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ASSESSING THE VIABILITY OF CULTIVATING MISCANTHUS AS A SUSTAINABLE BIOFUEL PRODUCTION

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Abstract: Biomass is abundantly present in diverse ecosystems, and is considered to be a highly valuable energy source worldwide due to its high diversity. Agricultural residues contribute substantially to the overall biomass potential. Although all agricultural residues can be used as fuel, their range is limited in practice by the possibilities of production, compaction, transport and use. The present paper presents a technology and the associated technical equipment developed and tested by INMA Bucharest for processing Miscanthus biomass that can be used for various energy purposes.
Keywords: biomass processing, energy producing plants, Miscanthus, renewable energy

1. INTRODUCTION

Biomass is the most abundant renewable resource on the planet and it is often considered an agricultural waste. It includes all organic matter produced by the metabolic processes of living organisms. Photosynthesis generates organic substances from mineral substances – carbon dioxide and water – which are stored in the plants, and oxygen is produced [1–3]. Due to the cyclicity of the production and conversion processes, biomass is considered a renewable energy source with a positive impact on the environment. It is also regarded as a highly available energy source worldwide, particularly because of its variety. Environmental biomass is made up of the biomass of various ecosystems: forests, savannahs, steppes, tundra, deserts, agro–ecosystems, agricultural, industrial and urban wastes and residues.

In the process of burning coal, dust, soot, sulphur, chlorine, fluorine, zinc, lead, nickel, etc. are released into the atmosphere. In large cities and industrial centres, these releases form smog. In practice, the use of fossil fuels poses two major problems: their reserves are depletable, but above all their use leads to environmental pollution through harmful emissions of carbon dioxide and sulphur and nitrogen oxides. The answer to the two big problems – renewables and energy crops – is that their use leads to a significant reduction in the amount of carbon dioxide emissions into the atmosphere, which causes the so–called 'greenhouse effect' [4]. Energy crops that produce biomass used for energy purposes are:

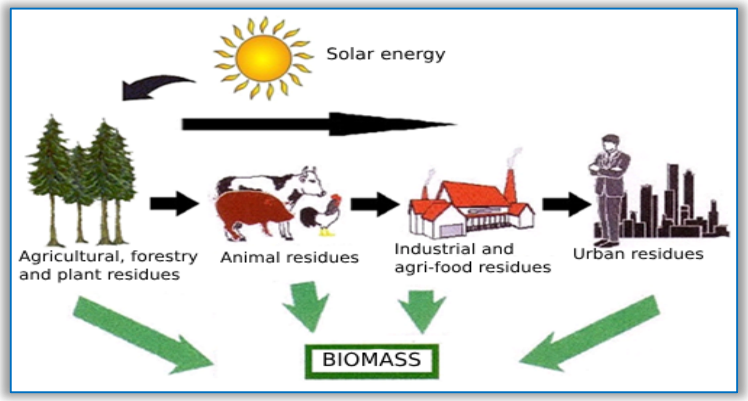

Figure1. Biomass cycle in nature [1]

- starch–producing crops: cereals, potatoes;
- sugar crops: sugar cane, sugar beet;
- oil–producing crops: rapeseed, sunflower, camelina, etc.;
- ligno–cellulose crops: willow, poplar, Miscanthus, artichoke, Cynara, Panicum etc.

Energy crops (ligno–cellulosic crops) can be grown on agricultural land that is not used for farming (usually land that is set aside for various reasons or land considered unsuitable for growing food crops).

Compared to traditional agricultural crops, energy crops require less care and fewer mineral fertilisers and pesticides. Future biofuel production relies on these energy crops (ligno–cellulosic crops) because they represent a promising solution for global energy security due to the cyclical nature of the biomass resulting from these crops [5, 6].

Based on these considerations, in recent years, energy willow, energy poplar and *Miscathus* crops have gained momentum and have been used both as an energy source and in other areas.

Energy willow (*Salix Viminalis*) and energy poplar biomass crops are grown in agricultural areas rather than in forest areas. Miscanthus cultivation has become more and more widespread worldwide because of its

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economic advantages, but especially its positive effect on the environment. According to worldwide studies, mature Miscanthus crops can produce 48.5 tonnes of dry mass per hectare with an energy conversion of 1.2–2% of incident solar radiation [7].

Some studies consider that the establishment of energy crops can be a solution, especially on non–productive marginal lands, to prioritize marginal lands for food production [8, 9], while other studies consider that a solution would be the biomass thermochemical treatment to obtain chemicals with high economic value [10, 11].

2. MATERIAL AND METHODS

The process of obtaining energy from biomass, Figure 2, comprises three main stages, each stage being associated with specific technologies, namely:

- production of biomass,
- biomass processing
- biomass conversion,

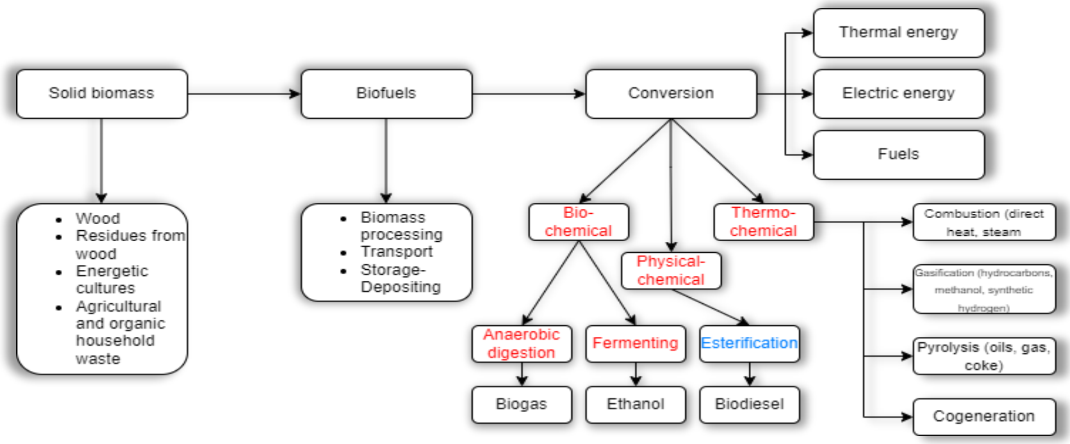

Figure 2. The process of obtaining energy from biomass [4]

Energy crops – *Miscanthus x giganteus* perennial grass is in the same taxonomic group as maize, sorghum, sugar cane and prairie grass. Unlike these varieties, photosynthesis is not affected at temperatures up to 5°C [12]. Table 1 shows the energy ratios between different energy crops.

Table 1.Energy ratio (between extracted energy and energy used to obtain biomass) between different energy producing plants

Harvest	Input energy (MJ/ha)	Extracted energy (MJ/ha)	Report
Miscanthus	9.224	300.000	+ 32.53
Willow	6.003	180.000	+ 29.99
Hemp	13.298	112.500	+ 8.46
Wheat	21.465	189.338	+ 8.82
Rapeseed oil	19.390	72.000	+ 3.76

As can be seen from Table 1 Miscanthus has the highest ratio of energy extracted to energy input and erodes the least soil. From all this it can be concluded that Miscanthus is the most suitable for biomass production. Because of its perennial nature, Miscanthus does not go into fallow, but is grown extensively on certain soils less suitable for other crops, where it remains for 15–20 years. Perennial cultivation has the advantage of reducing land preparation and planting costs. Miscanthus does well after any crop. Figure 3 shows the technology applied by INMA Bucharest to establish a Miscanthus crop [13].

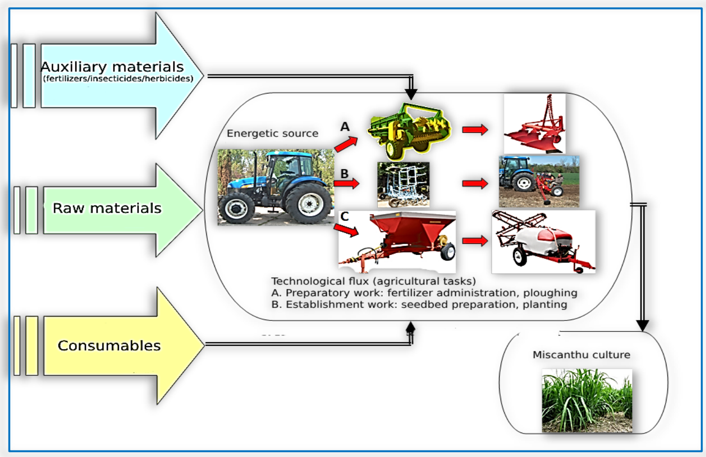

Figure 3. Miscanthus plantation establishment technology

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In order to set up the Miscanthus crop, INMA Bucharest made a Miscanthus rhizome planting machine, figure 4 and a Miscanthus rhizome harvesting technical equipment, figure 5. The Miscanthus planting machine MPM4 figure 4, works in aggregate with the 65 hp wheeled tractors, equipped with three–point suspension mechanism [13–15].

In order to use Miscanthus plants, they must be harvested. Miscanthus plants are harvested from the third year of growth, in February when the stems have reached [13]

Figure 4. Miscanthus rhizome planting machine MPM4 [13]

At an optimum moisture content of 11 to 12%, depending on the requirements for the use of the harvested material, there are two technological harvesting options [16–18]. In order to use Miscanthus plants, they must be harvested. Miscanthus plants are harvested from the third year of growth, in February, when the stems have reached an optimum moisture content of 11to12%. Depending on the requirements for the use of the harvested material there are two technological harvesting options [19–21]:

Figure 5. Technical equipment for harvesting Miscanthus rhizomes ERR [13]

- Technology of harvesting directly from the heath with forage harvesters (towed or self–propelled), which in the working process performs shredding and loading of the shredded mass into transport means, if the transport to the processing place is small. The method, similar to that used in maize harvesting, is simpler and faster.
- Split harvesting technology, using rotary mowers to cut and lay the stalks in a continuous furrow on the ground and baling them with balers into large parallelepiped bales when long–term storage for processing or long–distance transport is required. The disadvantage of this method is that it is relatively slow and requires lower costs.

In the case of direct harvesting of Miscanthus (a perennial crop with a height of more than 2 m and high density), the technological process consists of cutting, chopping and loading the harvested material into transport vehicles [22].

The technological process is efficient if the forage harvester is equipped with high–growing harvesting equipment capable of cutting the entire plant (the full working width) [23,24].

Figure 6. Miscanthus Culture [22]

Figure 7. Tractor unit – towed combine for harvesting [22] MISCANTHUS stalks, during work

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The trailed combine for harvesting Miscanthus stems was tested on the experimental Miscanthus cultivated plot of INMA Bucharest, Figures 6 and 7. In the technological process of the combine the most important working organ is the chopping drum, which, thanks to its peripheral speed and the air current it creates, fragments the feed to the required size and throws it towards the exhaust system of the combine. Tables 2 and 3 show the working quality and operating indexes of the trailed combine for harvesting MISCANTHUS strains [22].

Table 2. Qualitative work indices

Nr. crt.	Specification	Measurement Units	Values			
			Test I	Test II	Test III	Average
1	Toothed rotor speed	rpm	46	46.5	45.4	46
2	Knife speed	rpm	288.4	288.6	288.5	288.5
3	Working width	m	1.6	1.6	1.6	1.6
4	Plant cutting height	mm	120	130	145	120 – 145
5	Degree of shredding	mm	12 –85	17–90	15–98	12 – 98
6	Material loss	%	≤ 5.2	≤ 5.5	≤ 5.3	≤ 5.3

Table 3. Operating indices

Nr. crt	Size determined	Measurement Units	Values			
			Test I	Test II	Test III	Average
1	Working speed	km/h	5.8	6.1	6.3	6.1
2	Total power to drive the working combination (without coupled trailer p_{tot}	kW	39.60	39.70	39.9	39.70
3	Effective working capacity (without towing trailer) (w_{ef})	t/h	7.6	7.9	8.1	7.9
4	Effective hourly working capacity	ha/h	0.75	0.77	0.81	0.8
5	Fuel consumption	l/ha	18.8	19.1	19.1	19

Agricultural waste represents a significant share of the total biomass potential. Theoretically, all agricultural residues can be used as fuel, but the range is limited in practice by the possibilities of production, compaction, transport and use [22].

The following types of agricultural residues are considered: straw, maize stalks and stalks of corn, vine ropes, biomass from cleaning of orchards, yards, parks, etc., biomass from felling and cleaning of trees on forestry farms, hemp and flax stalks. Pellets and briquettes can be produced from these sources. To obtain heat, they are burned in special installations: small boilers or large thermal power stations.

Biomass processing technologies aim to transform biomass so that it can be used for energy purposes, Figures 8, 9, 10 and 11.

The technological flow of biomass processing can include the following steps:

- baling the biomass;
- marking the bales (by crushing, grinding, granulating, cutting) in preparation for compaction;
- compacting the material (pelletizing, briquetting);
- transport and storage of biomass.

During this technological process, phases such as drying, sorting, etc. may occur.

Figure 8. Technology for obtaining pellets and briquettes from Miscanthus and forest residues [12]

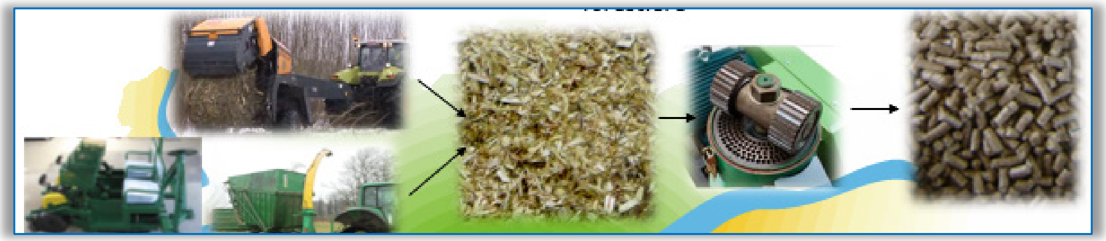

Figure 9. Energy willow pellet technology [12]

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Every year, a large part of the straw left after harvesting agricultural crops is burnt or buried in the soil with ploughing. However, straw and other cereal residues are the most accessible and efficient alternative sources of energy. Heating systems based on burning straw (boilers, heat generators) are used to heat homes, schools, farms, greenhouses, drying grain, Figure 10, etc. They operate on solid biofuels (straw rolls, bales weighing up to 50 kg, briquettes and pellets) to produce hot air, water and hot steam. [13]

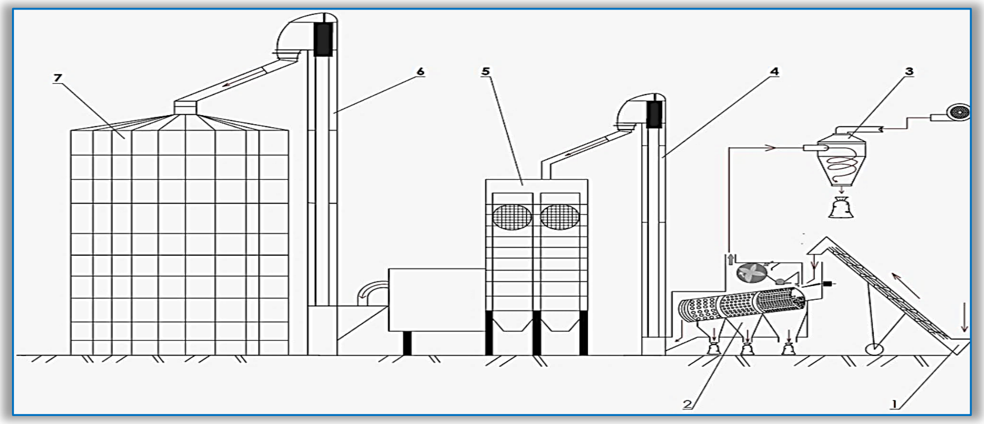

Figure 10 . Conditioning plant for cereals and technical plants [14]

Advantages of using bio–waste for heating [16]:

- Heating or drying of cereals, medicinal plants, fruit, etc. uses local straw resources;
- the heating system does not require a gas pipe;
- resolves the problem of unauthorized burning of surplus straw in the field and reduces environmental pollution from burning;
- cereal straw has a very high energy potential: one tone of straw replaces 550 kg of coal or 350 m3 of natural gas [17]

3. CONCLUSIONS

- By using the technologies and equipment related to these technologies it is possible to develop energy crops on land not used for agricultural purposes: on slopes, fixing the soil and improving its quality; on highly degraded land – barren soils, saline, eroded, sandy soils, etc., achieving bioremediation of polluted soils by assimilating excess ions; on marshy soils (recommended).

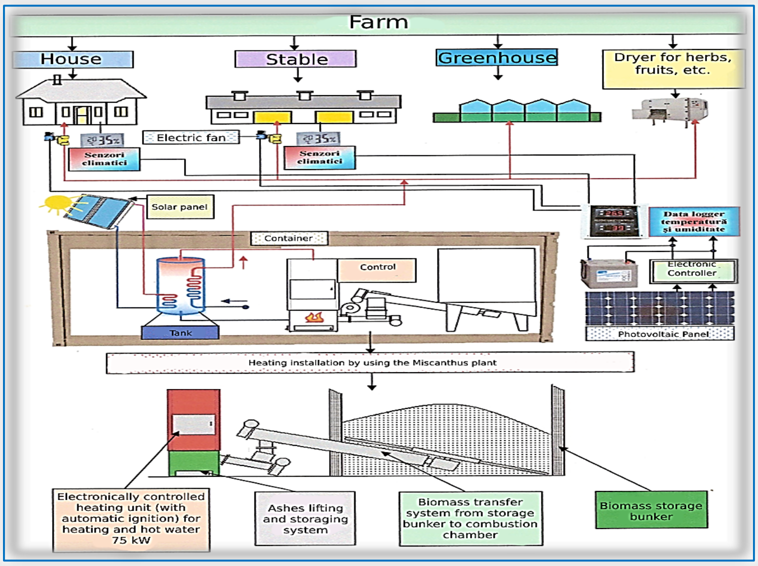

Figure 11. Miscanthus IIVM energy plant heating system [16]

- Biomass is a globally accepted form of renewable energy that contributes to reducing global warming by reducing greenhouse gas emissions.
- The availability and valuation of natural, renewable resources is a complex issue that needs to take into account a variety of factors such as: availability of resources over time; geographical distribution; share in production; price stability; legal and commercial status; reliability of sources; social effects of exploitation; environmental effects.
- Biomass is a particularly promising renewable energy source for Romania, both in terms of potential and in terms of possible uses. This type of clean energy is virtually inexhaustible in the medium and long term.

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