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Renewable Energy for Smart Growth and protected Environment

Biomass energy

A practical guide to the use of biomass

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R·A·R·I·S
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THE CONTENT

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ABBREVIATIONS AND THEIR MEANING

RES - Renewable energy sources

ROI - Return on investment time

ICT - Information and communication technologies

MSW – Municipal solid waste

RDF – Fuel from waste/Derivative fuel

AF – Alternative fuel

TRF – Waste tire fuel

GHG – Greenhouse gases

CHP - Cogeneration plants for combining the production of heat and electricity

PM – polluting particles in the air, PM 10 (10 microns and less), PM 2.5 (2.5 microns and less)

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INTRODUCTION

1. IMPORTANCE OF ENERGY IN CONTEMPORARY WORLD AND TRENDS

Along with water, energy is one of the two most important resources that are crucial for the current and future survival of the human community. It may sound a bit scary, almost cataclysmic, but everyday life confirms that without one of these two resources, there can hardly be any sustainable development of society or even preserving of the existing state of the art. Energy has always been a significant factor that ensured progress, starting with very basic use for food preparation, light and heating, until today where there is NO activity that is feasible without more or less energy. The consumption of this key resource began to grow exponentially with technological development in the 17th and 19th centuries, especially after the First Industrial Revolution, where energy began to be used extensively in the mass production of goods for an increasingly demanding and growing markets. Consumption is proportional to the level of industrial development, but also to the level of living standard. From 1965 to 2021, consumption in some countries increased up to 500 times (Oman), in a number of developing Asian countries ten or more times, while in a number of very poor countries it even fell by 50%, due to reduced industrial activity (Syria, Gabon, North Korea...) or the reductions are the result of the introduction of more efficient technologies and strict energy efficiency programs (Great Britain, Denmark, Luxembourg...).

During the last twenty years, the demand for electricity has been growing rapidly due to efforts to reduce the impact on climate change, i.e. because of increasingly strict measures for the introduction of decarbonisation, i.e. industries that do not emit or have a significantly lower emission of CO_2, being it the main cause of the global warming. The consequences are already clear to everyone, because the incremented average temperatures cause a change in the movement of air masses and water flows, which results in extreme climatic phenomena, large droughts throughout the year, and on the other hand, huge amounts of precipitation in a short time, even at the time of the year when there has never been such climate turmoil. Electricity is perceived as the cleanest form of energy that is not polluting the environment, although this is must not always be the case. Take, for example, the production of electricity from thermal power plants, where large amounts of polluting gases, especially CO_2 and PMs are emitted, even when the installations have very complex and very expensive air purification systems. At the same time, the use of hydro or nuclear energy are driving controversies. Large hydroelectric plants do not emit CO_2, but have a great impact on the microclimate, conditions on groundwater, on habitat and biotope and also at the social level when entire settlements and infrastructure are moved from areas where reservoirs are formed. Nuclear power plants are potentially at very high risk due to the even the smallest possibility of a nuclear accident and/or due to the demanding storing of nuclear waste.

The events from recent years have only brought up all these issues to the fore front, particularly the conflict in Ukraine, which resulted with massive displacements and huge disruptions to the food and energy supply chains, therefore some almost forgotten capacities for dirty fuels, primarily coal, are resurrected by force of circumstances and returned to production.

For all these reasons, the whole world, and especially the European Union, has been trying for a number of years to introduce programs aimed at producing clean energy in sufficient quantities, aiming at sustainable development goals (RIO process, Kyoto Protocol, Green Agenda, Fit for 55).

2. WHAT ARE RENEWABLE ENERGY SOURCES

Renewable energy sources (RES) are sources that are renewed at least the same rate at which they are exploited. Everything in nature what could be renewed is done spontaneously and without side effects, thus RES are considered to be clean energy and the right choice for solving energy needs without polluting the environment with no, or very little, impact on climate. Unlike RES, non-renewable resources are depleted over time and cannot be renewed, at least not on timescales comparable to our understanding of time. Non-renewable energy sources are all fossil fuels (coal, oil, natural gas), for example, because they cannot be renewed even during the time that was sufficient for the creation of human civilization.

Renewable energy sources include:

The energy of water is the energy of rivers, the energy of waves and tides. It has been used to run mills or any other installations that require mechanical energy, threshing machines, saw mills, weaving mills... Since the 19th century, the production of electricity has emerged and since then, water is one of the most common way of using energy sources that are constantly renewed.

The energy of the sun is the energy that our star radiates to the earth's surface and is of both heat and light nature (although they are of the same, electromagnetic origin, but in different spectrums of radiation). This is also a form of energy that has always been available. In the beginning, the sun was only used as a thermal source, for heating homes, for boiling water and in very early stage to dry and preserve the food because, in addition to heat, the sun also radiates ultraviolet rays, which are excellent disinfectants, thus very good for preserving the food. For this reason, the sun is used to dry meat, plants and plant products. It was only in the 20th century when it was discovered that, when crystallized silicon is exposed to the sun, it causes electric voltage on its ends. This phenomenon is widely used today to make photoelectric panels that generate electricity.

Geothermal energy is the energy of the earth which is a huge heat reservoir. The earth radiates its own energy and the miners know this best because the temperature in the pits is much higher than on the surface. The earth is a great generator and this feature was used, above all, for balneological and health purposes. Each spa utilizes warm water from depth. Thermal waters, however, can be used for the production of electricity, for heating swimming pools, residential areas, for heating roads and streets (Iceland, which is all resting on geothermal springs, uses them abundantly for exactly these purposes), greenhouses and fish ponds. However, geothermal energy is not used only for heating, but for also electricity production and can be put to work with the heat pump technology for both heating and cooling.

Biomass - Energy obtained from burning plant residues, using bio gas as a product of decomposition of plant mass and from bio fuel (fuel obtained from processing high oil content plants). Biomass is the oldest form of renewable energy since the humans used wood for heating, to prepare food and as a source of light ever since. Woods grow, so if used carefully, it will always be there. Biomass are both plants and residues from agricultural production and in general, all biological material that can be used as fuel. This is the primary way of using biomass (straw, residues from harvests, residues from vegetable crops, dry branches and plants, etc...). Biomass could be collected from special energy plants that are grown only for this purpose (fast-growing willows, for example). Today, biomass is commonly available in shape of pellets, compressed plant residues that provide uniformity and easy way to use it as a fuel.

Wind energy - Wind is a result of the movement of large air masses in the earth's atmosphere, due to climatic, thermodynamic phenomena, differences in temperature and air pressure above the earth's surface. Wind occurs occasionally and we cannot precisely nor predict with certainty when it shall blow, albeit it was also used as a source of energy. In the beginning, it was a driving force for ships with sails which were energy "catchers", and later on, as a driver for mills and everything that could be powered by external energy (water pumps, saw mills...). The energy that was initially used to propel vessels is now largely used to generate electricity with the help of wind generators.

3. WHICH ARE THE ADVANTAGES OF USING RENEWABLE ENERGY SOURCES

Renewable energy sources are available in some form everywhere and can be exploited in any place, immediately and without the need to transport any fuel. This means that the infrastructure for exploiting energy from renewable sources is more compact, simpler and less demanding. Large facilities such as large storage and/or reversible hydropower plants or facilities for the massive use of geothermal water, such as exist in Iceland, for example, are not considered in this publication.

The energy security status is much more favourable when it comes to dispersion of energy sources on smaller units, rather than large energy installations, with the capacity to overwhelm significant consumption. Failure of a small plant shall not jeopardize the power system, while failure of a large power installation leads to very serious problems in the energy production and distribution.

From purely technical perspective, the generation of energy in small plants provides distribution throughout the electrical grid at a lower voltage, which reduces losses in energy transport and makes it more efficient.

The price of energy production from renewable sources has a downward trend and on the other hand, the market price of energy has a tendency to increase, which justifies investments in RES.

The green economy, and therefore the industry of renewable energy sources, is, in addition to ICT, the fastest growing industry, since the transition to RES requires development of new technologies and considerably greater production of equipment and services in this particular niche, so the benefit is twofold, on the one hand energy is significantly cleaner and safer to use than the one from conventional sources and on the other hand, the level of energy security is increased and the dependence on other sources and/or energy providers has been reduced. Finally, the price of energy production from renewable sources is falling down because of the number of equipment manufacturers increases, thus the equipment becomes cheaper.

4. WHICH ARE THE CHALLENGES IN USING RENEWABLE ENERGY SOURCES

The biggest challenge in using energy from renewable sources is that the two most popular and easiest to exploit, wind and solar energy, are of such a nature that they are not produced continuously. Energy from those two sources is generated when it is available, that is, when there is sun or wind, which is predictable only to a certain extent. The electric power system, roughly speaking, rests on three key pillars: the producer, the distributor and the consumer. Energy distribution is carried out through the electrical distribution grid, which, in order to operate in an optimal mode, must have a constant load. An analogy could be made with water pipes, where also must be water all the time. Otherwise, air can enter the pipe and reduce the flow, or impurities can accumulate in the pipe due to stagnant water, which reduces flow rates.

In order to ensure the optimal load to the grid, more or less the same amount of energy must flow through it, for which we need to have uniform or harmonized consumption and production. This requires energy contingency that will be introduced to the grid when lacking sun or wind. That additional energy is the, so-called "balance energy" and must be provided in whatever way. So far, the grid operator is required to acquire balance energy, in accordance with the regulations both in Serbia and Bulgaria. However, in the future, most likely part or all of the obligation will be transferred to energy producers from renewable sources, which will make investments more expensive and less attractive, at least for large systems because small ones shall be exempted from it, in whole or in part.

It is also necessary to secure environmental safety with no impact on the environment (this especially applies to small, run-off hydroelectric power plants and large scale installations on biomass)

Although energy from renewable sources is cheap, the system must be regularly maintained (cleaning the panels, pruning trees so that they do not cast a shadow on the panels, checking the fluid in the solar collectors, checking the fluid in the heat pump system, maintaining the channels and catchment at the hydroelectric power plants, cleaning the stoves and chimneys in case of biomass stoves...) and replacing parts that exhausted their life span (accumulators, for example).

BIOMASS ENERGY

5. WHAT IS BIOMASS, ITS FORMS AND ENERGY POTENTIAL

Biomass includes matter, of plant or animal origin, that can be used as a source of energy or for industrial production.

Advantages and flaws of using biomass: forests and agriculture

	Energy efficiency	**GHG**	**Air quality**
	Combustion in small installations, including households		
Advantages	High conversion efficiency with modern combustion technologies	Lower than when using fossil fuels	-
Flaws	Older furnaces have low conversion efficiency. Heat is not always used efficiently.	-	High emissions of polluting gases in older furnaces
	Combustion in medium-sized plants, including in buildings		
Advantages	High energy conversion efficiency	Lower than when using fossil fuels	-
Flaws	-	-	Emissions are lower than with small stoves, but higher than when using natural gas

	Combustion in medium-sized furnaces at high temperatures		
Advantages	High energy conversion efficiency	Lower than fossil fuels; Huge GHG reductions, especially in CHP plants	Better emission control
Flaws	-	-	Higher level of emissions than when using natural gas
	Hydrolysis and fermentation		
Advantages	-	Large GHG reductions in cases of integrated processing and with low use of fossil fuels	Biofuels have low GHG emissions when used as fuel in vehicles
Flaws	Biomass utilization rate is only 50%	-	-

Biomass is considered a renewable source of energy since it is physically renewed by growing of the next generation of plants. Although, when extracting energy from biomass (regardless of the applied technology) carbon dioxide (CO_2) is released, it is considered that biomass is in fact CO_2 neutral because plants use CO_2 for photosynthesis and growth, thus there is no net yield and such, no net increase in concentration of this gas in the atmosphere.

There are several forms of biomass:

A. Solid biomass

- Wood biomass (forest wood for firewood, residues and waste from sawing, grinding, planning, etc.).

- Residues and waste from agriculture (straw, corn stalks, stalks, seeds, husks, etc.).

- Animal and human manure.

- Biomass from municipal waste (the so-called green fraction of household waste, biomass from parks and gardens from urban areas, sludge from waste water collectors, etc.).

B. Liquid biomass

Liquid biomass or biofuels can be classified into two subgroups: bio-alcohols (such as bioethanol) or bio-oils (such as bio-diesel and pure vegetable oil) and can be used in internal combustion engines or burned in boilers.

There is a classification of biofuels according to technologies and raw materials from which they are obtained:

• **First generation biofuels** - The basic raw materials for the production of first generation biofuels are most often cereals and seeds, some of which are more suitable for the production of bioethanol and others for biodiesel. The first generation of biofuels are composed of sugar, starch, vegetable oil and animal fat and are extracted using conventional technologies.

• **Second generation biofuels** - Second generation biofuels rely on practically the same raw materials as first generation biofuels, but new processing technologies have been and are still being developed. These are largely biofuels produced from organic waste residues, from agricultural production, industry, catering or municipal waste.

• **Third-generation biofuels** – Third generation biofuels are based on algae, which are believed to provide at least a tenfold yield of biomass per hectare.

BIOETHANOL is produced from potatoes, sunflowers, corn and similar biomasses and is mostly produced and used in Brazil.

BIODIESEL is the commercial name for methyl-ester obtained by esterification of unsaturated fatty acids and alcohol in the presence of Na-methylate as a catalyst. High fatty acids are oils and fats of various origins, and the alcohol in this case is methanol. The methyl-ester made from rapeseed oil is most often denoted by the acronyms MERU or MER, while the methyl-ester of sunflower oil is denoted by the acronym MESU.

Tests have shown that diesel engines powered by biodiesel have significantly lower smoke and particle emissions. The emission reduction is on average about 47%. Lower smoke and particle emissions are achieved by using a mixture of conventional diesel fuel and biodiesel.

Biodiesel is economically cheaper than commercial fossil fuel, and, ecologically is incomparably healthier and more profitable.

C. Biogas

Biogas is obtained from anaerobic decomposition or fermentation of organic matter (with the help of microorganisms in an environment without oxygen) and can be obtained practically from any biomass. Basically, biogas is a mixture of several gases, where methane is the most dominant. The residing solid waste can be further used as biofuel or as fertilizer.

Today, biomass is the most important renewable energy source in the world, slightly less then coal, oil and gas, providing around 10% of the world's total primary energy consumption. About 85% of the energy obtained from biomass is forest biomass.

Technically available biomass is sufficient to satisfy the total current energy consumption in the world, and even the one predicted in 2050.

By burning biomass, heat is obtained, which until recently was most often used for heating, cooking or boiling water. In this century, biomass has also been used for the production of electricity. Biofuel, from converting biomass into a liquid state, as well as biogas, obtained by breaking down different bio-waste into a gaseous state, can also be used for energy purposes.

Biogas represents a mixture of gases, consisting of 50 - 70% methane (CH_4), 25-45% carbon dioxide (CO_2) and small amounts of water vapour 2-7%. In addition, biogas also contains other gases such as hydrogen sulphide, oxygen, nitrogen, ammonia and hydrogen, but in a much smaller proportion.

Materials whose decomposition creates and from which biogas can be exploited are:

• Manure

• Organic waste from the food industry

• Organic waste from the slaughterhouse industry (animal waste)

• Municipal waste waters and waste water from the food industry

• Municipal solid organic waste

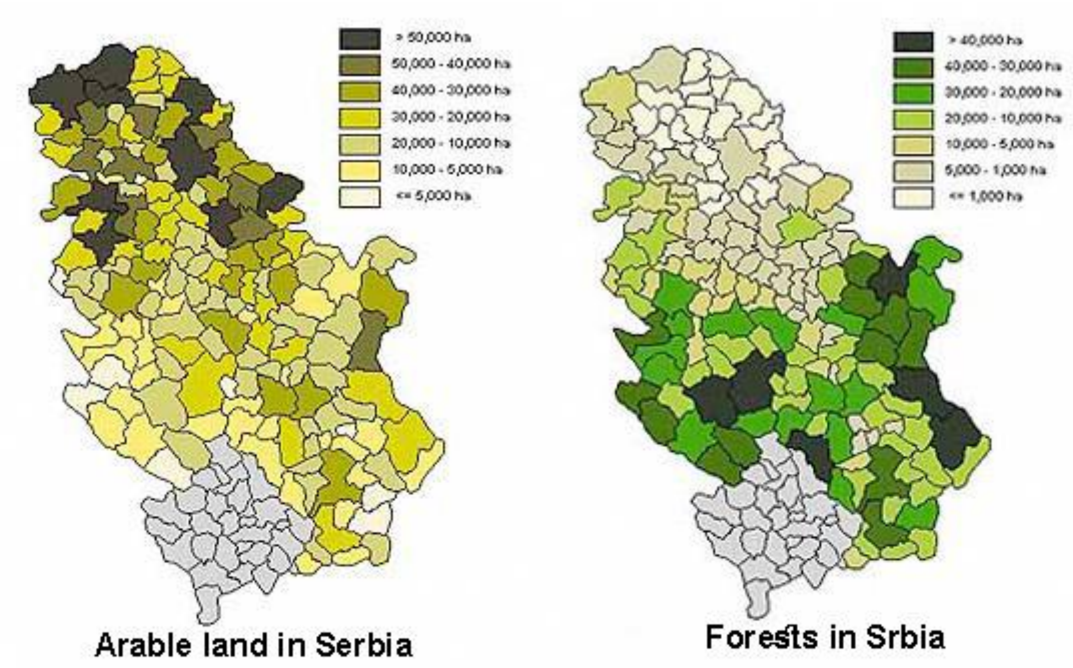
• Plants grown specifically for the needs of the biogas plant (most often silage)

Aerobic fermentation breaks down organic matter into carbon dioxide, while anaerobic fermentation produces biogas dominated by methane. Methane is a fuel gas, and the goal is to produce it for energy purposes. The process of anaerobic decomposition (fermentation) is widespread in nature, wherever anaerobic conditions and anaerobic bacterial species exist. Their composition depends on organic sources of material (substrate) and specific conditions of the decomposition process (primarily temperature and pH level).

Biomass potentials

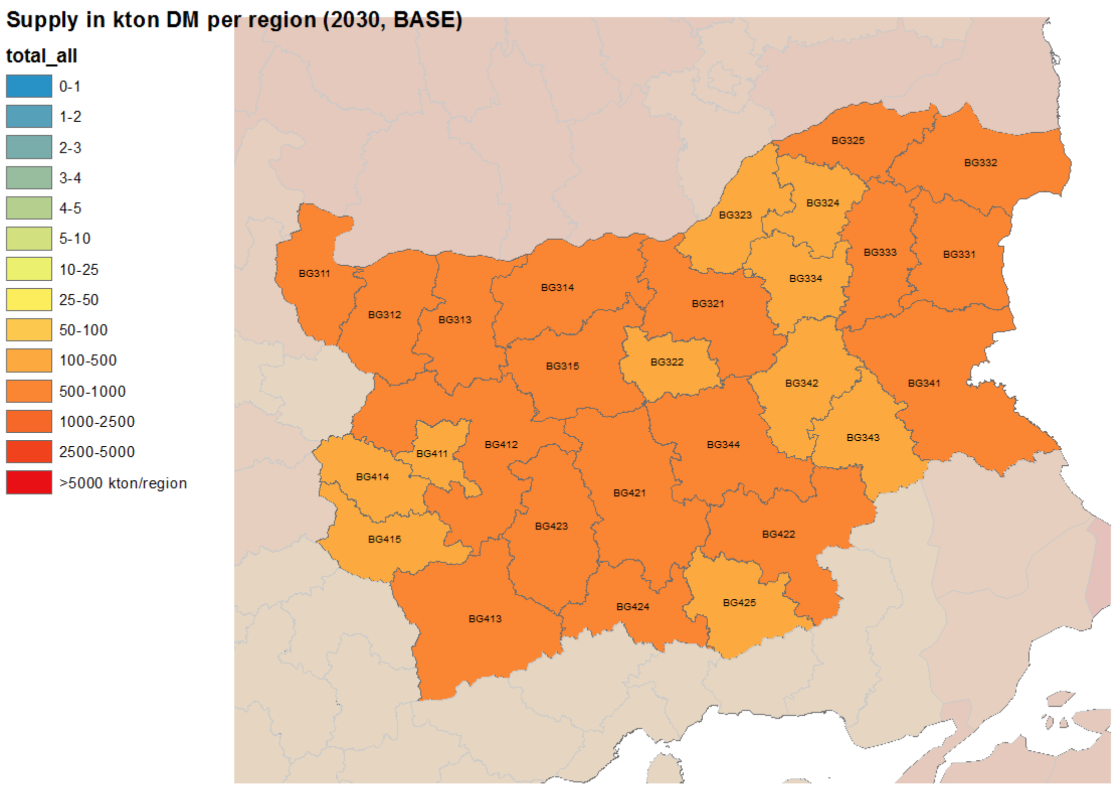
Biomass in Serbia is not evenly distributed. Forest biomass is more prevalent in the southern - hilly parts of the country, while agricultural biomass is more prevalent in the northern - plain parts of the country.

Forests in Serbia cover an area of about 2.25 million ha, which represents about 29.1% of the total territory of Serbia. One large region in the east of Serbia, in the municipalities of Majdanpek (over 80%), followed by Kučevo, Žagubica, Despotovac, Bor and Baljevac (all with 41-60%). Another large forest-rich region is located in the southwest of Serbia, and consists of the municipalities of Prijepolje (over 80%), Priboj and Kuršumlija (61-80%) and several neighbouring municipalities with a share of forested area between 41 and 60% of the municipality's territory. Serbia is considered a medium wooded country. According to the National Forest Inventory of the Republic of Serbia from 2009, the total area of forests



in Serbia is 2,252,400 ha, which is 29.1% of the total area of the territory of Serbia. Of that, 1,194,000 ha or 53% are state-owned, and 1,058,400 ha or 47% are privately owned.

Serbia's forest cover (29.1%) is close to the world's average, which is 30%, and is significantly lower than the European one, which tops at 46%. Forest coverage in Serbia is similar to that of Romania (28.0%), Spain (28.8%), France and Greece (27.9%) and slightly lower than Bulgaria (34%). The increase in forest coverage compared to the reference year



Total biomass potentials in Bulgaria

of 1979 is 5.2%, which certainly had a positive impact on the state and quality of the environment as a whole. The area of forests in Serbia in relation to the number of inhabitants is 0.3 ha per inhabitant.

Bulgaria is richer in forest biomass and this provides exceptional opportunities for its commercial use.

Data on forests in Bulgaria for 2019:

- 3,789,195 ha under forest (about 34% of the country's territory);
- Over 680,500,000 m^3 of total volume;
- 14 million m3 of annual growth;
- 8,007,915 m^3 per year, the amount of growth of forest wood
- 4,095,423 m^3 of firewood

If we want to use biomass for the production of electricity, we must first choose the appropriate technology that will make the most of its energy potential. In CHP plants (cogeneration production of heat and electricity), the total degree of energy utilization of biomass can be even higher than 85%, while in conventional plants for the production of electricity, the utilization factor of biomass (or any other fuel) practically cannot be higher than 30 - 40%.

For individual use, pellets are the optimal solution. By the way, pellet is a high-calorie renewable biofuel, which is obtained by grinding, drying and pressing sawdust or agricultural residues. Biomass that is sufficiently dry and fine shredded is then introduced into a device for pressing into pellets.

The advantage of pellets is that its energy value is higher than coal and it has a high calorific value (between 15MJ/kg and 20MJ/kg), and is suitable for automatic burning process as it burns at an even temperature, without oscillations during combustion. Pellet energy utilization is 95%, while it does not exceed 75% for other types of firewood. The importance of heating or for energy production/conversion.

Pellets made from agricultural residues are very suitable for commercial use, especially considering the quantity and availability of this biomass and its high calorific value.

Basic characteristics of agricultural residues

Agricultural residue	Moisture during harvest, [%]	Cap thermal power, [MJ/kg]
Weak wheat straw	14-20	17,2-17,6
Strong wheat straw	14-20	17,2-17,6
Residues from other cereals	14-20	13,8-14,2

Corn stalks	40-60	16,7-18,0
Corn ear and leaves	30-55	16,7-18,0
Residues from cutting vines	45-55	18,0-18,4
Leaves and twigs when cutting an olive tree	50-55	18,4-18,8
Remains of fruits	35-45	18,0-18,4

6. TECHNOLOGIES FOR THE PREPARATION OF BIOMASS

Biomass preparation includes all the activities that need to be carried out in order to collect biomass and prepare it for exploitation in order to:

• Optimization of the process, the volume of fuel manipulation at the plant itself, automated fuel dosing process;

• Increasing the specific energy density of biomass and thus reducing the required storage space and

• Cleaning biomass from debris (stones, soil, sand, metal parts, etc.)

Shredding the forest biomass

Forest biomass can have a whole range of shapes and sizes, from wood dust created when cutting wood, to pieces with a diameter of 50 cm, so it needs to be shredded and homogenized:

• breaking into pieces of 50-250 mm,

• cutting into pieces of 5-50 mm,

• by spraying/pulverizing into particles up to 5 mm.

Shredding is done in shredders, the devices that are preparing biomass for transport and drying. The shredders can be stable when they are in a warehouse or part of the dryer, or mobile when the biomass is treated at the place of origin. This reduces the volume of biomass and facilitates its burning because the surface area of the fuel material increases. The most common types of shredders are disc and drum. The disc chopper has a massive disc with a diameter of 600-1000 mm with two or four blades, while the thickness of the chips of biomass can be changed by adjusting the gap between the blades. These machines produce chips of fairly uniform shape and dimensions

For the production of pieces of biomass whose dimensions are less than 5 mm, fine mills are used that contain a large number of blades placed on a drum. After grinding, the biomass is passed through a stationary mesh ring/sieve using centrifugal force, and the size of the piece produced depends on the size of the sieve opening.

Mobile shredder

Characteristics of different types of shredders

Size	Production, m^3/ha	Diameter of used biomass - cm	Feeding	Motor power in KW
Small	3-25	8-35	Manually, crane	20-100
Medium	25-40	35-40	Crane	60-200
Big	40-100	40-55	Crane	200-550

The hammer mill has a high-speed rotor with tools for breaking and shredding the biomass. This mill has a very robust construction, but it is much more sensitive than shredders to any metal pieces that may enter with the biomass.

Preparation of waste wood biomass

Waste wood biomass is a very attractive and cheap source of energy for large energy plants, so it has been receiving a lot of attention in Europe, lately. Waste wood biomass is primarily residue from the wood processing production, various types of pallets, waste furniture, waste construction carpentry and all other wood products that can be grounded. In addition, the use of waste as a raw material is a new paradigm of the circular economy aiming at using all materials that have passed their life span or basic purpose of use, and can be used for a new cycle of production. Pieces of this type of biomass can be of very different dimensions and of different quality and they can contain different ingredients that, when burned, can have a harmful effect on the environment. That is why it is necessary to take into account the choice of burning method and technological measures necessary to prevent harmful effects.

In Europe, the wood waste is classified into several groups:

Q1: chemically untreated wood,

Q2: bark,

Q3: wood containing a halogen-free binder,

Q4: surface treated wood,

Q5: wood treated with resins

Q6: impregnated wood,

Q7: wood containing halogens and plastic materials.

The categorization from Q1 to Q7 was done according to their harmful impact, with the last group being the most dangerous. In addition to the above, waste wood biomass can contain many impurities (most often metals) that significantly affect the technological process of combustion. After shredding the biomass, metal impurities are removed using a magnet and other impurities are separated by sifting through 10 mm sieves, because it is assumed that the largest percentage of impurities is below this granulation. After this sieve, the biomass enters the separator of non-magnetic metals and further to the storage. The production of such integrated plants can be up to 100t/ha.

Baling biomass

The baling process most often refers to biomass from agricultural residues. Baling increases, the energy density of biomass and facilitates handling. In the case of energy plants, such as miscanthus, this process represents the only and basic operation because the plant is grown only for energy purposes. The quality of fuel (biomass) can also be improved if baling is carried out after drying in the field, because then the concentration of water-soluble elements, such as potassium and chlorine, which adversely affect the combustion process, is reduced. Depending on the machinery, different shapes and sizes of bales can be found: small square, cylindrical, large square and compact.

Baling forest waste biomass before transport is the most economically profitable way of manipulating this type of biomass. Which is later further crushed and prepared for commercial use.

Baling of forest biomass

Pelleting, briquetting and biomass torification

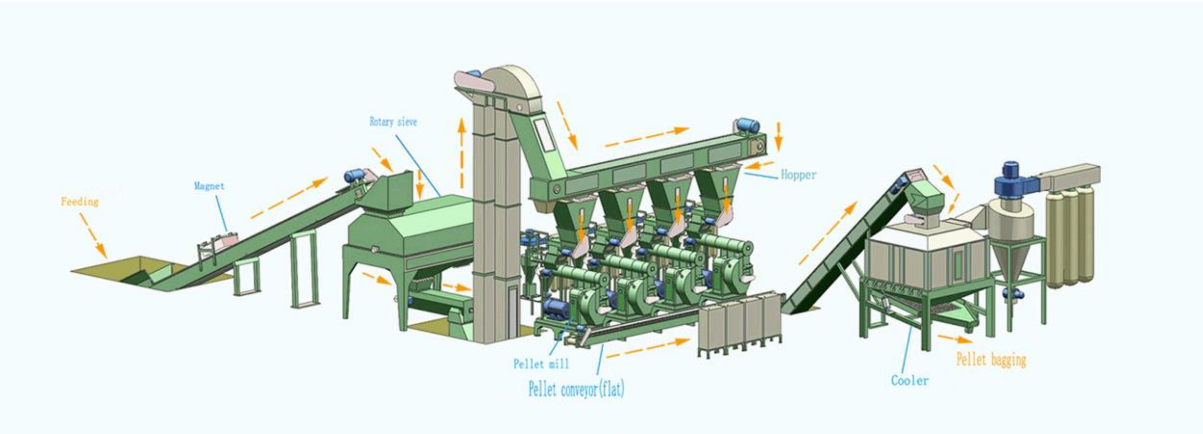
Pelleting and briquetting are applied in order to increase the density of biomass and its energy, and they are made mainly from small pieces of dust. Pellets are cylinders with a diameter of 6-10mm, while briquettes are 30-100mm in size. Because of their size, briquettes are not suitable for automated burning systems and are used mainly in households. The pellets are characterized by a homogeneous composition and low moisture content and are suitable for automatic combustion systems, both in household furnaces and in the furnaces of large energy plants.

The process of producing pellets has several stages:

<u>Drying.</u> Depending on the biomass used, the moisture content of the raw material before entering the process must be between 8 and 12%. The stability of the pressing process depends on the moisture content of the material, so a constant moisture content is essential. If the material is too dry, carbonization may occur on the surface of the particles and the binder will burn before the process is complete. If the biomass is too wet, the moisture can increase the volume of the pellets, thereby impairing its stability.

Grinding. The particle size of the biomass must be reduced in order to produce pellets that are extruded through the die. Hammer mills are used for this purpose.

Preparation. In order to achieve optimal adhesion of the biomass particles, they must be covered with a thin layer of water vapour.



Pelleting process

Production of pellets. Wood pelletizing machines use a flat or ring die. The productivity of the pellet press ranges from about 100 kg to about 10 tons per hour.

Cooling. The temperature of the pellets increases during the pressing process. That is why careful cooling of pellets is of great importance for its storage ability.

Several European countries have national standards for pellets and briquettes, e.g. Austria, Germany and Sweden.

Below is a table of chemical and physical properties of pellets and briquettes in accordance with the Austrian standard ONORM M 7135:

	Unit	Pellets	Briquettes
Diameter D	mm	4-10	40-120
Length	mm	<5×D	<400
Density	t/m^3	>1,12	>1,00
Moisture	%	<10	<10
Ash content	%	<0,5	<0,5
Maximum energy	MJ/kg	>18,0	>18,0
Additives content	%	<2	<2

Torrification. The characteristics of biomass differ from type to type, and its thermal power mainly depends on its moisture content. In order to create a highly energy-efficient form, torrifaction with pelletizing and briquetting offers an excellent solution.

Torrification of biomass can be described as a mild form of pyrolysis at temperatures ranging from 200-320°C, under atmospheric pressure and in the absence of oxygen. This is essentially the carbonization process that takes place in every charcoal plant. During carbonization, water and other volatile elements are removed and biopolymers are partially decomposed.

The final product is a solid, dry, combustible mass called "torrified biomass" or "bio-char" (charcoal). During carbonization, biomass changes its properties so that a much higher quality fuel is obtained for combustion where pelletizing and briquetting produces fuel with a significantly higher thermal power, of 20-25 GJ/t.

In the process of carbonization, the basic biomass loses are about 20% of its mass with the consumption of about 10% of energy. This energy can be used as fuel for the torification process.

The process of converting biomass into bio-coal can also be carried out in places that are not directly next to the facility where combustion takes place, because the cost of transporting the fuel obtained in this way is significantly lower than the cost of transporting conventional biomass.

7. METHODS OF USING BIOMASS

Biomass is utilized for burning. The released heat is used either for thermal energy to support industrial technological processes or in households, for heating rooms. The released thermal energy can be used to produce electricity and that utilization is very attractive because electricity can be easily transferred and used for other purposes besides heat generation. This applies to all types of biomass being it in solid, liquid and gaseous state.

Modern industrial plants for burning solid biomass can generally be divided according to the following combustion technologies, which differ in the method of burning biomass taking into account the form in which it is introduced into the furnace and which serves as fuel:

• combustion in a fixed bed,

• combustion in a fluidized bed,

• burning in air dispersion.

The differences are in the methods of fuel management, in the introduction of air, i.e. oxygen, into the combustion chambers and in the transport and management of ash, as a residue of combustion.

Biomass combustion technologies in liquid and gaseous form do not differ much from the technologies used for other fuels of the same aggregate state. Namely, as methane is represented to a large extent in biogas, it can also be used in conventional OTO motors to run a machine or generator for the production of electricity.

How to use biomass for energy production?

Except for superheated steam generators that drive steam turbines, a unique thermodynamic process of combined production of heat and electricity is applied in co-generative plants (CHP - combined heat and power), which drastically increases the efficiency of biomass or biogas utilization.

The efficiency of the primary fuel is from 30 to 40 percent in conventional plants, while in CHP installations it reaches even more than 85%, since waste thermal energy, whether it is steam or hot water from the electricity production process, is used for the technological process or for space heating. This increases efficiency and achieves significant cost savings.

Biomass in the form of wood is the most commonly used and easiest to produce and prepare. It does not require special treatment (compression into pellets, for example) and is used in bulk. It is relatively easy to store and is most widely used in heating plants for district heating

If pellets are used as fuel, good combustion and high energy efficiency are achieved. A low emission of carbon monoxide affects slower combustion, and thus savings. At the same time, the pellet has a very low percentage of moisture, which, in return provides the longer life span of the boiler. Usually, humidity is between 8 and 10%. Finally, burning the pellets leaves a small amount of ash. For wood pellets it ranges between only 1 and 2%, and for agro pellets between 3 and 6%. In addition, for the storage of pellets, a significantly smaller space is required than for other solid fuels, because 650 kg of prepared pellets can be placed in 1 m^3.

Individual use of biomass

Biomass is used in households for the distribution of heat energy obtained by burning biomass, whether that heat is used for space heating or sanitary water or for both purposes. Stoves and boilers on biomass are mostly for pellets and briquettes.

They can be used for spot heating of certain rooms or for a central heating system with floor and/or wall heating, with fan-coilers or with radiators. Pellet stoves and boilers enable automation of heating, without manual filling and with continuous fuel supply. In addition, the pellet generates extremely small amounts of ash and does not require frequent emptying of the firebox. Finally, the production of CO_2 and greenhouse gases is far below the level of other solid fuels. Moreover, the density of pellets and briquettes allows the storage of the required quantities in a relatively small space.

8. WASTE TO ENERGY

How do waste-to-energy plants work? These power plants burn municipal solid waste (MSW) to produce steam in a boiler that is used for electricity production. In addition, the heat energy is used to heat industrial buildings and technological processes that require heat and/or for residential and commercial buildings with a district heating system. Municipal solid waste is a mixture of energy-rich materials such as paper, plastic, household waste and wood products, although its composition depends on the environment in which it is generated. In rural and peri-rural areas, the components of biological waste are more common, while in urban areas, most of the waste consists of packaging made from materials with a high calorific value. For every 100 kg of MSW, about 85 kg can be burned as fuel for the production of heat and electricity. Waste-to-energy plants, by burning, reduce the amount of waste from, for example, 2t to ash weighing between 300 and 600 kg, and the volume is reduced by about 87%. There are different types of waste-to-energy technologies. The most common one is the mass incineration system, where unprocessed municipal waste is burned in a large incinerator with a boiler and a generator to produce electricity and heat.

There are also more developed methods of using waste, where selection of recyclables form MSW is done before the rest is burned for energy purposes (see illustration). This means that the input component in the incinerators has a lower calorific value, but therefore valuable materials are returned to production, respecting the principles of circularity.

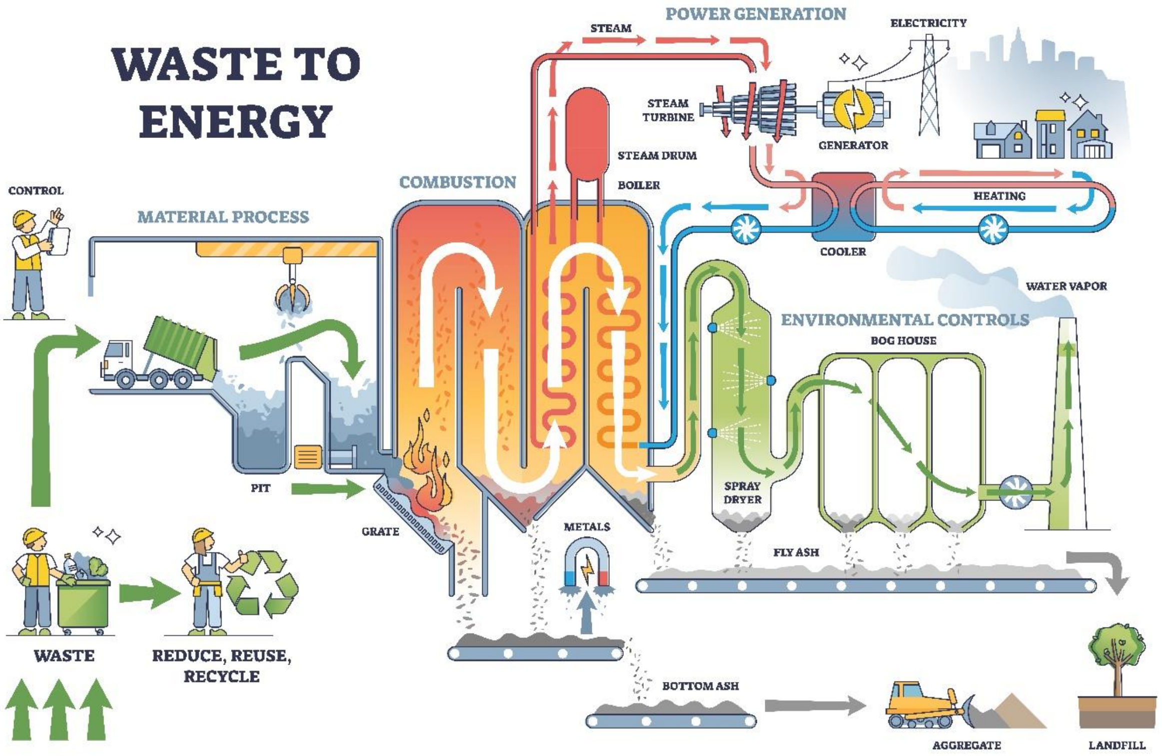


Illustration of a plant for mass incineration of waste to energy

The process of energy production in a waste incineration plant has seven stages:

a) The useful components are separated from the waste and the rest is deposited into a large pit.

b) The waste is transferred from the pit to the combustion chamber.

c) Waste (fuel) is burned, releasing heat.

d) Heat turns water into steam in the boiler.

e) High pressure steam turns the blades of a turbine generator to produce electricity. The energy released by cooling the steam is diverted to heat the buildings.

f) An air pollution control system removes pollutants from the combustion gas before it is discharged through the chimney. Pollutant particles can be removed by flushing the exit gases, electromagnetic separation, the use of fine filters, electric filters or a combination of different methods.

g) Ash is collected from the boiler and air pollution control system. The ash can be further used in the construction industry or for the construction of infrastructural facilities (as a foundation of roads, for example) if they do not contain excessive pollutants or toxic substances, in which case the ash is deposited under controlled conditions

	Energy efficiency	GHG	Air quality
	Incineration of municipal waste for energy purposes		
Advantages	Using waste for energy purposes improves waste management; high efficiency if CHP plants is gained	Significantly lower GHG emissions, especially when compared to landfilling (avoids methane emissions); the energy obtained replaces fossil fuels utilization	If landfilling is avoided, emissions of polluting gases are reduced
Flaws	Relatively low degree of utilization; there is a possible need for additional fuel considering the low calorific value of the waste, as a fuel	-	It is necessary to minimize the emission of gases during burning; The cost can be a third of the total investment
	Combustion at medium scale, heat driven)		
Advantages	>85% conversion efficiency in case of heat only; 65-85% efficiency for CHP installations.	Low input of fossil fuels; especially in case of CHP GHG savings can be high	Better control options for PM emissions compared to small scale installations.
Flaws	-	-	Still higher PM emissions than natural gas combustion.
	Gasification & CHP at medium scale - heat driven		
Advantages	Up to 80% conversion efficiency, depending on heat only or CHP installations.	Low/no input of fossil fuels; especially in case of CHP GHG savings can be high	Low emissions of gas engine or turbine

Value chains in municipal waste incineration

9. BIOGAS TECHNOLOGIES

What are biogas plants?

Biogas is about 20% lighter than air and is odourless and colourless. Its ignition temperature is between 650°C and 750°C, and it burns with a pure blue flame. Its calorific value is about 20 MJ/Nm^3 and it burns with about 60% efficiency in conventional biogas furnaces. One and a half cubic meters of biogas is equal to one cubic meter of natural gas. One hectare of corn

Plant for the production of biogas from waste municipal water

silage is sufficient for the production of 10,000 cubic meters of biogas, which generates over 20,000 kWh of electricity that is enough for the average consumption of 4 households per year. About 500,000 hectares of various plants would provide power of about 1,000 MW, which is in proportion to the production of a significant power plant (slightly less than the Đerdap hydroelectric plant). Bio gas is a product of biological decomposition of organic matter, plants, residues from arable and agricultural production, and especially residues from livestock farms, primarily manure as well as municipal waste water. In addition, biogas can be obtained by gasification of wood or wood pellets.

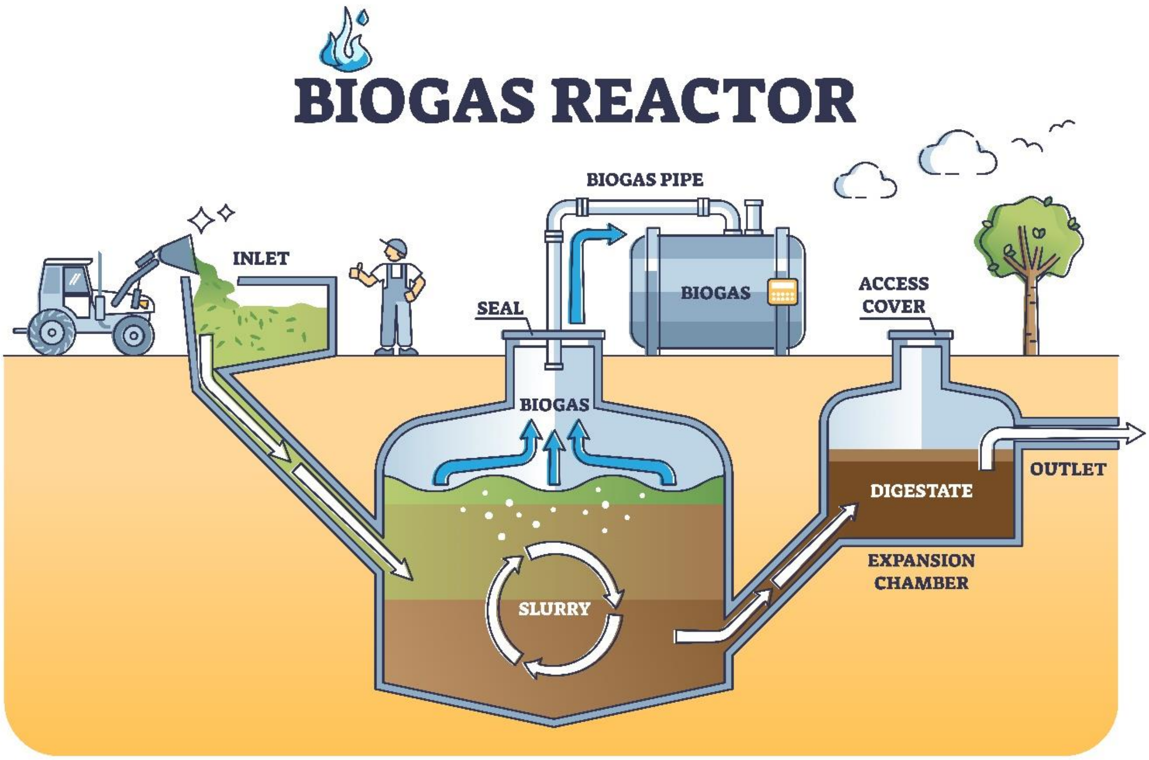
Biogas is used for the production of heat or electricity, the combined production of electricity and heat (in a cogeneration plant) or the combined production of electricity, heat and cooling energy (trigeneration).

There is an increasingly intense trend for utilizing biogas through the existing natural gas network and thus transported and used for the same purposes. In this way, greater flexibility in the use of biogas is secured because it can be used in places that are not in the immediate vicinity of the biogas production plant.

When using biogas in the cogeneration process, electricity is continuously produced and delivered to the public electricity grid. The production of thermal energy follows the production of electricity, but it is necessary to ensure its continuous use, which is not always possible. Part of the thermal energy is used for heating the substrate and digester, while the remaining part is mostly used for heating nearby glass houses or livestock farms.

Small biogas plants.

Plants on smaller farms that mainly use animal manure as raw material and the produced biogas is utilized at the location of the plant for the combined production of electricity and



heat, can be considered a small biogas plants. Simple constructions using organic waste from individual households including animal manure, widely used in China and India, are not common in these areas, although they have a great potential. A biogas reactor is a hermetically sealed chamber that facilitates the anaerobic degradation of sewage and/or biodegradable waste (e.g. animal manure, kitchen and garden waste). It also facilitates the collection of biogas, a mixture of methane (CH_4) and carbon dioxide (CO_2) produced in the reactor during fermentation process. Gas is collected at the top of the chamber, agitating the sludge as it rises. The pressure exerted by the rising gas can be used to transport the gas to a collection vessel or directly to where it will be used. The rest, i.e. dig estate, is rich in organic matter and nutrients, almost odourless with pathogens partially inactivated.

Advantages of small biogas plants

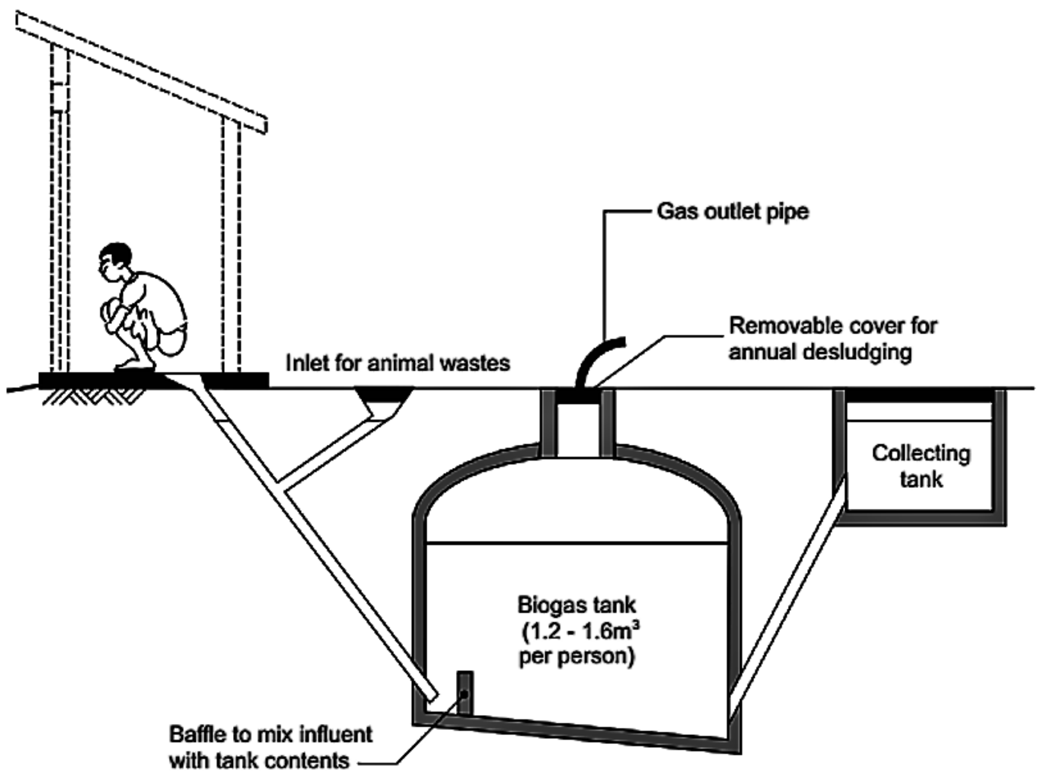
Biogas reactors are often installed in households or communities in rural areas for the co-fermentation of animal manure and toilet waste. The gas produced can be used directly for cooking and lighting or can be transformed into heat in a gas heating system or even into combined heat and power (CHP) in a co-generation unit. Digestiate (residue rich in nutrients) can be used as a fertilizer to feed the soil in agriculture. Animal manure and dung and kitchen waste contain a lot of organic matter and in principle, the process can produce enough biogas for a family to cover at least their cooking needs. Humans produce less excreta and they contain less substances that can be converted into biogas than animal dung (e.g. cows). However, toilets, if available, can be directly connected to a biogas plant where human faeces are fermented alongside with other waste. This option ensures the safe treatment of human excrement and thus improves the hygiene of the treatment of waste materials. The availability of renewable energy sources reduces the use of firewood for cooking and indoor air pollution. Thus, biogas digesters also have the potential to minimize health risks and environmental pollution.

The value chain for biogas and elements for assessing the justification of its use

Appropriate fermentation temperature	20 to 35 °C
Decomposition time	40 to 100 days
Energy harvested	6kWh/m^3 = 0.61 litres of diesel fuel/m^3
Biogas production	0.3 – 0.5 m^3 gas/m^3 of digester volume
Human faeces	0.02 m^3gas/per person, per day
Cow	0.4 m^3gas/Kg manure per day
Cooking needs for a gas supply	0.3 to 0.9 m^3/per person, per day
Gas lamp consumption	0.1 to 0.15m^3/h

Types of reactors

Biogas reactors can be brick domes or prefabricated tanks, placed above or below ground, depending on space, soil characteristics, available resources and the amount of waste generated. They can be built as fixed or floating dome digesters. In a fixed dome, the volume of the reactor is constant. As the gas builds up, it exerts pressure and pushes the slurry upwards into the expansion chamber. Once the gas is removed, the slurry flows back into the reactor. Pressure can be used to transport biogas through pipes. In a floating dome reactor, the dome rises and falls with gas production and withdrawal. Alternatively, it can expand (like a balloon). Biogas plants with rubber balloons are the simplest and cheapest to build. To minimize distribution losses, reactors should be installed close to where the gas can be used. Anaerobic digestion is a biological process that is stimulated by a special mixture of bacteria. When reactors are first started, it can take some time for the specific biogas-producing bacterial community to develop and stabilize. It may help to seed the reactor with anaerobic sludge from a septic tank or other anaerobic digester. The hydraulic retention time of the fermenting mass in the reactor should be at least 15 days in hot climates and 25 days in moderate climates. For highly pathogenic inputs, a period of 60 days should be considered sufficient to interties the sludge. Biogas reactors operate in a temperature range from 30°C



to 38°C. A temperature of 50 to 57°C would destroy the pathogens and can only be achieved by additional heating. If the biomass temperature is below 15°C, the gas production will be so low that the biogas plant is no longer economically justified. At a higher temperature, not only methane production can increase, but also free ammonia, which can have a negative effect on digester performance**.** Often, biogas reactors are directly connected to private or public toilets with additional access to organic materials. For households, reactors can be made of plastic containers or bricks. Sizes can vary from 1,000 L for a single family to 100,000 L for institutional or public toilets. Since the production of dig estate is continuous, there must be possibilities to store it, use and/or transport to a suitable location. The design of the reactor depends on the temperature and volume of the fermenting material.

Small-scale biogas digesters, receiving animal waste show higher biogas production rates because animal dung has a much higher methane-producing potential than human faeces, for example. Fermentation of human faecal matter alone would not be economically interesting because the organic waste produced by a typical average family would not produce enough biogas to cover its needs. Taking into account the production of 0.12 kg to 0.6 kg of faeces per day per person and 20 to 150 lit. of biogas per kg, biogas production in litres would vary from a few litres to a maximum of 90 litres. (the real value is 20 to 30 litres of biogas, per person, per day). This is far less than the amount of biogas needed to prepare a meal for one person, which amounts to about 300 to 900 litres of biogas per day. In addition to kitchen waste, garden waste and plants can be added to the reactor in order to increase biogas production. Green plants are very suitable for anaerobic fermentation and their gas yields are high, usually above that of manure. Lignin-containing feed material, such as straw or wood, is resistant to anaerobic fermentation and therefore should not be used in biogas plants or at least pre-composted and preferably shredded before fermentation.

Biogas production according to the amount of biomass

	Livestock	Pigs	Poultry	Human and sewage waste
Litres of biogas per Kg of waste	40	60	70	60

Health aspects

Anaerobic digestion removes only organic matter, and the main mineral material and almost all nutrients remain in the bottom sludge. Almost 100% of the phosphorus and about 50 to 70% of the nitrogen in the form of ammonium is still in the digested sludge. For this reason, the by-product compost from biogas reactors is a valuable fertilizer for food production. Generally, in a well-designed biogas digester, the removal of pathogens in the sludge solution is sufficient to allow the treated sludge to be reused for soil fertilization. To increase safety, it can be aerobically composted (or processed in a drying plant) before reuse.

Costs

The investment costs of anaerobic digesters are moderate, and the utilization potential is relatively high (although planning requires skills and expert design). Both biogas and manure sludge create added value, thus installing a biogas digester is economically viable.

Operation and maintenance

If the reactor is properly designed and built, repairs should be minimal. To start the reactor, it needs to be seeded with anaerobic bacteria, for example, by adding cow dung or septic tank sludge. Biogas reactors require a start-up phase during which the microorganism responsible for anaerobic digestion is propagated and stabilized. Organic waste used as a substrate should be chopped and mixed with water or dig estate before being fed into the digester.

Gas equipment should be cleaned carefully and regularly to prevent corrosion and leakage. Sand and stones that have settled to the bottom should be removed. Depending on how it was designed, the reactor should be emptied every 5 to 10 years. Reactors should also be checked regularly for foaming, slime formation, or digester leaks (and rust, in the case of floating drum reactors using a steel drum). A qualified operator is not required, but households should be trained to understand how the system works. Precautions should be taken to manage flammable gases.

Application

This technology can be applied in households, in small settlements or for the stabilization of sludge in large wastewater treatment plants. Biogas reactors provide energy for cooking, lighting and heating, as well as for soil fertilization. In rural areas, they are often used to ferment animal manure, kitchen waste (and only optionally toilet waste). Reactors are best used where regular loading with biological material is feasible.

Often a biogas reactor is used as an alternative to a septic tank, as it offers a similar level of treatment, but with the added benefit of biogas. The highest levels of biogas production are obtained with concentrated substrates that are rich in organic material, such as animal manure and organic commercial or household waste.

Biogas reactors are less suitable for colder climates because the rate of conversion of organic matter to biogas is very low below 15°C. In those cases, the digestion time must be significantly longer, and the projected volume must be significantly increased.

Small biogas plants, for example in Germany, which use at least 80% of animal manure in the total fresh mass of the substrate and have installed electric power of the generator up to 75 kW, receive a guaranteed (feed-in) tariff for the electricity supplied to the grid, which makes the investment worthwhile. If the farm has 100 with cows, it is possible to provide 15 to 18 kW of electric power from the obtained liquid manure. Accordingly, a 75 kW biogas plant requires about 500 animals, not counting by-products from agriculture and the food industry as substrates for biogas production.

In Serbia and Bulgaria, there are incentive measures as feed-in tariffs for the production of electricity from biogas and this can help investments, but the production of biogas only for heating purposes and for household use is not supported, so the entire cost is forwarded on to the user, despite an outstanding quality in use of biogas in households.

In 2019, there were 22 biogas plants in operation in Serbia, with a total installed power of 21.21 MW. Most of the plants have a power of around 1 MW, a few in the range of 500 to 650 kW, and only one with a power of 200 kW. Together, these plants used about 175,000 t of equivalent amount of liquid manure in that year, which is less than 1% of the total potential in Serbia. Therefore, the total share of manure that is properly disposed of in Serbia is negligible so far, and it is absolutely unused on small farms.

In Bulgaria, the situation is no better. The use of biogas, despite all the advantages, is not at a high level. In accordance with statistical data and analysis on the possibility of using livestock manure in biogas production systems in Bulgaria for the year 2020, it was estimated that a total of 1,142 installations of 500 kW each could be implemented in farms. The obtained results are promising and are a prerequisite for further technological and economic research of this type of biological fuel.

The promotion of the use of biogas as a supplementary fuel is of great importance in both countries, primarily for rural areas. This would improve the quality of life of local people and makes a significant contribution to energy stability.

Small biogas plants are the key technology for the appropriate treatment of manure from small farms, which represents the largest part of the total potential. Untreated manure has negative impact on the environment. The construction of small biogas plants would significantly contribute to the reduction GHG and CO_2 emissions.

10. BIOMASS STORAGE METHODS

Special attention should be paid to the management and storage of biomass, since its production varies throughout the year. It is most intense during the growing season, that is, from spring to autumn. This is especially true for biomass originating from agricultural production. For this reason, biomass storages must be tailored and prepared in such a way to accommodate all annual needs and have a contingency that can mitigate the deficits that may occur due to reduced production during the year season. This might be resolved by erecting two warehouses next to the plant that uses biomass, one for current needs and which can meet requirements for few days of operation and the other one, for the long term storage. Since biomass has a low specific weight and density, its volume is relatively large, so the long-term storage needs to be of large dimensions and is usually built outside the plant or on its very edge, because it is not necessary to have it right next to the plant, itself. Fuel transport between these two warehouses could be done with conveyor belts or various types of loaders, depending on the type of biomass.

Forest biomass is most often stored long-term as wood chips, in bulk. However, it should be noted that as a result of biochemical decomposition, the temperature in the warehouse may rise to the point of self-ignition. This can happen due to a number of factors such as the type of biomass stored, the size of the pieces, the height of the storage, the ambient conditions, the ventilation conditions of the storage, etc.

When fresh wood chips or bark are stored, the temperature in the core of the layer reaches 60°C during the first days. Self-ignition can be avoided when the bark is stored up to a maximum height of 8m and when the storage time is less than five months. The biomass in the filled layer should not be too compacted because this can lead to the concentration of moisture in certain places what can cause the biomass to overheat.

Increased concentrations of CO_2 represent the initial stage of auto-ignition, while detecting the presence of carbon monoxide indicates that auto-ignition has already occurred. When it comes to storing fresh biomass indoors, the moisture content can be reduced by natural or forced ventilation. The walls of the storage hall should allow air flow. Open storage for biomass with small particles, such as sawdust, can cause dusting and is not recommended in populated areas. For this kind of biomass, storage in closed rooms or silos is recommended.

Short-term biomass storages are in direct connection with the fuelling system at the plant. For biomass such as bark and wood chips, bunkers with moving floors can be used. Moving floors are particularly suitable for automatic emptying of long-term storage, without additional devices.

Sawdust and fine wood waste are best stored in closed silos to avoid dust emissions. The diameter of such a silo can be up to 15m, and the height can be up to 40m. An inclined screw dispenser is used to automatically discharge these silos.

Baled wood biomass can be stored outdoors as its sensitivity to biological degradation is very low.

Baled agricultural biomass can be stored in various ways but cannot be kept outdoors due to the risk of wetting. Long-term outdoor storage of this type of biomass can create large losses in the upper and lower layers of the storage due to the reaction with moisture. Covering the bales with blankets or a solid roof would protect the top layer, while the bottom layer is still exposed to moisture. Closed storage systems are the best but also the most expensive and represent the best way to store baled agricultural biomass.

Biogas is not stored because it would not be profitable and it needs to be used immediately after production, which streamlines the design of the system for the production and further utilization of gas which can, as mentioned earlier, be distributed through the existing gas supply network.

11. SELECTING THE OPTIMAL SYSTEM AND ESTIMATING COSTS

As biomass is an energy source that needs to be prepared before use, i.e., a certain amount of work needs to be invested before it can be used, it is a marketable commodity that is subject to market conditions, so it is more difficult to make a comparative calculation with another energy source because of the volatility and market fluctuations, the mutual relations can change in a short time and at significant scale. Namely, we have the sun, wind, heat of the earth, and to some extent water for free, and we do not pay for the fuel we need to produce energy from, so the investment pays off rather quickly for the savings we make by using free energy source. Biomass is bought or used from the property, but in any case it has a price. We have witnessed that due to the energy crisis in Europe because of to the conflict in Ukraine, there have been large turmoil in the price of energy, so investing in plants that use biomass is a matter of good consideration. As it will be presented hereof, investing in energy systems that use biomass do not have the advantage of having energy source free of charge, but on the other hand, plants could be grown and biomass can be found in variety almost anywhere and do not strictly depend on the location of the energy source, as is the case with all other RES. Furthermore, biomass is usually by-product of some industrial activity that uses biomass for prime activity, thus use of biomass contribute to efficiency to circularity.

As a case study, we will consider two plants for individual use of biomass, i.e. biogas. As already mentioned, we will not be able to make a real comparison between the proposed solution and the other one, because nowadays energy prices are unpredictable and volatile, so it is difficult to make a real calculation of profitability and ROI. There is a comfort factor, accessibility to the energy source and its availability. For example, you cannot store solar energy in its original form for later, neither can wind, but you can biomass. This secures a fairly high degree of independence and security of fuel supply.

The case study refers to a house with a living area of 150 m^2, with significant energy losses in a fifty-year-old family house with, at that time, standard insulation. For such a facility, we will need a boiler of 30kW of thermal power that can optimally heat water for space heating as well as sanitary water.

Biomass or biogas heating is most often realized with radiators, considering the temperatures that are developed in the boiler.

We will assume that the house does not have a built-in heat distribution system, what we will also take that into account when calculating the required investment.

Pellet heating

For a house of suggested dimensions and mentioned type of insulation, it is possible to make rough calculations of the required amount of pellets for average thermal power consumption. We would need to have 17-20 kg/m^3 of pellets for heated space and for the whole heating season. Respectively, with an average room height of 2.8 m, we will have to heat 405 m^3, thus, we will need about 8 tons of pellets for an average winter (150 m^2 x 2.8 m x 19 kg/m^3 = 7980 kg). This is a very rough estimate, but it is good enough to comprehend the consumption for which we have to provide enough fuel. Bearing in mind that 1 m^3 of storage area contains about 650 kg of pellets, it is necessary to provide a warehouse of some 12 m^3, that is dry and protected from atmospheric precipitation.

Somewhat better pellet boilers of 15 kW, cost around 1,000-1,500 EUR, and the installation for distribution of heating via radiators depends on the material and the number of heating elements. However, it can be accurate enough that the complete installation of the heating system together with the boiler is within the range of 25-42 EUR/m2

Building - Residential building with a total area of **150 m2**

Area - Zaječar

Insulation - Gutter block 25 cm plastered on both sides, single windows, single glazed**.**

Set internal temperature - 22 degrees**,**

Heat losses - 196.92 W/m2

Required heat energy - 29.54 Kw

BOILER ROOM	
Boiler and accessories	2.136 EUR
HEATERS AND RADIATOR FITTINGS	
Radiators and related equipment	1.583 EUR
INSTALLATION OF PIPES AND FITTINGS	
Installation of pipes and fittings	790 EUR
INSTALLATION COSTS	
Installation of a pellet boiler and heating elements	700 EUR
TOTAL	
Total investment in central distributed heating system	**5.210 EUR**
Boiler for sanitary water 200 lit. with heat exchanger and with installation	550 EUR
GRAND TOTAL	**5.760 EUR**
ANNUAL FUEL CONSUMPTION	
The amount of pellets on an annual basis	8.000 kg

The costs of introducing pellet heating for a house of 150 m2

This is the calculation for the building and installation of a heating system together with a boiler for the preparation of sanitary water. However, the cost of fuel must be taken into account, which can greatly compromise the profitability of the investment, even though the use of pellets is very comfortable.

Heating costs can be greatly reduced by good thermal insulation, i.e. by closing thermal bridges on the facade, roof or carpentry through which heat is lost.

Biogas plants

The construction of a small biogas plant requires high specific investment costs. The average amount of investment for a biogas plant that produces electricity with the help of a generator at an installed power of 75 kW is about €9,000/kW, while a plant with a power of 1,000 kW requires an investment of about €3,750/kW. However, there is room for using biogas as an additional or even the only energy source in households that have access to livestock farms, the main source of fermentable biomass. Here we will consider one case of introducing biogas as the only energy source for the production of thermal energy.

BOILER ROOM

Gas boiler 26kw condensing + chimney kit:	920 EUR
HEATERS AND RADIATOR FITTINGS	
Aluminium radiators, pipes, valves and fittings:	2.000 EUR
INSTALLATION	
Installation of internal gas installation 30 meters x 18 euros (material and labour)	540 EUR
INSTALLATION COSTS	
Installation of 8 radiators x 30 euros:	240 EUR
TOTAL	
Total investment in central distributed heating system	**3.700 EUR**
Boiler for sanitary water 200 lit. with heat exchanger and with installation	550 EUR
GRAND TOTAL	**4.250 EUR**
ANNUAL FUEL CONSUMPTION	
The amount of pellets on an annual basis	7.000 lit.

Costs of introducing biogas heating for a house of 150 m2

This is an installation price that can also be used for natural gas. However, if we want the installation to use only biogas, then it is necessary to build a digester with the associated equipment. For comfortable use of biogas, it is necessary to receive at least 6,500 to 7,000 litres of gas per day in the heating season and half as much for the rest of the year. Gas is used for current needs in the household, and during the winter for heating. To produce required quantity of gas, it is necessary to build a digester with a volume of 15m^3 and feed with manure from 260 cows. The investment in such a facility is around 5,000 - 7,000 EUR, depending on the type of digester and the required work. If biomass is mixed in the digester with silage and green plant residues, the same production of biogas can be achieved with half the number of cattle. It is clear that the use of biogas as a fully sufficient energy source requires access to a livestock farm. A compromise can be made by bringing the material from the surrounding farms and fields, either to purchase or as leased material that is later returned as high-quality organic fertilizer. In that case, the investment in a plant for the exploitation of energy from biogas is worthwhile because the fuel is free or has a very low price, so the ROI could easily be calculated.

12. PRACTICAL WAYS FOR CROSS-BORDER COOPERATION

Although it is not possible to physically connect projects to use of energy from biomass, this does not mean that there are no other ways to achieve cross-border cooperation.

The exchange of experiences and examples from practice are of valuable importance for the development of biomass exploitation because the configuration of the terrain and the potentials in the border area are similar, which means that the ways of using biomass and biogas are also similar.

The inconsistences may occur from different legal solutions as well as from development of the infrastructure. However, by promoting good practice, most of these limitations can be mitigated. There are a number possible forms of cooperation:

• Joint meetings, forums and places for the exchange of knowledge and experiences, where the best and most effective solutions would be promoted.

• Joint projects that would be used on both sides of the border, with different contractors but with the same goal. The results of the implementation and exploitation of such projects would be an excellent basis for a comparative analysis of success in similar conditions and a good guide for resolving potential problems.

• Setting up joint energy cooperatives, that is, a pool of small investors who could invest in projects within cross-border cooperation.

• Development of tourism with an emphasis on "green tourism" and the use of renewable energy sources for the purpose of self-sustainability and new quality in the service offered, for air conditioning, for supplying electricity, for heating sanitary water, for swimming pools...

• Elaboration of models to use plant residues in farming and agriculture, animal farming and in sustainable exploitation of forests.

• Animating SMEs for circular economy model and to be reoriented to activities related to the exploitation of energy from renewable sources: production of parts, for example biomass boilers, small devices for the exploitation of bio-gas for domestic needs, digesters, system installation and maintenance services, design and project implementation, consultations, etc. These products and services could be used in both countries.

13. GOOD PRACTICE EXAMPLES

Power plant with co-generation, Frederisije, Denmark

Located near Fredericia, Denmark, the power plant is one of installations operated by energy giant DONG, and was recently converted to a biomass power plant. Originally built for natural gas, the power plant was converted to bi-fuelled co-generation (wood chips and natural gas) in 2017. Two new highly efficient 140 MW wood chip boilers were installed during the reconstruction. Wood chips are the primary fuel, with natural gas as a backup. The main purpose of the plant is to provide district heating for about 200,000 people. However, the new wood chip boilers can also supply steam to the existing turbine, so the plant can be entirely electricity-only or run in co-generation (heat + electricity) mode. This provides maximum flexibility during the summer or periods when wind or solar power production declines. The plant has a heat storage system of 5500 GJ which covers approximately 8 hours of heat consumption during winter days.

Installing wood chip boilers required new water and steam piping and connections to the original gas plant.

CHP on straw and woodchips Sleaford, UK

Sleaford is a 39 MWe combined heat and power (CHP) plant, which uses a mixture of straw and wood chips to produce renewable energy and heat. Located within the 'Grain Belt', in Lincolnshire, the factory provides a reliable route to market for straw, an agricultural by-product that now provides an additional source of income for local farmers. The plant's heat production is supplied to a local swimming pool and other community facilities and the plant has recently signed a new community funding agreement.

In commercial operation is since 2014, the Sleaford Renewable Energy Plant (Sleaford REP) in the UK is a 39 MWe straw-fired combined heat and power (CHP) plant.

Sofia Water, Bulgaria

"Sofijska voda" presented its new digester at the wastewater treatment plant in Sofia. The tank, which cost 3.1 million euros, increased the biogas production capacity by 25%. A wastewater treatment plant near Kubratov in the Bulgarian capital has added a 7,000 cubic meter digester for sludge fermentation. The construction of digesters and tanks for the extraction of biogas from waste sludge will increase the capacity of green energy production by 25 percent.

Company contributes to circular economy through the existing four digesters built in 1984, and the new tank allowed the company to upgrade the old ones. Methane from the sludge powers the co-generation system, which produces 24 GWh of electricity per year. Sofia Water operates four drinking water treatment plants and two waste water treatment plants, as well as three combined heat and power plants and is planning to build another co-generation unit. After the sludge is stabilized in the digester, it is drained and donated to farms for fertilizing certain types of crops. The purified water is sent to the river Iskar, which completes the cycle.

Sofia Water claims that its biogas and co-generation system will protect it from the recent spike in electricity prices because the production is 10% higher than the waste water treatment plant's consumption. The company aims at becoming completely energy independent. The Kubratovo facility processes more than 350,000 cubic meters of wastewater daily. Sofia Municipality owns 22.9% of Sofia water. A similar wastewater treatment plant with a biogas co-generation system was recently built in Kruševac in neighboring Serbia.

Biomass heating plants in Priboj and Mali Zvornik, Serbia

Priboj and Mali Zvornik were the first in Serbia to get biomass heating plants, which completely switched the district heating systems in these municipalities from oil to renewable source.

For Priboj, this means that the emission of 40 tons of sulphur dioxide will be reduced to less than one ton, and the emission of carbon dioxide will be reduced by 90%. With 20,000 cubic meters of wood chips for the season, the heating plant in Priboj, with a power of 12,5 MW, will heat about 1,600 apartments, schools, and public companies.

The district heating program cost about 20 million euros with a grant of two million euros from KfW and five million euros from the Swiss Secretariat for Economic Affairs SECO.

Ekonomija biogas power plant project, Alibunar, Serbia

In 2016, the company Ekonomija built a biogas plant for co-generation in Ilandža, near Alibunar in Vojvodina, which has an installed electrical power of 3.57 MW and an installed thermal power of 2028 kW. Thermal power is used for heating the digester and for the own heating needs of the administrative building. The basic fuel for this plant is biogas produced from nearby farms' manure, corn silage and agricultural residues from barley. A storage facility was built within the plant for the green substrate.

In order to secure stable operation of the power plant, the plant is connected to a natural gas supply installation that is used as an auxiliary source in cases of biogas shortage or reduced production.

The plant has four digesters and three electricity generators with the annual production of 29.2 GWh.

Biogas plant Mirotin-energo, Vrbas, Serbia

In 2012, the company Mirotin-energo from Vrbas put into operation a biogas plant with a total capacity of 1 MWe. This plant produces energy from cow manure and silage. The required annual amount of raw materials for the operation of the plant is 27,000 t of manure and 10,000 t of silage. The maximum percentage of methane in biogas is 55%. The company uses part of the thermal energy produced from the co-generation unit to heat the digester, while in the winter months, 200 kW of heat power is used to heat the business premises. The rest of the dig estate from anaerobic fermentation is mechanically separated into solid and liquid fractions, which are further used as fertilizer in agriculture. The investment in this facility amounted to over €5 million.

14. INSTEAD OF CONCLUSION

Energy is crucial both for global development and for every individual, and solving a stable supply is of priority importance.

The use of renewable energy sources provides an exceptional opportunity to solve the energy security of the state and its citizens.

The 10 most important advantages of RES are:

1) It is available everywhere

2) It is easy to use and suitable for both small and large consumers

3) Stimulates the local economy

4) Reduces dependence on energy imports and geopolitical influences

5) Low exploitation costs

6) Plants can be easily expanded.

7) They do not pollute the environment.

8) They are safe

9) They are not so expensive anymore

10) They enable an increase in the standard of living.

The 5 most important challenges in using RES are:

1) It is not always and everywhere to the same extent

2) Higher initial investments

3) Lack of infrastructure

4) Insufficient knowledge and practice

5) Saving energy

This Guide aims to explain the nature and use of biogas and to point out practical solutions, along with any challenges that may arise along the way.

As for all other forms of renewable energy sources, we are of the opinion that it is good and profitable to invest in plants for their exploitation. Modern technologies enable more efficient use and thus justify investments in RES. Biomass is somewhat specific because there is an intermediate step in its use, that is, it needs to be collected and prepared for use. In contrast, all other RES are used with one- or two-stage conversion (wind and water power are converted into mechanical and then into electrical energy, geothermal is only transmitted and solar is directly converted into electrical energy) and the only cost is the investment in the installation, while energy itself, practically free. On the other hand, biomass has the advantage that the installation for its use does not have to be at the place of origin of RES, but can be relocated. However, because the preparation of biomass requires human labour, treatment and transportation, it has its own price that is subject to market movements. We are witnessing that, due to the energy crisis in Europe, the price of biomass is changing because other sources of energy have become unavailable. Such jumps in value make investing in biomass riskier than other models of RES use.

On the other hand, the future of energy will certainly rely to a large extent on biomass, especially that from agriculture, which is available in large quantities and is still used on a small scale. Particularly interesting is biogas, which is a by-product of the biological decomposition of biomass, but which, by accelerating that process, can be obtained in quantities that have great economic justification. Biogas can be used as fuel for internal combustion engines for direct conversion into mechanical energy, as heat fuel for heating the medium (water, air), in industry where heat is needed for a technological process or in the chemical industry.

Due to fluctuations in the procurement price, it is difficult to reliably determine the return time of the investment in biomass and biogas plants, but it is certainly profitable because, in addition to bringing a greater degree of energy independence, it uses fuel that will always be there, to a greater or lesser extent, and which will certainly always be cheaper than other types of conventional, non-renewable sources.

When it comes to households, there are solutions for using biomass and especially biogas that are acceptable and provide a long-term solution. Apart from individual stoves that are part of standard commercial offers, it should be borne in mind that the price of the system itself is not negligible for the average household budget, and it is important to plan the financing well and find the most suitable way. If the financing is done without credit and without incentives, then the biomass heating system is a financial effort, although it will certainly pay off over time, especially considering that the price of energy will certainly increase in the future, which will increase the profitability of the system and shorten the investment return time.

15. ABOUT THE PROJECT

Project name	Renewable energy for smart growth and protected environment
Leading partner	Vidin Chamber of Commerce, Bulgaria
Partner	RARIS, Regional Agency for the Development of Eastern Serbia, Serbia
Priority axis	Environment
Project objectives	The main objective of the project is to increase capacity and improve awareness of environmental issues such as renewable energy sources and energy efficiency among the target groups: SMEs, local authorities, environmental organizations and institutions, the general public

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