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Characteristics of biomass utilization in Hungary; possibilities and restrictions regarding sustainability

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Abstract. Hungary, lacking other natural resources to provide the sufficient amount of reserves to cover its population's energy-needs, has become a leading biomass producing country. Hungarian agriculture is capable to provide only an infinitesimal proportion of the current energy needs, and, despite the fact that agriculture is creating jobs, plundering agricultural energetics is not a solution and is contrary to the interest of those living in the Carpathian Basin. Besides our relatively huge extant potentials (topsoil, waters, forests, etc.) the consideration of the aspects of sustainability is indispensable because of the limitations due to the size of the country. In the field of agro-energetics, the appropriately controlled production and utilization of biogas is recommended the most of all.
Key Words: biomass, biomass potential, sustainability, energy crops.

Introduction. Biomass-based energy production is the oldest way of mankind to satisfy energy needs, and at present, being aware of the scarcely exploited potentials of biomass, many people consider it as the final solution to our energetic and environmental problems. Unfortunately, without supports and subsidies, even nowadays most secondary fuels made from biomass are noncompetitive against fossil fuels. However, the price of oil, reports on decreasing supplies, the expectably increasing demands, and the oil-dependency of certain economic superpowers are all pointing out that the old/new unexploited resources, as well as the restructuring of the energy-wasting economy in the first place, are necessary for progress.

As to the perspectives of biomass and other renewable and potentially environment-friendly energy sources, an approach with a wider context is suggested. This wider context is obviously provided by sustainability, since energy production has been placed into focus by the unsustainability of recent solutions. Hungary is a biomass superpower, but being aware of our supplies of environmental resources, practically this is our only resource that we can count on. This all raises the value of the relatively huge extant potentials (topsoil, waters, forests, etc.), but at the same time, because of the limitations due to the size of the country the consideration of the aspects of sustainability is essential.

Concept of biomass, biomass potentials. Renewable energy sources are natural resources that are reproduced through natural processes and the amount of which does not decrease during their transformation into utilizable forms. Such renewable energy sources are solar-, wind-, water-, sea current-, undulation-, tidal-, and geothermal energy. Biomass may also be considered as a renewable source of energy, although due to human exploitation there is a higher risk of it becoming less reproductive.

Legal concept of biomass is defined by the 2010 CXVII Regulation on the facilitation of vehicular utilization of renewable energy and the reduction of greenhouse gases (1 § 3):

"Biomass consists of the biological components of agriculture, including animal and vegetable materials, the biologically decomposable products, wastes and residues of forestry and related industries such as fishing and aquaculture, and the biologically decomposable components of industrial and communal waste."

Process of organic matter production of autotrophic vegetation is called primary production, whereas secondary production is the process during which heterotrophic animals build vegetable organic matter into their own bodies. Velocity of processes (intensity per time unit) is called productivity, and the result of those is called product; both are referred to as per area units.

Biomass (BM) is the total amount of organic matter that can be found at a given area unit in a given time. Biomass is added up by the total quantity of vegetation (fitomass, FM), animals (zoomass, ZM) and other living beings (EM). Human organic matter is not considered as biomass. However, most living beings have de facto living and dead parts (e.g. deadwood makes a significant proportion of the biomass of the forests' ecosystem), the latter of which is called necromass (NM). Necromass is not identical with mortified organic matter (ESZA), which includes mortified vegetable and animal organizations, fallen leaves, mould, etc. Biomass may be only a small proportion of the mortified organic matter but it may as well exceed the amount of that, depending on the type of symbiosis. Mortified organic matter is doomed to decompose or burn (e.g. in forest fires) thus ending the matter- and energy-cycle of the biosphere, or, it may as well get buried in oil- and coalfields (Bai & Zsuffa 2001; Bai & Lakner 2002).

Due to terrestrial primary production 3.4 tons of organic matter is produced per annum on one acre, and 6250 kJ of energy/m^2 gets bound. Secondary production is approximately one order of magnitude less than primary production (Mátyás 1997).

Out of $2,6x10^{24}$J/annum of solar energy hitting Earth slightly bit more than 2 ‰ produces, via photosynthesis, biomass by the energy value of $5,7 \times 10^2$ J/annum. This can be considered as the theoretical quantity of biomass produced through photosynthesis on Earth. In Hungary, 437×10^{18} J/annum of solar energy, with regard to terrestrial proportions, produces 958×10^{15} J/annum = 958 PJ of biomass a year. The primary aim of biomass production is the maintenance of life, but certain proportion of biomass can also be used for energetic purposes. Renewable energy derived from biomass is, after all, solar energy (Tóth et al 2011).

Primary source of biomass is the anabolic activity of vegetation. According to its place in production-utilization chain, biomass may be:

- primary biomass: main- and byproducts of forestry (products of conventional and intensive forests), natural vegetation (e.g. nature conservation areas, national parks, certain units of biotope networks, etc.), plants for food (grain, vegetables, fruit, etc.), plants and products for industrial purposes (rape, corn, herbs), plants and products grown for energetic purposes (Chinese cane, energy grass, rape biodiesel, corn ethanol, etc.), agricultural byproducts (e.g. straw, corn-stalk, sunflower-stalk, etc.);
- secondary biomass: byproducts of animal husbandry (organic dung, liquid manure), animal husbandry wastes (animal carcasses);
- tertiary biomass: organic wastes from the industrial sector and service sector, wastewater, sewage sludge, communal waste, sorted waste, recycled waste.

Energetic potentials of biomass. Researches dealing with the utilization of renewable energy resources kicked off at the end of the 1970s, after the energy price explosion. The recently developed, up-to-date large scale biomass combustion systems widely spread in certain countries' agricultural, local industrial and communal spheres. However, the development of more complex and more expensive technologies was called to a halt because of the subsequent constantly low energy prices on the international market. Nevertheless, in recent decades the development of technologies using renewable energy resources has again gained bigger attention because of the ever increasing environmental threats. The other reasons for the enhanced attention to the development were the reutilization of abandoned land in Western Europe and the attempt to refrain rural population from moving away (Monoki Á.).

Subcommittee of Renewable Energies of the Energetics Committee of the Hungarian Academy of Sciences, in the academic years 2003-2005, presented the theoretical potentials of the Hungarian renewable energies. According to the study, Hungary's theoretical energy potential of biomass is 203.2–328 PJ/annum. Studies created for the estimation of sustainable bioenergetic potentials present the estimated potentials of the residues of plant cultivation, forestry, and wood processing (Table 1).

Table 1
Estimated potentials of the by-products of crop production, forestry, and wood processing (Source: Tóth et al 2011)

	PJ/year		*PJ/year*
Crop by-products	169,6	Cane-cuttings	2,7
Cereal straw	67	Forestry by-products	31
Corn-stalk	78	Traditional firewood	24
Sunflower-stalk	17	Sawmill by-products	7
Rape-stalk	3	Wood processing	4
Sunflower seed hulls	1,9	Wood dust, shavings, natural wood waste	4
Total lignocellulose		204,6	

The main profile of biomass utilization is food production, forage, energetic utilization, and the production of agro-industrial goods. The most important methods of energetic utilization are incineration, briquetting, pyrolysis, gasification, and bio-gas production. Fields of biomass-based raw material cultivation:

- cultivation of woody plants of various cutting cycle (wattle, alder, willow, poplar, etc.);
- field cultivation of herbaceous plants (energy grass, reeds, etc.);
- cultivation of oilseed crops for biodiesel production (sunflower, rape, etc.);
- growing of plants suitable for ethanol production (barley, wheat, corn, etc.) (Dinya 2010).

Various possibilities of bioenergy utilization within primary biomass subdivision:

- enhancement of energetic utilization of crop production residues;
- conscious establishment of energy plantations with high energy yield for energy production;
- increasing utilization of forestry residues.

The bigger part of secondary biomass consists of byproducts, mostly animal dung, which, in form of biogas, may possibly be utilized for energy production.

Tertiary biomass is formed by the organic wastes of food industry, light industry, timber industry, and by those of settlements. Wastes of timber industry are already widely used for energy supplies, and settlements also tend to use organic waste for energetic purposes (Tóth et al 2011).

Biomass, as an energy resource, may be utilized in the following ways:

- directly: by combustion, with or without preparation;
- indirectly: after chemical transformation (liquefaction, gassing) as liquid propellant or as flammable gas; as fuel after alcohol fermentation; as biodiesel by esterification of vegetable oils; as biogas after anaerobic fermentation.

Biomass can be used for low and mid performance decentralized heat and energy production, as well as a propellant due to its relatively low energy density (Monoki Á.).

Characteristics of biomass utilization in Hungary. In Hungary among the renewable energy sources the central role of biomass has been emphasized because of its excelling utilization due to the favourable natural circumstances and the extant technical background. In 2009 Hungary used up 65 PJ of biomass based energy: 92% of the total energy production based on renewable energy sources (Eurostat 2011). Furthermore, it gives 35% of the total of approx. 750 PJ of renewable energy potentials.

Energetic use of biomass is possible primarily within the range of woody and herbaceous energy plantations and that of the utilization of wastes and residues produced by conventional agricultural branches.

Energy use and energy needs of the Hungarian national economy and agricultural production have increased quickly after WW2. The main drive of the economic growth was the increase of human performance together with the recourse of the technically utilized energy sources. Due to the forced industrialization and in sync with the demands of the society, the production of food- industrial raw materials gained central position in the agricultural sector. During the socialist era Hungary became a world leader food producer, hence the enhanced export toward socialist countries. After the political transition in 1989 the system of export trade was restructured and so agriculture had to face different challenges. The realignment of our agricultural production resulted in the decline of food production. Because of this, the establishment of technical-economic foundations of the agro-industrial raw material production in behalf of the maintenance of ecological balance and agricultural employment became a new field of agricultural energetics. Within this field a massive energy-need showed up.

Hungary has outstanding agro-ecological opportunities for the competitive production of biomass. Hungarian agriculture is capable of the sustainable production of biomass at an amount that exceeds provisional and feeding needs. Hungary's potentials for biogas production are also significant. Theoretical potentials of biological energy sources (bioenergy) may exceed 20% of the estimated energy needs by 2020. Bioenergy based electricity production is predictable and manageable, thus bioenergy production faces only the challenges of competitiveness in the first place. Risks of climate change (the climate is becoming drier) might also be taken into consideration. In the future bioenergetics may gain an increasing role in supplying local heating needs, and furthermore, the distribution of low and mid capacity electric and thermal energy systems will also be emphasized (Figure 1).

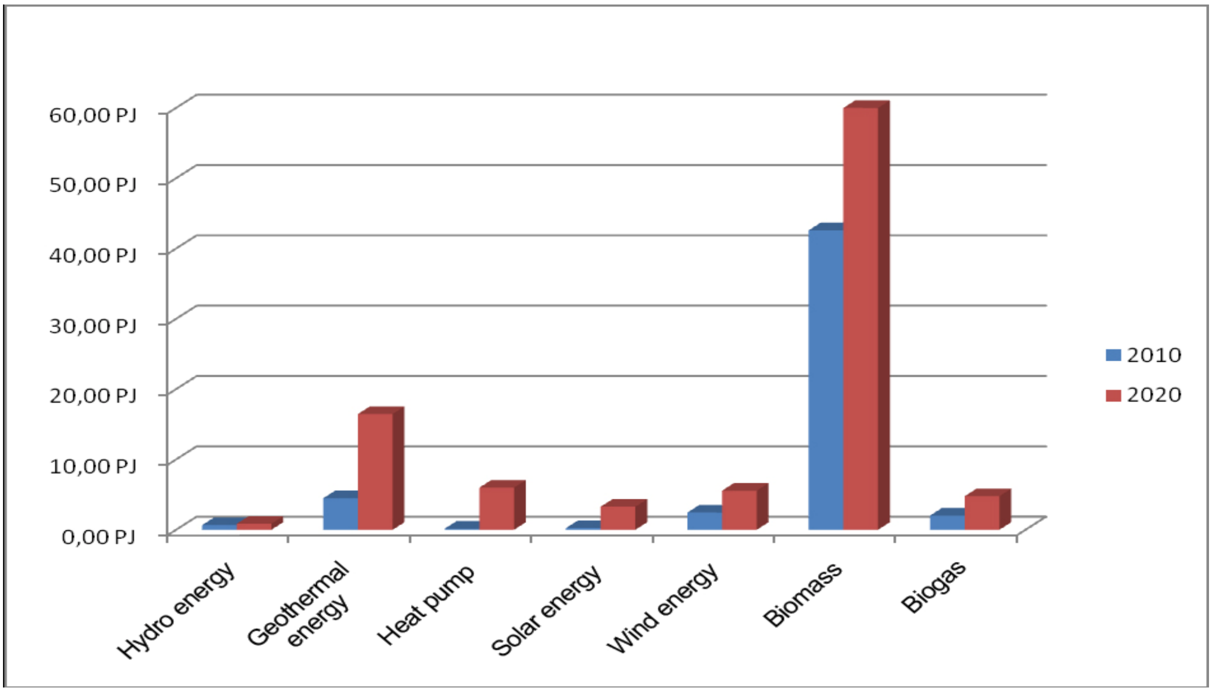

Figure 1. Amount of Renewable Energy and Forecast of Changes
(Source: Hungary's Renewable Energy Utilization Action Plan 2012-2020)..

In Hungary, the amount of renewable vegetable dry matter biomass is 55-58 tons (byproducts included). Under appropriate conditions out of 25-26 million tons of agricultural residues and 1-2 million tons of forestry residues approximately 6-8 million (3-4 million tons at the very least) tons of organic matter would be useable for energetic purposes. In order to make this utilization larger scale and more effective, appropriate ecological, economic, and technical conditions must be fulfilled. The total energy source of the utilizable 6-8 million tons of biomass equals to approx. 1.5-2.0 million tOE (Kocsis 1993).

Biomass based energy sources are usually cheap, decentralized energy sources. Calorific value of dry biomass is close to the energy content of medium quality lignite (17-18 MJ/kg or 0.41-0.43 kg OE/ kg). One of the basic characteristics of the production of biomass based energy sources is that the dry matter yield per area (t/ha) and the corresponding net-gross energy yield (tOE/ha) are reasonably low in case of traditional cultures (1.5-3.5 t/ha, 0.3-1.3 tOE/ha). However, these figures can be raised by the improvement of biological foundations and agro-technical methods, that is, in case of energetic tree plantations and other energetic plant cultivations the rate may raise up to 8-9 t/ha, and 1.7-2.6 tOE/ha, respectively. However, most of the agro-technical methods plunder the ecological system more and put food production at a higher risk by placing agro-energetic production to more productive soils (Figure 2).

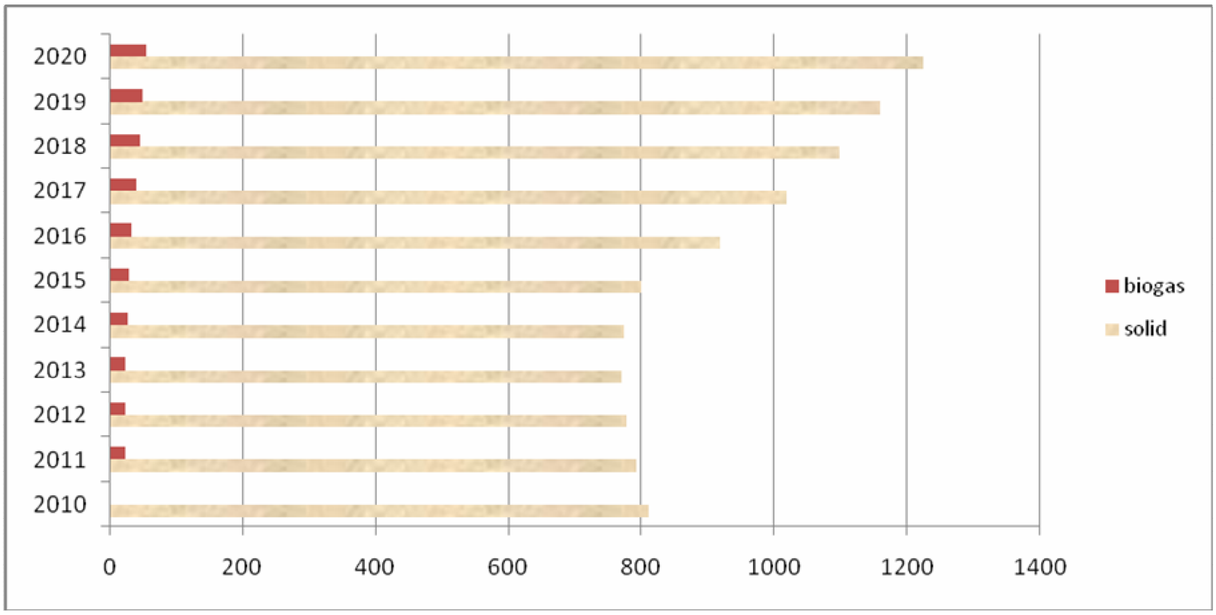

Figure 2. Expected contribution from biomass use in kilotons of oil equivalent (ktOE) (total biomass consumption) (Source: Hungary's Renewable Energy Utilization Action Plan 2012-2020)

Because of the relatively low energy density, these energy sources are recommended for low and medium range, decentralized local thermal-and electric- energy needs (Table 2). Utilization of biomass (fitomass) as a combustible is most favourable if biomass is produced and combusted within the range of 20-30 km.

In case of biomass combustion emission rates are more favourable than those in case of ordinary combustion systems. Nevertheless, in case of certain contaminants surplus emission should be expected (e.g. NO_x, dust). Certain bio-combustibles (wood, compressed slacks, etc.) can be combusted in ordinary coal combustion systems (furnaces), however, in such cases most of the calorific value of volatiles exhausts together with smoke, unutilized. In this case the amount of environmental pollutants is smaller than in case of coal combustion, but worse than if it was incinerated in high performance furnaces or special combustion systems (Tóth et al 2011).

Table 2

Heating value and energy efficiency of biomass energy (Source: Tóth et al 2011)

Megnevezés	*Moisture %*	*Biomass yield t/ha*	*Heating value MJ/kg*	*Net heating value kgOE/kg**	*Net energy yield kgOE/ha**
Cereal straw	10-15	1.5-3.5	15.3-16.2	0.29-0.31	435 - 1085 HE
Rice straw	20-25	1.3-3.2	13.5-14.4	0.26-0.28	338 - 986 HE
Sunflower-stalk	25-30	1.9-3.5	12.4-13.5	0.24-0.26	456 - 910 HE
Corn-stalk	35-40	3.5-5.5	10.2-12.4	0.19-0.24	665 - 1320 HE
Firewood	15-25	2.0-2.5	13.5-15.3	0.26-0.29	520 - 725 HE
Forest wood waste	25-30	1.5-2.0	12.4-13.5	0.21-0.23	311 - 451 HE
Forest wood shavings	25-35	8.0-9.0	11.3-13.5	0.22-0.26	1760- 2610 HE
Silage for biogas	-	8.0-9.0	10.5-12.6	0.22-0.26	2000-2700 P
Oilseed rape	-	1.0-1.5	35.6-36.8	0.85-0.88	850 – 1320 P
Straw	10-15	3.0-4.0	15.3-16.2	0.29-0.31	870 – 1240 P
Total	-	4.0-5.5	-	-	1720-2560 PHE
Bio-ethanol	-	1.5-3.5	25.1-27.1	0.6-0.66	900 – 2275 P

* Efficiency: 80 %, HE: Heat energy, P: Propellant

Sustainability during biomass utilization. Objectives of Hungarian environmental policy, the Kyoto treaty, and obligations on behalf of the European Union demand the growth of renewable energy sources.

One of the important fields of sustainable energy economy is eco-energetics, that is, the exploitation of renewable energy sources. However, nonrenewable energy sources should also be treated as part of sustainable energy economy, since the full scale replacement of them is impossible before long. In close relation with this it is of course inevitable (though undoubtedly it requires money investment) to replace nonrenewable energy sources with more efficient, environmentally friendly technologies.

It is a disputed question to what extent biomass based energy production is capable of complying with sustainability requirements. Many argue for the so called external benefits of biomass based energy production. These external benefits have many components and they concern many actors not involved directly in energy production. Energetic utilization of abandoned lands, rural employment possibilities, and the social benefits of population retention and financial earnings must be mentioned. It is an understood thing that in the background there are vast conflicting political and business interests and concentrated capitals. There are plenty of questions in the background, which raise various dilemmas and result in the lack of determination (Dinya 2010).

In Hungary the proportion of animal husbandry and plant cultivation has significantly changed. Animal husbandry, unfavorably enough, is incapable of taking up products from plant cultivation, and these products are difficult to realize. Plant growing for energetic purposes may thus induce structural changes of the crop land, which will inevitably decrease surplus in plant growing (Gyulai 2007). Unfortunately politics is not very busy trying to solve this socially disadvantageous situation, but on the contrary, in accordance with global trends that ignore Hungary’s capabilities, politicians have the intention of taking advantage of it. It is justified by present Hungarian situations that all this may only be ecologically sustainable if agro-energetics maintains the possibility to integrate into the biological cycle. Hungary’s Renewable Energy Utilization Action Plan (2012-2020) declares that biomass use based on favourable domestic agro-ecological attributes, with regard to sustainability criteria, may contribute to the preservation and creation of workplaces. Energetic usage of organic matters of animal husbandry (biogas) may enable the productive treatment of waste, thus improving the competitiveness of the sector. Local energetic usage of forestrial and agricultural residues and other solid wastes (e.g. plow-land byproducts, loppings of orchards and vineyards) results in supplementary revenues for farmers and growers, and it significantly decreases fossil energy needs.

Energy producing facilities take it for granted that resources are always at their disposal and that there will be a constant energy need. However, environmental limitations of steady renewable supplies (including biomass) must be considered:

- yield fluctuation (quantity and quality differences depending on annual weather);
- periodicity (primarily in case of wind- and solar energy; in case of the lack of storage of biomass);
- seasonality (in case of all renewables);
- low energy density (as compared to fossil energy sources and to users' needs).

Seasonal harvest, and the transportation, treatment, and preparation of the significant amount of mass are very complex logistic tasks. Furthermore, since the average energy density of biomass is significantly lower than that of classic energy sources, logistic costs restrain the size of the optimal processing plant. This means that the readjustment of present high performance fossil fuel power plants to biomass based combustion systems is economically unprofitable, that is, it does not comply with the economic requirements. For example in case of Mátra Power Plant, to be able to fully replace coal combustion, according to rough estimations, energy plants should be grown around the power plant in a radius of approximately 120 km. Furthermore, mixed combustion of biomass and coal in low efficiency coal combustion systems is also out of question (the average efficiency of our older power plants is hardly up to 30%) (Dinya 2010).

The production of renewable energy sources compete with food production, nature preservation, and other ways of land use. The increase of energy needs, the decrease of cheap fossil fuels, and the misguided environmental policy have compelled the enhanced production of biomass. It is also evident that if the pressure to use biofuels increases, there will be an enhanced need for bio-raw materials. Along with the need the prices rise, and so does the chance for a great deal (Gyulai 2007). All this leads to the growth of croplands, which takes place for the detriment of nature: harmful biological aftermaths of crop monocultures, degradation and pollution of soil may occur (Dinya 2010).

Ambitious plans of energy policy do not calculate with the land needs of raw material production. Proposed land conversions and the restrictions of ecological objectives are ignored most of the times, however, taking these aspects into consideration it seems obvious that although it is possible to grow energy plants in Hungary, the size of land to be used for energetic purposes is viewed too optimistically. In the future, the size of the land utilizable to create energy plantations may be approximately 1/2 million acres, which is already exceeded by the land needs of plants grown for biomass raw materials (Pappné Vancsó 2010).

Due to a European impact assessment it became clear that complying with the requirements of the EU (10% biofuel ratio until 2020) would require 72% of the community's croplands, and fuel would more than double in price (Szemzõ 2004). In Hungary to fully replace benzine and diesel, counting with 1000-1200 liters of ethanol and 1200-1400 liters of biodiesel per acre per annum, there would be a massive need for approx. 2 million acres for bioethanol production and another 2 million acres for biodiesel raw materials. It is close to the total amount of 4.5 million acres of cropland in Hungary, and food production has not yet been taken into account (Gyulai 2007). Since the production of biofuel is the least favourable of biomass energy sources, it might be worth reconsidering the objectives of energy policy and the structure of Hungarian croplands: fields unnecessary for food production should be converted into energetically, ecologically, and socially profitable and efficient energy plantations (Pappné Vancsó 2010; Elekes 2008).

In case of biomass use the reduction of the environmentally harmful effects of production and utilization to the lowest possible level is crucial, and so is the maximization of environmental and economic advantages.

As to biomass utilization the following order of priority may be set up:

- utilization of wastes and byproducts created during the production, processing, or consummation of biomass used for non-energetic purposes;
- recultivation of abandoned lands for energetic purposes (biomass production as an energy source);
- forestry exploitation and the inclusion of land used for other purposes.

So the main question in connection with biomass is whether the energy balance is negative or positive, or to put it another way, is more or less energy needed for the production of biomass than the expected energy output of renewable energy sources? (Gyulai 2007) Beyond the previous question, the authors of this article certainly consider, and so does the frequently cited Gyulai Iván, the complex ecological effects of biomass production and utilization to be crucial.

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