and climatic conditions are cultivated. For net economic margin for the farmer to be attractive, species that allow obtaining low cost are required (around 20 Tons per hectare of dry matter, that is, with less than 30% humidity). In addition, the location of the crop must be close to the consumer plant so that the crop is profitable (it is estimated that at distances of less than 50 km in order to reduce transport costs).

4) What opportunities do energy crops offer for the rural environment?

They can represent an alternative allowing the reuse of withdrawal lands or diversification towards new crops, favouring the creation of agricultural employment in rural areas through the development of new economic activities, contributing to the fixation of the rural population.

5) What are the environmental risks or impacts associated with these crops?

As a main environmental impact is the possible risk of potentiation of intensive monocultures and the use of pesticides and herbicides with the consequent environmental contamination but it can be avoided by choosing crops with low fertilizer, phytosanitary, irrigation water and fuel requirements to carry out the necessary agricultural work. And always choosing crops that do not pose a danger to the rest of the flora or is easily controllable; those species with easy propagation outside the cultivation area should be avoided due to their dissemination.

When it comes to crops for biofuel production, we must take into account that transformation into fuel requires a complex prior transformation that causes high pollution.

Work sheet 4.

ENERGY CROPS 1/2

__EXERCISE 4.1.__ Why do you think it is important that energy crops adapt as much as possible to the climatic and soil conditions of the place where they are being planted?

__EXERCISE 4.2.__ According to the established classification, the same energy crop can be classified into different groups depending on the criteria. Example: barley is a __traditional crop, terrestrial, herbaceous and for the production of biofuels, specifically alcoholic.__

Set the classification for each of the following crops by checking in the corresponding boxes in the table.

			THISTLE	POPLAR	RAPESEED	SORGHUM	SUNFLOWER	CORN
Depending on the kind of biomass	Herbaceous							
	Woody							
Depending on its tradition as crop in the region	Traditional							
	Alternative							
Depending on the environment where plant lives	Terrestrial							
	Aquatic							
Depending on the kind of biomass that they produce and its final use	Lignocellulosic biomass							
	For obtaining biofuels	Biodiesel						
		Bioethanol						

__EXERCISE 4.3.__ Indicate whether the following statements about energy crops are true (T) or false (F):

Statement	V	F
• They contribute to reducing dependence on the exterior for the supply of fuels, contributing to ensure a stable supply of local origin or near the area of use.		
• It is not important to look for a type of crop that adapts to the characteristics of the soil and to the conditions of the place where it is going to be cultivated because it can be solved with greater amounts of fertilizers, phytosanitary products and, irrigation water.		
• Energy crops must have high levels of biomass productivity and have a positive energy balance, that is, the energy they produce must be greater than the energy invested in their cultivation and subsequent transport to the transformation plant.		

Work sheet 4. ENERGY CROPS 2/2

	V	F
• *They have a neutral or positive balance in CO_2 emissions to the atmosphere. The amount of CO_2 emitted in the combustion was previously captured by the plants during their growth.*		
• *The management of energy crops is complex and requires techniques, work and machinery that involve large initial economic investments for the conversion to their cultivation.*		
• *The location of the crop should be as close as possible to the consuming plant to reduce transportation costs; for the crop to be profitable it is estimated that the distances must be less than 50 km.*		
• *The main environmental impact is the possible risk of potentiation of intensive monocultures and the use of pesticides and herbicides with the consequent environmental contamination.*		

EXERCISE 4.4. *Analyse the following table that shows the biodiesel and bioethanol yields of different crops.*

YIELD OF BIOETHANOL AND BIODIESEL OF DIFFERENT CROPS		
CROPS	LITERS of BIODIESEL/Ha	LITERS of BIOETHANOL/Ha
Palma	4.000-5.000	
Rape	900-1.300	
Soy	300-600	
Sunflower	600-1.000	
Castor	1.000-1.200	
Jatropha	800-2.000	
Cane		4.500-8.000
Corn		2.500-3.500
Sweet Sorghum		2.500-6.000
Switchgrass		3.000-7.000
Beet		2.500-6.000

What is the crop that gives the highest yield for biodiesel production? And for bioethanol?

Does that imply that these two will be the most recommended crops to cultivate? Reason your answer.

GLOSSARY

Acid rain: Precipitation in which water contains dissolved acids produced from sulfur oxides and nitrogen (SO_2, SO_3, NO, NO_2) emitted into the atmosphere as pollutants, usually from industrial combustion. Acid rain causes significant environmental damage to forests and soil.

Alternative energies: Energies obtained from sources other than the classic ones such as coal, oil and natural gas. Alternative energies are bioenergy, solar, wind, geothermal, etc. which are also renewable energies.

Anaerobic digester: Part where the most important part of the biogas formation process takes place; It is a gas resistant reactor where the decomposition of raw materials takes place in the absence of oxygen and biogas is produced.

Bioeconomics: Smarter way to use and conceive biological resources, converting renewable resources from land or sea into other products or bioenergy, for example by giving waste a "second life" by converting them into valuable resources thereby generating economic resources with the close of the production cycle. It is a way of preserving nature and biodiversity while generating new economic activities and income for farmers, forest entrepreneurs, fishermen, ... promoting employment, economic growth and therefore local development in rural areas.

Biodiesel: Biofuel produced from different raw materials mainly vegetable oils (such as sunflower oil and other oilseeds, rapeseed, soybeans and palm) but also animal fats or even algae.

Bioenergy: Energy derived from certain agricultural or forestry crops planted for energy purposes, and by-products, residues and wastes of agricultural, livestock, forestry and industries linked to these activities.

Bioethanol: Biofuel produced from sugar-rich plants such as sugarcane, corn, beets, wheat and sorghum.

Biofuel: All fuel - solid, liquid or gas - produced from biomass.

Biogas: Gaseous biofuel obtained through biochemical processes of anaerobic digestion from different residues and agro-livestock by-products and food industries mainly. It is also known as renewable gas and is very similar to what we know as natural gas in the sense that its main chemical element is methane CH_4.

Biomass: Biological mass or amount of organic matter produced in a certain area of the earth's surface being susceptible to being used as a renewable energy source, so it is sometimes used as a synonym for bioenergy and biofuel (especially solid biofuel).

Biomass energy: The one that can be obtained from organic combustible compounds obtained from organic matter.

Biorefineries: A new generation of refineries that, as expected, will produce not only thermal and electrical energy, but also transportation fuels and industrial products.

Biotransformation of energy: Use of biological processes to obtain products of energy interest, for example biogas from fermentation.

Carbon cycle: Term used to describe the flow of carbon on Earth (through the atmosphere, oceans, terrestrial biosphere and lithosphere), in various forms, including in the form of CO_2 (carbon dioxide).

Carbon dioxide (CO2): Colorless and incombustible gas that is a normal component of the atmosphere (0,03%) and is used by green plants through photosynthesis as a source of carbon and released into the atmosphere by both plants and by animals during the breathing process, but it is produced in large quantities during the combustion of different types of fuels (mainly from oil and coal), being highly polluting because it is one of the main gases responsible for the greenhouse effect.

Cellulose: main organic constituent of terrestrial plants; It is found in wood, associated with hemicellulose and lignin.

Circular economy: Resource utilization system where the reduction of the elements prevails, minimizing the production to the indispensable minimum, reusing the elements that due to their properties can't return to the environment and taking advantage of waste from different activities as raw material for energy production or other products. The circular economy aims to change the paradigm of producing, using and pulling the current linear economic model that could be coming to an end.

Climate: Average weather status or statistical description of the weather in terms of average values and variability during periods considered (30 years as defined by the World Meteorological Organization.

Climate Change: It is the total variation of the climate on Earth attributed directly or indirectly to human activity. The elevation of a few degrees in the annual average temperatures produces increases in the sea level, alteration of the ecosystems, increase of extreme atmospheric phenomena, phenological changes of the species, changes in the distribution of cultivation areas etc.

Cogeneration: Combined production of electromechanical energy (electricity) and thermal (heat) useful from a single source of energy or fuel.

Conservation: development of policies, laws, plans and actions to prevent and mitigate the alteration of natural ecosystems and therefore of the communities of species due to activities of human origin.

Consumption: The fact of using and abusing all kinds of natural resources, energy or processed products.

Chemical energy: That which is released or absorbed during a chemical reaction, such as during photosynthesis.

Dendromass: Raw materials of wood energy: Wood and biomass recovered in forests and trees and used to produce fuel.

Digestate: Waste obtained after biogas production as a byproduct of anaerobic digestion plants and serves as fertilizer that can be used in agricultural or forestry crops.

Electric power: It is the one that has a system of electric charges, which can be fixed or moving. That last one is electrical energy, which is what we use and is measured in watts.

Emissions: Is the release of pollution in the form of gases into the atmosphere in a specified area and period of time from industrial, domestic and urban activities, transport, production of electricity in thermal power plants and combustion derived from consumption of different fuels.

Emissions rights trading: system of marketable quotas for emissions of gases into the atmosphere, based on attributed amounts calculated from and on the emission reduction and limitation commitments to achieve environmental objectives that allow countries to reduce greenhouse gas emissions below the required levels, use or market the remaining emission rights to offset emissions from another source inside or outside the country.

Energy efficiency: Relationship between the energy product of a conversion process or a system and its energy input. The more efficient energy process, the less wasted energy losses exist.

Energy crops: Cultivation of those fast-growing plants that are planted for the purpose of harvesting for energy or as a raw material for obtaining other combustible substances.

First generation biofuel: Fuel produced from crops planted on purpose. Biodiesel, vegetable oils, bioethanol obtained from cereals and sugars found in other plant products, bio-ethyl-tert-butyl ether (ETBE) and biogas, belong to this category

Fossil fuels: Non-renewable fuels that come from the remains of living beings from previous geological times that have been formed during geological periods of time, that is, very long and therefore are non-renewable resources. They are coal, oil and natural gas and still constitute most of the energy sources consumed today.

Fourth generation biofuels: Fourth generation biofuels take the third generation a step further. The key is carbon sequestration and storage, both at the level of raw material and process technology. The raw material is not only adapted to improve process efficiency, but is designed to capture more carbon dioxide, as the crop grows. Fourth generation biofuels embody the concept of "bioenergy with carbon storage."

Gasometer: Biogas storage tank that is a tight and tight membrane, resistant to pressure, atmospheric agents, weather conditions and ultraviolet radiation. It can also serve as an anaerobic digester cover.

Global warming: Global warming is an increase, in time, of the average temperature of the Earth's atmosphere and the oceans, due to the human activity that has taken place since the end of the 19th century, mainly due to the CO_2 emissions that increase the greenhouse effect.

Greenhouse effect: Natural effect that allows the earth to have an acceptable temperature for the development of life (some gases that make up the atmosphere of the atmosphere, such as CO2, concentrate on the earth part of the heat that it emits once it is heated by the sun causing this heat to be returned to the earth) but it has become a problem due to the increase of those GHG gases of anthropogenic origin and the global overheating that they are causing.

Greenhouse gases (GHG): Gases whose presence in the atmosphere block solar radiation and heat, contributing to the greenhouse effect. The most important GHGs are water vapour, carbon dioxide, methane and ozone.

Geothermal energy: Heat energy that can be obtained from abnormally hot terrestrial materials (water, rocks). In general, the temperature of terrestrial materials increases with depth on a regular basis (geothermal gradient), but there may be specific points where there are high temperatures at less depth which can be exploited.

Hydraulic energy: Potential energy of water that can be used to move a turbine and generate electricity.

Hydraulic retention time: Term that is often mentioned in relation to anaerobic digestion systems to biogas production and determines how long the raw material must remain inside the digester to obtain optimum biogas production.

Hydrocarbon: Organic compounds formed by Carbon and Hydrogen.

Kilowatt: Unit of electrical power equivalent to 1000 watts. Abbreviation Kw.

Liquid biofuel: Fuel of biological origin that is used in its liquid form, such as biodiesel and bioethanol, and which is currently manufactured essentially from crops such as sunflower, palm, sugarcane, corn, rapeseed, soy and wheat.

Mechanical energy: It is what generates movement, and it can be of several types: kinetic if it is due to speed, elastic if it is related to the deformation of an elastic body, pneumatic if it is caused by compressing a gas.

Methanogenesis: Biological decomposition of biomass in the absence of oxygen, mediated by anaerobic microorganisms, with the final result of methane gas production.

Natural gas: A gaseous mixture of hydrocarbons among which methane is found in greater proportion. It is formed inside the earth and usually appears associated with oil, it is used as fuel for domestic and industrial uses.

Net carbon dioxide emissions: Difference between sources and sinks of carbon dioxide in a specific period and in an area or region.

Nuclear energy: Conventional energy due to a transformation of a mass of energy through nuclear fusion that can be used for electricity production.

Oil: Bituminous oily liquid of natural origin composed of different organic substances that is found in large quantities under the earth's surface and is used as fuel and raw material for the chemical industry. Different fuels are obtained from its distillation (Kerosene, diesel, gasoline, etc.)

Pellet: One of the solid biofuels used for power generation, in form of small particles made with dried, pressed wood and cutting remains.

Photovoltaic solar energy: Production of electrical energy from solar energy by means of photovoltaic cells that respond to the sun's light energy.

Primary energy: Energy that has not undergone transformation, such as wind kinetic energy or solar radiant energy. Photovoltaic energy: Electric energy obtained from light through photoelectric cells that respond to light energy by releasing electrons.

Pyrolysis: Process of decomposition of organic materials by heat in an oxygen-free environment; It is a method to convert biomass into biodiesel.

Quadgeneration: Combined production process of heat, electricity, cooling and CO2 resulting from biogas production processes. Modern biogas facilities can capture the CO2 that is part of the biogas resulting from the process to be used in greenhouses that need it for the photosynthesis of vegetables or in industries that use it in the manufacturing process (soft drinks, medicinal gases).

Raw material: Any biomass from crops, waste or by-products that is destined to be converted into energy, biogas or biofuels for transport.

Renewable energies: Energies from indefinitely renewable sources for being part of natural cycles and in opposition to those that come from fossil or mineral reserves or deposits. Renewable energies are solar, wind, hydraulic, sea and biomass.

Renewable resources: Resources that are regenerated by natural processes, so their use does not imply an irreversible decrease if the consumption rate does not exceed the setting-up rate. Renewable resources are agricultural and forestry products, among others.

Second generation biofuel: Fuel produced from cellulosic materials, crop residues and agricultural or urban waste. Bioethanol produced from cellulosic raw materials, bio-hydrogen, syngas, bio-oils, biomethane, biobutanol or synthetic diesel belong to this category.

Solar energy: Energy from the sun in two ways: radiant (which can be used for the production of electricity by virtue of the photoelectric effect) or thermal.

Sustainable development: Development that addresses current needs without compromising the ability of future generations to meet their own needs, bearing in mind that the exploitation of natural resources should not be above their ability to generate themselves.

Thermal energy: It is the energy that is produced in the form of heat or that is transmitted between two foci at different temperatures.

Trigeneration: Combined production process of three types of energy: heat, electricity and cooling energy that can be provided by cogeneration plants, providing the air conditioning of an entire building, or can guarantee the necessary cooling in an industrial process.

Third generation biofuels: Fuels that use production methods similar to those of second generation, but using energy crops specifically designed or adapted as raw material to improve the conversion of biomass to biofuel. An example is the development of “low lignin” trees, which reduce pretreatment costs and improve ethanol production.

Wind energy: Wind kinetic energy, which can be used to move the blades of a wind turbine and produce electrical energy.

GUIDELINES FOR THE VIABILITY STUDY OF THE IMPLEMENTATION PROJECT OF A BIOENERGY INSTALLATION

RURAL BIOENERGY

It is necessary to carry out an analysis of the technical and economic viability before the execution of a bioenergy exploitation project that analyses the technical conditions of the installation, its location and the quality and supply of raw material to make it possible and profitable.

This analysis ideally involves the following stages (although not all projects involve the development of all of them):

1. POTENTIAL BIOMASS STUDY.

A fuel supply must be guaranteed for which we must check the sufficiency or lack of material from waste so that in the negative case, take into account other alternative sources of biomass raw material that complement the amount of resource necessary for the operation of installation.

For this we will take into account the production of raw material from waste (quantities, specific types and location of origin):

- Agricultural activities.
- Livestock activities.
- Agri-food industry activities.
- Wood and furniture industry activities.

Once the biomass sources existing in the farm itself and / or in the area most immediately next to it have been studied and the amount of biomass generated is known, we need to apply the different factors and conditions that restrict the use of a part of the raw material to reach a final amount of biomass really usable with the technical and human resources available. Finally, a factor of availability is applied, taking into account the possible uses with which it would enter into competition or current uses of this waste.

It is essential to carry out this study before the sizing of the installation based on its quantity and type, since otherwise the plant can be oversized being forced to supply it with distant resources that have an impact on the viability of the project.

2. STUDY OF BIOMASS CHARACTERISTICS.

The process of energy use of waste as a biomass raw material requires knowledge of its characteristics as a fuel, in order to size the equipment to be used and optimize its process operating parameters and ensure optimum product quality.

The **energy analysis** indicates the heat capacity of the fuel, however it is essential to know other parameters to predict its quality and suitability. The most important parameters that are taken into account in the evaluation of a biomass are:

- **Moisture content**. The moisture content is decisive as it influences the pretreatment to be carried out, making the process more expensive and slowing down, also conditioning storage needs as well as reducing the energy content of biomass.
- **Volatile content, fixed carbon and ash**.
- **Elemental analysis:** Contents in C, H, N, S, Cl, O.
- **Fusibility and mineralogical analysis of ashes.** They determine the tendency to the formation of slags that decrease the performance of the equipment.
- **Granulometry.** This affects the need to install crushing equipment.

3. LOGISTICS: TRANSPORT AND LOCATION.

As a result of this part of the study, the location of the points with maximum biomass concentration and the most optimal collection and transport of biomass will be obtained, analysing the needs and possibilities of storage and the costs of biomass placed at the plant.

Collection, transport and pretreatment systems. First of all, the most appropriate collection systems and biomass pretreatment systems are studied, studying for example the chipping, grinding, drying and densifying needs required by biomass in order to achieve a suitable raw material for the installation and that at the same time can improve economic returns. These activities should be mechanized as much as possible in order to reduce costs.

As regards woody biomass, the machinery to which the study is directed by the reduction of associated costs is the collection and densification machinery used before transport to the place of use or second transformation, while for herbaceous plants, the most important aspect It is the reduction of losses of the vegetative part that occur in the processes of mowing, spinning and packing.

In the pretreatment, some aspects that can cause some problems in treatment and handling equipment have to be considered (such as filling in the equipment, formation of vaults in silos and hoppers, fermentation of the biomass piled up, losing part of its calorific value or the increase).

Evaluation and selection of the best locations. The objective is to evaluate all possible locations of the biomass plant from the point of view of distances, time and transport costs. The tools used should consider a series of fixed costs and variable costs (term of distance-dependent). Fixed unit costs are associated on the one hand with loading and unloading operations in which time, human resources and fuel are consumed. The personnel and fuel costs of this process will be calculated for a full load of the transport unit. The variable costs associated with the total distance necessary to bring all the biomes to the point are those due to the fuel consumed, human resources and vehicle maintenance.

The estimation of the local potential demand for thermal or cogeneration applications will allow: quantifying the percentage of biomass that could be consumed in the biomass contribution area. Considering the potential demand of biomass consumers, it is possible to estimate which are the most recommended energy products for the analysed area: Electricity, heat or solid biofuels.

4. CHOICE OF THE TECHNOLOGY.

The process and technology that best adapts to the nature and conditions of the available biomass must be determined to optimize the yield that will depend on biomass factors (quantities and characteristics) and final use of energy and energy needs to be satisfied with its use.

We must be aware of the existence of new technologies and the improvements of existing ones and know if they are incorporated into our project.

The expenses and income of the investment must be considered: cost of purchase, collection and transport of biomass, personnel costs, consumed electricity, operation and maintenance costs of the plant and insurance and unforeseen costs as well as income (cost of final product sales).

5. IMPLANTACIÓN DE INSTALACIONES DE APROVECHAMIENTO ENERGÉTICO.

At this stage, the most appropriate technology installation project will be launched, being essential to have measures for proper operation.

Co-funded by the
Erasmus+ Programme
of the European Union

RURAL BIOENERGY: Training Plan on Bioenergy for the agri-food sector

PROJECT 2017-1-ES01-KA202-038057