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The potential for the production and use of biomass-based energy sources in Hungary

Directive 2009/28/EC established a common framework for the use, production and promotion of energy from renewable sources. Subsequently, each European Union Member State was required to prepare a national Renewable Energy Action Plan (REAP) which specifies the share of energy from renewable sources to be consumed in transport, as well as in the production of electricity and heating, in 2020. The Hungarian REAP was published in December 2010. In order to identify what further steps are required to meet the targets set by the REAP, in this article we review the current situation and the potential in Hungary for the production and use of biomass, biogas and biofuel. We conclude that the annual quantity of required biomass is already available and it should be possible to meet the demand for solid biomass for direct combustion without the need for significant areas dedicated to energy crops. The establishment of biogas power plants is determined both by electricity generation and by waste management considerations. Targeted financial support and new regulations are required to promote the injection of upgraded biogas into the natural gas grid. Hungary has great potential to produce first generation biofuels, particularly ethanol, not only for domestic needs but also for export.

Keywords: biomass; biofuel; biogas; Renewable Energy Action Plan; Hungary

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Introduction

Directive 2009/28/EC established a common framework for the use, production and promotion of energy from renewable sources (European Parliament, 2009) in the European Union (EU). For each EU Member State it set mandatory national targets for the overall share of renewable energy in gross final consumption and for the share of energy from renewable sources in transport. It also required each EU Member State prepare a Renewable Energy Action Plan (REAP) which set a roadmap to reach its national target. These REAPs should take into account the effects of other energy efficiency measures on final energy consumption (the higher the reduction in energy consumption, the less energy from renewable sources will be required to meet the target). They also established procedures for the reform of planning and pricing schemes and access to electricity networks, promoting energy from renewable sources. The Hungarian REAP (REAP, 2010) was published in December 2010.

Owing to its geography and location, Hungary is not among the richest EU Member States in terms of sources of renewable energy. It has no high mountains, no rivers with great inclines and no perceptible wind blowing in from the oceans. Taking the country's financial situation into consideration explains why in Directive 28/2009/EC Hungary was committed to reach only 13% of renewable energy in its total energy consumption by 2020 (European Parliament, 2009). This level puts Hungary into the bottom quarter of the EU Member States, and this situation has not changed despite the fact that the final commitment in the REAP was increased to 14.65 per cent. Since in 2005 the base level of renewable energy share was also low (4.3 per cent), Hungary still needs to make significant progress to reach the 2020 target. Non-fulfilment of these commitments would result in not only the loss of funds which are linked to promoting renewable energy generation, but would result in proceedings being launched against Hungary by the EU.

Hungary has however favourable conditions for biomass production. A large share of primary energy consumption could be gained from biomass even with the presently available technology. In 2006-2008, biomass based renewable energy represented 68-70 per cent of the renewable energy mix in the EU, while in Hungary it had already reached 92 per cent, reflecting the potential. Further development of biomass based energy production is however limited by financial and sustainability issues on the production side, the low purchasing power of Hungarian households, and the slow spread of 'green thinking' in the country.

In view of their importance, this study focuses on the biomass based renewable energy sources and assesses the current situation and the potential of agriculture and forestry in Hungary to meet the targets set by the REAP. Because the nature of biomass conversion of the three processes strongly differs, the production and use of biomass (direct combustion for heat and power generation), biogas (gasification in biogas plants) and biofuel (first generation biofuel production) are discussed in separate sections. However, all three of these so-called technology platforms are technically and economically viable, feasible, at least under certain condition, and they should be the core elements of any mid-term plans designed to increase renewable energy utilisation.

The authors were the major contributors to Popp and Potori (eds 2011) and the purpose of this article is to disseminate the findings of this research to the wider scientific community. The analysis has been updated where necessary and has been extended by contrasting the Hungarian plans with those of other EU Member States. Data and information obtained from the national REAPs submitted by the other EU Member States have been used as one of the tools for evaluating the feasibility of the Hungarian projections.

Energy recovery from solid biomass

In the EU wood is the most commonly utilised renewable energy source. In 2008, 47 per cent of the renewable energy used in the EU-27 (kilotonnes of oil equivalent, ktoe) was derived from wood (Table 1). In Hungary, the share of solid biomass in green energy production increased from 75 per cent in 2008 to 83 per cent in 2010 (REAP, 2010).

While in most EU Member States primarily water and wind power plants produce green electricity, in Hungary combustion of solid biomass provides the bulk of renewable electric power. But, due to the inefficiency of the power plants, only 3.6 per cent of the overall electricity production was generated from renewable sources in 2009 (Őri, 2010). Despite this, 73 per cent of the green electricity was produced by the combustion of biomass in 2008 (Őri, 2010; Stróbl, 2010). Since it is unlikely that the share of wind energy and hydropower will increase in the next few years (REAP, 2010), in the near future it will be necessary to increase the efficiency of the power plants in order to use the available biomass more effectively.

Table 1: Renewable energy usage for heating, cooling and electricity in the EU-27 and in Hungary, 2006-2008 (ktoe).

	EU-27			Hungary		
	2006	2007	2008	2006	2007	2008
Solar energy	989	1,265	1,729	2	3	4
Biomass	87,332	97,807	102,315	1,245	1,288	1,520
Wood	65,222	67,344	69,677	1,128	1,146	1,244
Biogas	4,871	7,201	7,586	12	17	22
Other	10,969	14,438	14,848	94	108	92
Geothermal energy	5,562	5,751	5,778	86	86	96
Hydropower	26,537	26,666	28,147	16	18	18
Wind energy	7,077	8,971	10,165	4	9	18

Source: Eurostat

There is very little reliable information on the available quantities of the different types of biomass and their energy potential in Hungary. The data are scattered throughout the literature and usually consist only of the calorific value of the different types of biomass, so this information cannot be used for estimating the potential of Hungarian biomass. Thus, in order to do so, we firstly estimated the available amount of solid biomass from different sources, and then calculated the energy potential of the biomass that can be used for electricity and thermal energy production.

About 13 million m^3 of wood is produced every year from the two million hectares of forests in Hungary. Of this, 10.5 million m^3 (about 7.5 million tonnes) can be lumbered in a sustainable way. By comparison, every year only 7 million m^3 (about 5.3 million tonnes) was logged in the last decade and about 50 per cent of this amount was utilised for energy generation (REAP, 2010). Assuming that 50 per cent of the sustainable potential is firewood, currently only 67 per cent of this energy source is utilised. In addition to the timber, every year about 300-400 thousand tonnes (according to the REAP, 1.4-1.5 million m^3, namely 1.1 million tonnes) of logging waste remains in the forest because it cannot be collected with the commonly used technologies (Jung, 2009).

Every year about 700,000 m^3 (525,000 tonnes) of wood by-products (waste wood, wood chips) are generated in the wood processing plants (REAP, 2010). Because these are often contaminated with chemical substances, only about 50 per cent of the resulting quantity, mostly sawdust and bark, can be used for energy production (Szűcs and Szemmelveisz, 2002).

After the forest timber, agricultural by-products provide the next highest amount of biomass. Every year 4-4.5 million tonnes of straw originates from the production of grain cereals and of this about 2.4-2.8 million tonnes could be used for energy production in a sustainable way. In addition, 8-10 million tonnes of maize stover is produced annually (more than the weight of the grain). About 2.5-3.0 million tonnes of maize stover could be utilised as biomass for energy production (Biomassza Termékpálya Szövetség, 2008). In addition, a significant amount of sunflower stems and oilseed rape straw is produced annually, as is about 150-200 thousand tonnes of vineyard biomass and a further 400-500 thousand tonnes of orchard biomass. Although the heating value of these horticultural by-products is very similar to wood, and the wood chips thus produced can easily be stored and transported, at the moment most of the resulting biomass is either burnt on site or is chopped and ploughed into the soil. So at present most agricultural biomass is not used for energy production. The biggest problem is the lack of suitable combustion technology owing to the high investment costs. Because there is only a small number of plants and furnaces that can run on biomass, the by-products would have to be transported a long way to the place of utilisation (Marosvölgyi, 2010).

There are 400 hectares of perennial and 2,122 hectares of herbaceous energy crops in Hungary (REAP, 2010). On this production area, assuming an average yield of 20 tonnes ha^{-1}, about 50,000 tonnes of biomass is produced annually. Although there is increasing interest in growing energy crops, the production area has not changed significantly in recent years. The main reason for this is that the price for chips is almost the same as the price of firewood, but the production of wood chips from energy crops is more expensive than logging. Therefore the production of energy crops can only be envisioned if the distance to the recipient plant is no

Table 2: Estimated amount of the available solid biomass for energy recovery in Hungary (thousand tonnes).

	Potentially available biomass	Biomass used for combustion in 2009	Available biomass on medium term	Estimated consumption of biomass in 2020
Forestry (firewood)	3,439 (ca. 4.6 million m^3)	2,644	3,250	2,114
Logging waste	400 (ca. 533,000 m^3)			
By-products from orchards and vineyards	700 (ca. 933,000 m^3)			
By-products from the wood industry	260	260	550	231
Energy crops	50	50	5,600	1,914
Agricultural by-products	8,500	0	5,400	3,522

Source: REAP (2010) and calculations of AKI

Table 3: Planned cultivation area of energy crops according to the National Renewable Energy Action Plans of some EU Member States (ha).

	Perennial energy crops in 2006	Herbaceous energy crops in 2006	Total area in 2006	Area planned for cultivation in 2020
Austria	800	33,000	33,800	300,000[1]
Sweden	14,000	n.a.	14,000	44,000
Netherlands	0	10,000	10,000	10,000
United Kingdom	4,196	5,316	9,512	700,000
Poland	6,566	250	6,816	n.a.[2]
Italy	5,105	n.a.	5,105	n.a.
Slovenia	0	2,980	2,980	n.a.
Hungary	401	2,122	2,523	200,000
Germany	1,200	1,100	2,300	2,300
Denmark	1,000[3]	50	1,050	n.a.
Ireland	63	617	680	n.a.
Slovakia	150	200	350	n.a.
Lithuania	300	0	300	n.a.
Portugal	0	236	236	n.a.
France	192	0	192	n.a.
Romania	20	n.a.	20	n.a.

[1] In Austria only two per cent of the biomass used for energy production was solid biomass, the highest amount of biomass was silo maize in 2008 (Kranzl and Kalt, 2010)
[2] n.a.: data not available
[3] 4,000 hectares in 2010

Source: Renewable Energy Utilisation Action Plans of the EU Member States

more than 50-80 kilometres (Gyuricza, 2010).

About eight million tonnes of solid biomass for combustion will be needed to meet the 14.6 per cent targeted share of renewables in 2020 (REAP, 2010). It is scheduled that 45 per cent of this amount will originate from agricultural by-products and waste, 27 per cent will come from forestry, 25 per cent from energy crops and 3 per cent from wood industry by-products. Clearly, the authors of the REAP envisage a dominant role for energy crops. They estimate that there are about 1 million hectares of land that are not suitable for agricultural production, and from this area some 200,000 hectares could be used for the production of energy crops. The REAP anticipates the production of 5.6 million tonnes of energy crops annually (Table 2). However, to achieve this (based on an average yield of 20 t ha^{-1}) in the next 5-6 years about 280,000 hectares of agricultural land of average quality (i.e. also suitable for agricultural production) would have to be dedicated to the production of energy crops.

Among the EU Member States, only Austria and Sweden have areas dedicated to energy crop production bigger than 10,000 hectares. Therefore Hungary's aim to achieve about 200,000 hectares of energy crops is one of the most ambitious plans in the EU. Apart from Hungary only Austria, the UK and Sweden plan to dedicate major areas to the cultivation of energy crops (Table 3). Most of the EU Member States do not plan to meet their renewable energy target by cultivating energy crops. They would prefer to use solar, wind and geothermal energy to a greater extent or they plan to use the available biomass in a more effective way.

Biogas production and utilisation

Biogas production in the EU is growing rapidly. Consumption increased from 5 million toe per year in 2005 to 8.3 million toe in 2009 (EurObserv'ER, 2010). The most spectacular developments in the sector have been in Germany where smaller capacity biogas plants, principally processing maize and rye for silage and manure, with a generation capacity of 300 to 500kW on average, have been implemented. The total number of biogas plants in the EU Member States had already approached 6,000 in 2009, 4,900 of them operating in Germany. In Hungary, in spite of the huge amount of available agricultural raw materials, the rate of biogas production per 1000 inhabitants is lagging behind the EU average (Figure 1).

In Hungary, 21 municipal waste biogas plants operated in 2010, with a total electricity generation capacity of 12.6 MW. Landfill gas was obtained from 20 landfills, with a generation capacity of 4 MW, and 12.7 MW of additional capacity was under construction in 2010 (Bódás and Kovács, 2011). In 2010, 15 Hungarian agricultural biogas plants were operated, with an average generation capacity of 1 MW. So-called agricultural biogas plants in Hungary are usually closely connected with food processing factories (e.g. in Pálhalma, Nyírbátor, Kaposvár and Szarvas) or with farms generating

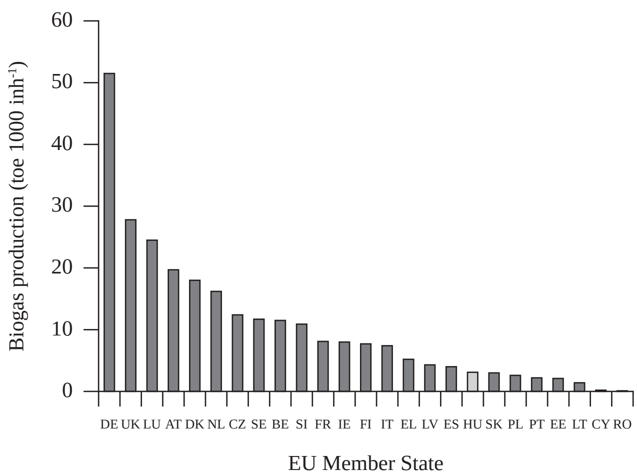

Figure 1: Primary energy biogas production per 1000 inhabitants for each European Union Member State in 2009.

EU-27 mean = 16.7 toe per 1000 inhabitants. No data are available for Bulgaria and Malta.

Source: EurObserv'ER (2010)

large quantities of agricultural by-products (e.g. in Kenderes, Csengersima, Kapuvár and Biharnagybajom). The average capacity of the smaller size biogas plants is about 500kW. Hungarian biogas generation capacity is projected to rise from 14 MW to 100 MW by 2020 (REAP, 2010). The electricity generated will reach 636 GWh by 2020.

The installation of biogas plants is determined by several factors (the quantity and quality of the substrates, the geographical position of the plant, the utilisation and the distribution of the produced biogas, flexible technological alternatives, available capital for the investment, investment return indicators etc.). Therefore, the construction of a biogas plant needs to adopt the most appropriate technology among many technological alternatives.

In Hungary, there is no standard procedure for licensing the construction of biogas plants due to the fact that obtaining permits is a complicated process with several threads running concurrently. The period required to plan and licence a biogas plant is twice or even three times as long as that of the construction itself. There are no two similar permit procedures for biogas plants: the procedure is rather difficult and not very transparent (Energia Klub, 2010). The estimated average investment costs for a biogas plant per 1kW of performance may amount to HUF 1.2 or 1.3 million. The project costs may be even higher if the biogas power plant has also to perform special functions (such as waste management). As a general rule, the specific costs are slightly decreased with increasing capacity. In Hungary, at the actual cost/return ratio and due to the Mandatory Take-off Scheme (*kötelező átvételi tarifarendszer*, KÁT) for electricity, biogas plants of small wattage (<500kW) can operate economically only in exceptional cases, while implementation of similar plants might be also necessary, principally for the sake of waste management.

In the context of the legal and economic environment, the three best available ways to use the biogas produced in Hungary are:

- Upgrade the biogas by increasing its calorific value to natural gas quality and to feed the biomethane thus produced into the natural gas grid. This is the most reasonable method but is not economic with the current prices and supports. Ten per cent of the 14 billion m^3 natural gas consumption could be substituted by biomethane production (Hungarian Biogas Association, 2011);
- The direct local utilisation of biogas. Biogas which has lower heating value could be utilised close to the biogas plant. Biogas plants which produce low calorific value biogas could be connected to the district heating system;
- Use the biogas for electricity production by decentralised power plants. Biogas produced in decentralised cogeneration is usually transformed by gas engines. This process can only be efficient where the cogenerated heat is used locally. If the heat cannot be recycled, the efficiency of biogas production is about 40%, when the cogenerated heat can be used for heating systems, the efficiency could reach 80%.

The most important aspects when setting up a biogas factory utilising agricultural materials are the optimisation of the logistics background and of the raw material provision. Biogas generation based exclusively on liquid manure is not typical either in Hungary or in any other EU Member States. From biological aspects, the C/N ratio required for efficient fermentation and biogas production can only be achieved by using a mixture of several vegetable and animal materials. German biogas plants which work with three or four kinds of raw materials have lower production costs than those which produce biogas only from liquid or solid manure [ADEME, 2010].

A large quantity of fermentation residues is generated during biogas production. In addition to guaranteeing raw material supply, the storage, marketability and/or usability of the residues should also be taken into account during planning of the plants, as all of these factors may influence the profitability of production. Both the geographical location of the land producing the raw materials and the land available for allocating the decomposition residues of the biogas plant has an impact on the profits, as transport is a major cost factor.

A significant amount of waste and by-products are produced during agricultural production and food processing. In the current economic regulatory environment, the optimal way to dispose of these by-products is to use them in biogas plants (Bódás and Kovács, 2011). In ensuring compliance of the treatment and the receipt of by-products with the regulatory system, the investment costs of a biogas plant, based on the data in Table 4, could rise significantly and can achieve 1.2-1.3 billion/MW_{el} as well.

Table 4: Source materials of a typical Hungarian biogas plant.

Material	Volume used (tonnes year^{-1})	Average dry matter (%)	Organic dry matter (%)	Organic dry matter (tonnes year^{-1})
Maize silage	22,750	33	95	7,132
Animal/slaughterhouse by-products	8,750	20	80	1,400
Pig manure	8,750	6	85	446

Source: MEH-Pylon (2010)

Table 5: Estimated potential levels of biogas production in Hungary.

Substrate	Quantity million tonnes year^{-1}	Biogas production billion m^3 year^{-1}	Natural gas equivalent billion m^3 year^{-1}
Animal by-products	43	1.6	1.1
Landfill wastes	10	0.7	0.5
Energy crops	30	3.3	2.2

Source: Lovas (2010)

By using 1.6 billion m^3 of animal and slaughterhouse by-products (including manure) and 0.7 billion m^3 of landfill wastes, 2.3 billion m^3 of raw biogas could be produced which could be enough to substitute 1.6 billion m^3 of natural gas, i.e. 11% of the yearly natural gas consumption in Hungary (Table 5). By producing energy crops, this quantity of biogas production could be more than doubled (Lovas, 2010).

Estimates for the potential of biogas production in Hungary range from 40 to 223 PJ year^{-1} (Szunyog, 2009). The theoretical energy potential, if the whole quantity of biomass is used to produce biomethane with the most efficient technologies, is estimated by Szunyog (2009) to be as follows, allowing the replacement approximately 9.5 billion m^3 of natural gas: plant production by-products: 131 PJ; forest by-products: 39 PJ; animal husbandry by-products: 4 PJ; sewage sludge: 6 PJ; and landfill: 42 PJ.

Taking into account of the quantity of the theoretically available (maximum) raw materials in Hungary, the producible volume of raw biogas could, in the case of the highest heat value, 25 MJ m^{-3}, amount to 8.5 billion m^3. In the case of the highest heat value, 39 MJ m^{-3} (in natural gas equivalent), the biogas production could be equivalent to 5.7 billion m^3 (imported Russian) natural gas.

If the biomass were transformed into biogas/biomethane with lower efficiency, the available biomass could generate 75 PJ energy and could replace a maximum of 1.9 billion m^3 natural gas. Biogas will account for 5 PJ (4%) of the total 120 PJ bioenergy production by 2020 (REAP, 2010).

Thus in terms of the share of biogas in total electricity consumption, Hungary is likely to still be in a lagging position amongst the EU-27 Member States in 2020 (Figure 2). In spite of Germany's leading position in the EU in the installation and operation of biogas plants, Denmark and Latvia have the highest projected share of biogas in overall electricity production in 2020. According to the Danish Energy Strategy, Denmark intends to achieve independence from coal, oil and natural gas through a shift to wind and biomass. In Denmark, the favourable economic and legal framework has had a positive impact to the development of biogas industry. The Danish biogas industry was promoted by legislation regarding handling of manure, energy and waste treatment legislation, subsidies for construction, and research (Al Seadi, 2010). In line with the Danish Renewable Energy Action Plan, Denmark plans to use up 50% of the manure produced for biogas production, and increase the biogas based energy to 20 PJ (against 4 PJ in 2010, 0.5% of total energy consumption in Denmark). Denmark's estimated biogas potential is about 40 PJ (of which 26 PJ derives from manure).

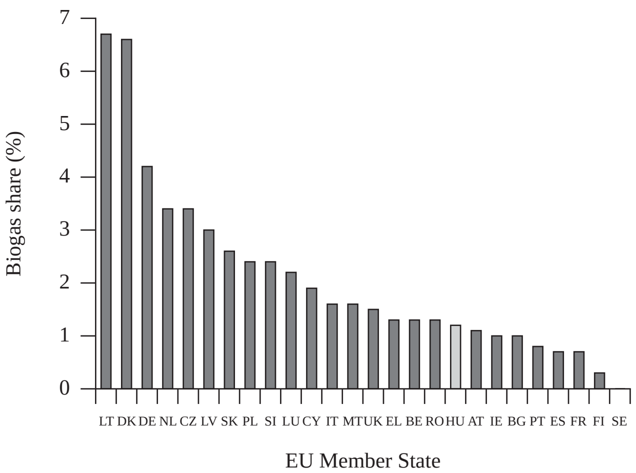

Figure 2: Projected biogas share in electricity consumption for each EU Member State in 2020.

EU-27 mean = 1.8%. No data are available for Estonia.

Source: ECN (2010)

Table 6: Projected renewable energy use in transport in Hungary, 2020 (ktoe).

Source	2005	2010	2015	2020	Distribution, 2020 (%)
Bioethanol/ETBE	5	34	106	304	56.8
Biodiesel	0	110	144	202	37.8
Hydrogen	0	0	0	0	0.0
Renewable electric energy (road)	0	0	0	2	0.4
Renewable electric energy (other)	0	6	15	22	4.1
Other renewable sources (biogas)	0	0	1	5	0.9

Source: REAP (2010)

Production and use of biofuels

Directive 2009/28/EC obliges each EU Member State to achieve a 10% share of renewable energy in transportation by 2020 (European Parliament, 2009). In order to comply with this requirement, the Hungarian REAP envisages increasing consumption of bioethanol to 304 ktoe, of biodiesel to 202 ktoe, of electric energy generated from renewable resources to 24 ktoe and of other biofuels (e.g. of biogas) to 5 ktoe by the end of the decade (Table 6). Liquid biofuels will have a total share of 95%; i.e. 475,000 tonnes of bioethanol and 230 tonnes of biodiesel (REAP, 2010). With regard to the continuing economic efficiency limitations of the production and use of second generation biofuels, 100% of the bioethanol used in Hungary in 2020 will derive from first generation production. As regards biodiesel, 205,000 tonnes of the envisaged 230,000 tonnes will be first generation fuel, while the rest could be manufactured from animal fats and used frying oil.

In 2010 petrol represented only 33% of fuels used for transport in the EU-27 while diesel accounted for 67%, if the energy content of the two types fuels is considered. There are some differences between EU Member States, but Hungary is close to the average with a distribution of 37% petrol and 63% diesel. It is unclear how the development of engine technology and implementation of new emission standards will affect fuel distribution by 2020, but major changes cannot be expected since commercial vehicles depend heavily on diesel engines. If an EU Member State would like to substitute petrol and diesel ten per cent equally, then the distribution of the two type of biofuels should reflect the share of the conventional fuels. If the distribution of biofuels strongly differs from the fossil counterparts, then the EU Member State should make extra effort to promote either bioethanol or biodiesel utilisation. This is the case in Hungary since, based on the data of the national REAPs, Hungary has one of the most ambitious plans concerning bioethanol use in 2020 (Figure 3).

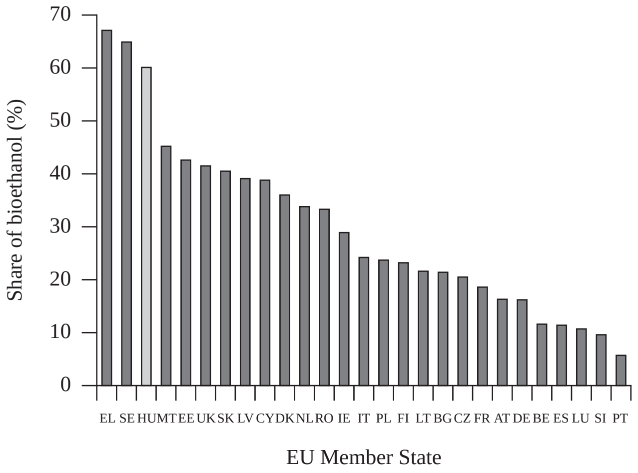

Figure 3: Projected share of bioethanol in liquid biofuel mix in the EU Member States in 2020 (%).
Data are based on energy content of fuels and biofuels. EU-27 mean = 25.2%
Source: Own calculation based on data from ECN (2010)

Promotion of biofuel usage began in Hungary in 2005. From 1 January 2005 biofuels were exempted from excise tax, but it was not sufficient to ensure profitability except ethyl tert-butyl ether (ETBE) blending. As in many other countries, only implementation of a mandatory blending rate in mid-2007 resulted in real development of biofuel utilisation. The rate is fixed at 4.8% vol for both petrol (3.1% ethanol in energy) and diesel (4.4% biodiesel in energy) (Table 7). According to the Hungarian government regulation 343/2010 XII 28 on biofuels, the next update is due in 2014 when mandatory blending of biofuels will be raised to 4.9% in energy content in both types of fuel. Hungary has clearly not fulfilled the requirements (5.75% biofuel content in energy of fuels in 2010) envisaged in Directive 30/2003/EC (European Parliament, 2003).

By 2010 the rate of use of ethanol had reached 6.4% in volumetric terms, greatly exceeding the 4.8% stated in the existing legislation. This can be explained if we know the present market situation. MOL, the company which supplies all petrol stations in the country, has been blending Slovakian ethanol in its refineries, since a Slovakian company won the multi-annual international tender. Hungrana, presently the only ethanol producer in Hungary, is forced to export its production and tried to sell its ethanol in the Hungarian fuel market in the form of E85 (max 85% ethanol and petrol mix) at petrol stations. The Hungrana E85 strategy turned out to be surprisingly successful. Supported by the then existing tax exemption and the rapidly increasing fuel prices, sales developed quickly. In 2009 the volume of sales reached 3.9 million litres, increasing to 36 million litres in 2010. In the first quarter of 2011 sales of E85 were again significantly higher than in the same period of 2010. Concerned by the loss of tax revenues and the financial crises of the country, the Hungarian Parliament raised the excise tax on E85 in several steps (by 90 HUF, 0.3 EUR), while putting aside the stated targets for 2020. Consequently by 2012 E85 had lost its attractiveness and competitiveness in the Hungarian fuel market. A similar development was not registered in the case of biodiesel, since pure biodiesel is not sold in Hungary.

In spite of the present situation, according to the REAP, in 2020 all bioethanol and biodiesel will be manufactured domestically, even if the mandatory blending of Directive 2009/28/EC requires only the use and not the production of biofuels. Hungarian agriculture will be able to produce – indeed it already produces – the required quantity of raw materials. The capabilities of Hungarian agriculture, the local traditions and experiences of arable farming put Hungary in a more advantageous situation than most other EU Member States concerning biofuel production. In contrast with the Hungarian situation, in 2009 the biofuels blending rate was 2.9% in the UK, but approximately 90% of biofuels produced in the country was processed using imported feedstock (Committee on Climate Change, 2011).

The Hungarian bioethanol industry presently absorbs about 400,000 tonnes per year of maize, the primary raw material for Hungarian bioethanol manufacture owing to its higher average grain yield and higher ethanol yield during processing than spiked cereals. Beyond current food, feed and industrial utilisation needs, about 2.5-3.5 million tonnes of maize is exported annually without processing. To achieve the goal set for 2020, i.e. to manufacture 475,000 tonnes of ethanol, an additional 1.1 million tonnes of maize would be required over and above the current 400,000 tonnes. This quantity can be produced on a land area of 240,000 hectares,

Table 7: Use of biofuels in Hungary compared to total fuel use, 2005-2010.

	2005	2006	2007	2008	2009	2010		
	ktoe	ktoe	ktoe	ktoe	ktoe	1000 t	million litres	ktoe
Petrol	1,457	1,552	1,595	1,679	1,634	1,378	1,755	1,415
Diesel	2,484	2,723	2,804	3,012	2,998	2,750	3,254	2,824
Total fuels	3,941	4,275	4,400	4,691	4,631	4,128	5,010	4,240
Of which:								
Bioethanol	3	12	27	47	50	89	113	57
Biodiesel	0	0	2	118	124	132	150	119
Total biofuels	3	12	29	165	174	222	262	175
Bioethanol share, %	0.20	0.75	1.69	2.80	3.07	6.48	6.41	4.01
Biodiesel share, %	0.00	0.01	0.07	3.90	4.14	4.81	4.61	4.20
Total biofuel share, %	0.07	0.28	0.66	3.51	3.76	-	-	4.14

Source: Country development reports of Hungary submitted to the European Commission according to Directive 30/2003/EC.

Table 8: Estimated Hungarian biofuel potential based on unprocessed raw material production and net export data for the period 2005-2009.

	Production (Average of 2005-2009)	Net exports (Average of 2005-2009)	Potential biofuel production from exported raw materials			
	1000 t		1000 t	million litres	PJ	ktoe
Maize	7,557	3,502	1,051	1,330	28	665
Wheat	4,700	1,962	588	745	16	372
Bioethanol, total			1,639	2,075	44	1,037
Rapeseed*	570	505	202	230	8	180
Sunflower seed	1 215	518	207	235	8	185
Biodiesel, total			409	465	15	365

* Average production of 2009-2010, average net exports of 2007-2009.

Source: Own calculation based on databases of Hungarian Central Statistical Office

i.e. one fifth of the present Hungarian maize production area. If the structure of Hungarian arable crop production does not change radically and the numbers of livestock continue to stagnate, still 1.4 to 2.4 million tonnes of maize will be available annually for selling on foreign markets, or for processing and export in the form of ethanol.

Although Hungary is one of the top producers of sunflower seed in Europe, rapeseed constitutes the primary raw material for biodiesel production. Sunflower oil for food usage is valued more highly than other common vegetable oils in Europe. Furthermore, rapeseed oil has better features concerning fuel quality. Production of at least 550,000 tonnes of rapeseed may be expected annually, thus Hungary's biodiesel need envisaged for 2020 can also be satisfied by using domestic raw materials.

We made a simple calculation to quantify how much first generation biofuel could be produced in Hungary by processing all of the currently exported raw materials (Table 8). This disregards the volume already used for manufacturing biofuels, and of the multiplying effect of ethanol production by-products (use of by-products for animal feed can free further basic crops for processing). Hungary has the potential to produce at least three times as much first generation bioethanol (the commitment is 304 ktoe; Table 6) and about twice as much biodiesel (the projected first generation use is 180 ktoe) than would be required by the 2020 commitments. Using only exported maize for first generation ethanol production would theoretically allow Hungary to replace 47% of the energy content of petrol in 2010 (petrol use 1415 ktoe; Table 7). It could be carried out without changing present land use, and without affecting any present food, feed and industrial use. Processing and domestic use would definitely hurt the agricultural trade balance but on the other hand biofuel use would a replace significant part of the petrol refined from imported mineral oil.

The huge maize and oilseed surplus has attracted many Hungarian and foreign investors. Prior to 2008 over two dozen projects were announced, in the case of ethanol plants with a total processing capacity of 7-8 million tonnes of maize, however due to the rapidly increasing agricultural prices in 2007 and the subsequent financial crisis, almost all were cancelled or postponed. The same happened with the thirty small-scale ethanol processors and oilseed mills, even if they applied for and were granted generous investment support from New Hungary Rural Development Programme (ÚMVP) funds.

Since most planned projects have been cancelled, processing capacities for producing the biofuel quantity envisaged for 2020 are available only in part. Ethanol for fuel is at present produced exclusively in the Szabadegyháza plant of Hungrana with 135,000 tonnes output capacity. Because the plant also produces isoglucose it was reconstructed with wet milling technology. Construction of Pannonia Ethanol's dry milling bioethanol plant of 160,000 tonnes output capacity in Dunaföldvár is at an advanced stage. For guaranteeing Hungary's self-supply, construction of at least 170-180 thousand tonnes of additional production capacity will be necessary by the end of the decade at the latest.

Small scale ethanol production could in theory be more economic, thanks to the accounting of the raw material of own production at cost (without profit sacrifice), the lower transport costs, utilisation of the by-products locally or within the plant and to the lower investment requirements (no need to dry the wet distillers' grain generated). However, efficient utilisation of the by-products in complex systems presents serious challenges (for example, integration of the raw material producers and the users of by-products).

The oilseed crushing capacity required for the satisfaction of the expected domestic demand of biodiesel will be abundantly available thanks to the Glencore plant in Foktő which is currently under construction and to the oil seeds processing factory to be built in connection with the biodiesel plant in Komárom of Envien and MOL, in addition to the already existing important vegetable oil factories in Martfű, Sajóbábony and Visonta. However, esterification capacities are still insufficient. Satisfaction of the biodiesel demand is possible from other sources, too. For example, MOL is conducting research into the production of biodiesel with cleaner burning properties than methyl-ester, based on utilisation of a wider range of basic materials.

Utilisation of the by-products of biofuel production defines the economy, energy balance and complex environmental effects of the production. AKI has calculated that the theoretical maximum use of DDGS (Distillers' Dried Grains with Solubles) as fodder with the current structure of the domestic livestock is between 300 and 350,000 tonnes. According to REAP (2010), generation of around that quantity of DDGS may be expected in 2020. Should Hungary succeed in restoring livestock numbers to the levels at the time of its EU accession, utilisation of rape meal for fodder might grow to 210,000 tonnes by 2020. On the other hand, the quantity available at that time may amount to 300,000 tonnes. The rest can be disposed of by burning or utilised as raw material for biogas production.

Discussion

It is expected that solid biomass will continue to be the most used bioenergy source in Hungary and, on the basis of the calculations of AKI, the amount of solid biomass that will be needed by 2020 is already available from forestry and agriculture. However, only about a quarter of the amount of solid biomass that could potentially be utilised for energy generation is currently used for heat or electricity generation. In order to supply the required amount of biomass from the already available sources a greater proportion of the by-products and waste biomass will need to be collected and the thermal and electric power plants will have to diversify their biomass consumption by using more by-products and waste material. The planting of energy crops will therefore only be necessary in the context of local considerations such as the supply of local generating plants.

Although we conclude that Hungary has the potential to fulfil all of its commitments made in the Directive 28/2009/EC, there are many uncertain factors, including agricultural and energy price development, technological development and environmental issues can affect the relative position and the profitability of biomass based energy production. Here we discuss some of these factors further.

In Hungary the potential to produce first generation biofuels from domestically grown crops is significantly higher than in most EU Member States but the development of the sector has not met expectations. To stimulate progress toward the targets set by the REAP the Hungarian government will have to clarify the uncertainties surrounding the sector, thus projecting a pathway for investors. Providing targeted financial support (for example to small-scale producers) is essential in order to gain the most benefit from biofuel production.

Were new factories to be constructed on the basis of the raw material surplus, sale of the maize-based bioethanol manufactured in Hungary would be certainly possible in foreign markets. Bioethanol production is competitive in the EC at the custom tariff presently applicable to non-denatured ethyl alcohol. Development of second generation technologies, even although their rapid spread is unlikely, may amend the demand for a total of five million tonnes of imported bioethanol, specified in the EU Member States' REAPs. Thanks to the existing technologies and the available professionals, the first generation bioethanol plants can be relatively easily and quickly converted, thus enjoying advantages against the newly implemented production capacities.

Comparing the envisaged consumption of biofuels with the expected consumption of petrol and diesel it can be estimated that the quantities specified in the REAP would imply a mixing rate of 16% in energy equivalent for ethanol and of 6% for biodiesel in 2020. In volumetric terms ethanol blend in petrol would reach 22%. Such a rate of utilisation of ethanol – whether in form of ETBE or blended therewith – is only possible after technological improvement. An efficient way could be to replace obsolete vehicles of public transport systems and in other services managing fleets (i.e. postal services, taxis, local delivery vehicles), but this would involve serious investment expenses.

In the EU Member States, different systems of subsidies exist which influence the penetration of renewable energies for electricity production: feed-in-tariffs, marketable green certificates, green premium systems (Fouquet, 2009). In the case of cooling and heating, the use of renewable energies is initiated by subsidies for investment costs (all EU Member States), feed-in-tariffs (Germany), investment tax credits (Netherlands, Sweden and Ireland), and special credit facilities.

In Hungary, feed-in tariffs regulate renewable energies for electricity production. The current KÁT for green electricity will be superseded in 2012 by a new Renewable and Alternative Energy Sources, Combined Heat and Power Feed-in Support System (METÁR), which incorporates features from the German, Austrian and Czech models. The Ministry of National Development plans to extend METÁR to heat from renewable energy sources, but the new system will not support natural gas-based combined power generation. It is expected that the basis of this statutory and regulatory scheme will be a guaranteed purchase price, but the amount of energy purchased will be capped by a quota system. Different feed-in tariffs will be applied to municipal waste biogas, agricultural biogas and landfill biogas. In the future, smaller power plants will be allowed to join the support system, but they will have to reach a higher overall efficiency than in the KÁT. The regulatory framework of METÁR was expected to be finalised at the beginning of 2012, but the specific tariffs will be defined in July 2012 (METÁR, 2012). Currently, neither the solid biomass-based energy production nor the biofuel production is profitable with the market feed-in tariffs in place in Hungary at present. The prospects for the currently operating power and biofuel plants, and also the future of the planned investments, together with the fulfilment of the 2020 goals, will depend heavily on the levels at which these tariffs are set.

At the time of completing this study, the necessary legal, technical and commercial conditions for gas grid injection were also not present. As the legislation is now emphasising renewable power generation, the biogas plants presently in operation are struggling to exploit their generating capacity. Full exploitation of the heat energy generated in the biogas plants designed for cogeneration of electric and heat energy is not an easy task due to the seasonality of on-farm energy requirements (heating, crop drying), while selling to outside may be difficult owing to the fact that the plants are often remote from residential areas. In cases where neither off-take possibilities of the electric energy, nor the local utilisation possibilities of the cogenerated heat are present, upgrading to natural gas quality is worthy of consideration, because in this case the biogas can be withdrawn from the system where its energy content can be used in the most efficient manner.

Production and utilisation of biofuels in a sustainable manner constitutes a prerequisite for their recognition as fulfilling the obligations and for receiving financial support. From 1 January 2011 the EC has endeavoured to ensure sustainability through introduction of so-called sustainability criteria. Such criteria however specify only a decrease in GHG emissions. Computation of GHG emissions and the determination of the other environmental indices of biofuel production (such as energy balance and water balance) are still awaited. With regard to the fact that such indices may considerably differ subject to the technology used and to the environment, the impacts of biofuel production in Hungary could be estimated by measurements and calculations adjusted to the domestic conditions, production practices and technologies, but such calculations have not yet been carried out. The extent and the time span, how and until when the production and use of biofuels could be beneficial in terms of energy safety and climate protection, in function of the technology, could only be established in the light of the knowledge arising from these calculations.

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