REMARKS ON THE PROBLEM OF OUR FUTURE ENERGY SOURCES

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1. Introduction

Renewable energy sources, such as biomass produced as agricultural and forest waste, have become very fashionable energy sources throughout the world and in Hungary as well. In contrast, coal is generally considered an old-fashioned fuel, and coal mining is accordingly not fashionable. This opinion is usually explained by the emission produced by burning coal, especially carbon-dioxide emission. It is not only supposed but generally accepted that the emission rate produced by burning biomass cannot be higher than the amount of carbon-dioxide that the plant captured during its whole life. Although this opinion is arguable, regulations are based on it. So coal-fired power plants are forced to use biomass too, produced mostly by agriculture and forestry. Thesises of a short objective comparison of emission rates of mineral and biomass fuels furthermore, some essential technical and economic aspect of their utilization are discussed in the paper.

Keywords: fuels, biomass, coal, power generation emission rate, CO_2 emission

2. Emission rates resulted by burning fuels

2.1. Energy consumption of Hungary Despite certain expectations neither the energy nor electric energy consumption decreased in Hungary since 1990, according to the 22 years official historical data published by the Hungarian Central Statistical Office. Unfortunately domestic production of mineral fuels decreased during almost the whole period in question with the exception of a slight increase in the last years. So the country has become strongly dependent on fuel (mostly hydrocarbons and uranium) imports [6, 12, 21].

2.2. An order of magnitude of fuel sources of the country Hungary is considered poor in mineral reserves including fuel sources. This is not quite true, as its explored industrial lignite, brown coal and hard coal reserves could provide a significant rate of its fuel demand for centuries using even the recent extraction technologies. More than 1900 million tons of hard coal with a significant methane content could be extracted from underground and approximately 4300 million tons of lignite with opencast method, according to the Hungarian Office for Mining and Geology (source: *http://www.mbfh.hu/*). Continuous opencast mining method is economic and efficient in lignite production. Recent underground mining methods probably do not enable mechanized and efficient extraction of deep hard coal seams due to their unfavourable geological characteristics. Certain results of underground coal gasification experiments can be encouraging if some essential problems, such as stable maintenance and regulation of the pyrolysis process, resulting gas

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of high heat content could be solved. It would be interesting to make an objective analysis of this and the conventional mining methods, comparing basic parameters, e.g. mine development, stability of cavities, surface subsidence, mine output, etc.

A further question should be the extraction method of coalbed methane content. Although a remarkable quantity of methane is contained in the coal seams, the rather low permeability of the coal seams and certain experiences obtained in the Mecsek and other coalfields do not support optimistic expectations.

2.3. Emission rate of burning different fuels Numerous combustible chemical compounds, many samples of biomass such as straw, corn-stalk and different kinds of firewood, etc., and furthermore chemical composition of coal samples from every coal basin of Hungary [1, 5, 8, 20] were examined in a long-term research to estimate the expected specific composition of the flue gas produced by burning the materials in question containing exactly 1 MJ of heat. The estimation method was basically stoichiometric. Results obtained by the analysis [14, 17-19] perfectly match the values contained in the Hungarian regulation. Consequently, regulation is based on stoichiometric calculations. The basic results can be summarized as follows.

The carbon-dioxide emission rate per heat content of the fuel is nearly the same for burning different kinds of coal (0.091-0.118 $MJ \cdot kg^{-1}$), according to the great amount of Hungarian coal samples. Emission from coal combustion is only slightly higher than from burning liquid hydrocarbon products and biomass, and *theoretically* 1.5-2 times higher than that of methane (0.55 $MJ \cdot kg^{-1}$), the basic component of natural gas. It is very important to emphasize, that if the influence of long-distance transportation (e.g. volumetric losses and energy consumption of the transportation, etc.) and the carbon-dioxide content of the gas is taken into account in the emission calculations, this result can be significantly unfavourable. Methane loss results greenhouse effect in the atmosphere to a 21-times greater extent than carbon-dioxide of the same quantity.

Although the greenhouse effect of vapour cannot be neglected, this factor is not limited by Hungarian regulations. The vapour emission rate of coal is significantly, 2-3 times lower than that of natural gas and biomass.

Sulphur-dioxide emission is significant if a great quantity of coal is used as source of heat. This is why flue gas desulfurization units should be operated in coal-fired power plants resulting extra costs. Utilizing natural gas and biomass does not result a high sulfur-oxide emission rate. The ash content of coal is the highest of all examined fuels. Although coal ash and flue gas desulfurization (FGD) gypsum are industrial wastes, but can be useful raw materials at the same time. [13,15]

2.4. Greenhouse equivalent of the emission from biomass The greenhouse equivalent of the gas emitted by the biomass in question is not equal to but higher than the quantity of emitted carbon-dioxide by the plants in question. The mass of the methane produced by the decay of the parts of the plant during its whole life and after it must be taken into consideration as well. As the greenhouse effect of methane is 21 times higher than of the carbon-dioxide, the greenhouse effect of the biomass is worse that of coal of low methane content. Unfortunately this fact was totally ignored when contributing the appropriate regulation which enables not to take into account the carbon-dioxide emission from biomass.

3. Technical and economic aspects of utilizing biomass and coal

3.1. Annual quantity of straw and corn-stalk Some 9 million tons of straw and corn-stalk are produced in Hungary annually. This quantity of biomass is called a by-product in recent common usage. Crop yields calculated for dry materials are rather low at the first sight: approximately 1.6 $m^2 \cdot kg^{-1} \cdot year^{-1}$ for corn and corn-stalk together, 1.0 $m^2 \cdot kg^{-1} \cdot year^{-1}$ for corn-stalk and straw, 0.6 $m^2 \cdot kg^{-1} \cdot year^{-1}$ for firewood from energy forests or other kinds of energy plantations, and 0.2 $m^2 \cdot kg^{-1} \cdot year^{-1}$ for firewood from conventional forests. The average lower heat content of the dry fuel is about 17.5 $MJ \cdot kg^{-1}$. [2-4, 22]

3.2. Value of a field in agriculture and mining Even for average 20-30 m thick sand and gravel deposits of approximately 250 years and the best soils are needed to produce agricultural products of the same value as the sand and gravel which can be found below the same area. [11]

3.3. Heat content of the agricultural and forest biomass The approximate heat content of 9 million tons of dry biomass of 17.5 $MJ \cdot kg^{-1}$.(lower) heating value amounts 157.5 $PJ \cdot year^{-1}$. The total amount of energy from other agricultural wastes can be estimated at a similar value [16,18]. Some 4991 MW of power could be obtained from burning all straw and corn-stalk reserves annually without any heat losses. For a 30 % efficiency in converting energy from heat to electricity a remarkable 1497 MW electric output could be obtained, 1996 MW for 40 %, 2495 MW for 50 % and 2994 MW for 60 %.

3.4. Area required for producing such a quantity of biomass If 1.0 $m^2 \cdot kg^{-1} \cdot year^{-1}$ crop yield is taken into account for corn-stalk and straw, a 9000 km^2 area is required to produce fuel for power generation, described in the previous paragraph [2, 10, 16, 18]. Beside harvesting corn and grain corn-stalk and straw must be collected from the same area, too. Unfortunately, while this area is continuous, it consists of fragmented fields of numerous owners, which make acquisition and transportation rather difficult. Areas of the three largest Hungarian counties can facilitate to imagine the real size of the area in question: Bács-Kiskun 8445 km^2, Borsod-Abaúj-Zemplén 7242 km^2 and Pest 6393 km^2 (on 1 January, 2004).

The area of Hungary per capita is 9300 m^2. If the total energy demand would be satisfied by domestic agricultural biomass production, a 6400 m^2 area would be necessary or 3000 m^2 if only electrical power generation is considered. [9, 16, 18]

3.5. Capability of soils to grow biomass for energy purposes Approximately 1700 to 17000 years are needed fo 1 m^2 area of good soil of Hungary to be able to produce the same quantity of heat in the form of biomass as could be extracted from the same area of a 2-2.5 m thick brown coal or a 7-10 m thick lignite deposit. So if the same quantity of heat is to be produced as agricultural or forest biomass instead of mining coal, a significantly (a thousand to ten thousand times) larger area of land of the country is required [16,18]. Consequently, the area occupied by mining operations is significantly less than the agricultural and forest area that could provide the same quality of energy. And even this smaller area is reclaimed. The use of agricultural and forest lands is not restricted by

Hungarian regulations. But several sales and purchases as well as changes in land registry must forego use of the same land for mining purposes.

3.6. Biomass storage facilities Straw and corn-stalk produced for energy purposes can be harvested once a year in the Hungarian climate. The duration of the harvest in question does not exceed a quarter year. Furthermore running out of the fuel reserve gathered in the previous year cannot be allowed for strategic reasons. Consequently storage facilities should be built for the biomass, whose total capacity must be equal to or more than the annual quantity of the fuel. Special precautions are needed to avoid risks (e.g. fire hazards, etc.) resulted by the concentrated storage of the total amount of the biomass.

The capacity of the transportation system, including the roads, must be sufficient for the haulage of the harvested biomass to the storage facilities or the power plants within a 3-months-period. Once ingathering is ready, equipment cannot be used for this purpose during the following 9 months.

3.7. Safety of fuel supply Any power plant should be supplied with fuel of the appropriate quality and quantity during its whole lifetime. Sometimes certain properties of quality can be significantly different from those of coal. To guarantee safe supply, biomass must not be allowed to be sold for other purposes even if temporary prosperity would offer more profitable possibilities. So long-term contracts are probably necessary for fuel supply as is quite usual in the market of mineral fuels, such as coal, hydrocarbons and nuclear fuel.

3.8. Biomass fuels are not free Production of agricultural and forest biomass is not free and usually requires human assistance, except if it is considered waste and only *in situ*. Utilization of biomass is costly, too, sometimes even for wastes. It should be emphasized that unexplored mineral reserves are free as well *in situ* as no human assistance was needed for their genesis. Furthermore coal reserves are renewed over geological ages too.

3.9. Area required for producing such quantity of biomass The price of fuels is determined by marginal costs regardless of whether the fuel is mineral, agricultural or forest in origin. So the price of products obtained by the processing of biomass, such as biomass pellets, biodiesel oil, bioethanol, etc., must not exceed the prices of other fuels for similar purposes made of coal or hydrocarbons. Consequently, usually either governmental subventions are needed and paid or taxes or other duties are introduced in order to eliminate the difference and maintain this activity. No matter which solution is selected, higher energy prices would be the result.

One of the main arguments against underground mining was its need for financial support [7]. This support, enabled by temporary regulation of the European Union, never exceeded an annual 8-10 billion HUF or 50 million US dollars during the past 6-7 years for a Hungarian underground coal mine of 1-1.5 million tons output per annum. As a result of this approach, almost all proposals concerning the coal industry are excluded from different funding possibilities, financed by the administration.

3.10. Energy biomass cannot be used for other purposes Straw, corn-stalk, sugar cane, sugar beet and other similar products cannot be utilized in the different branches of agriculture once used as a source of energy. Nor can the land which was occupied for production. A cleared forest cannot capture any carbon-dioxide from the atmosphere. On the other hand a living forest can not only stabilize the climate and reduce some environmental risks but finally is able to capture the carbon-dioxide from the atmosphere emitted by power plants, cement plants and waste incinerators.

3.11. Size of regions providing biomass fuel for a power plant A simple model was introduced to estimate the size of regions which can provide sufficient fuel for a power plant of P electric output and of $0.3 \le \eta \le 0.6$ efficiency of converting heat to electricity. The region is circular of R radius. A concentric circle of R_0 radius is reserved for the power plant and the storage facility. A q=1 $m^2 \cdot kg^{-1} \cdot year^{-1}$ average crop yield and H=17.5MJ$\cdot kg^{-1}$ lower heating value for biomass are taken into consideration. The radius of the region, mass of the fuel to be stored annually (m) and radial component of the freight ton kilometres (S_{rad}) were determined as follows, the results can be read in Table I:

$$R = \sqrt{{R_0}^2 + \frac{P}{\pi \cdot \eta \cdot q \cdot H}}, \quad m = \frac{P}{\eta \cdot q} \quad \text{and} \quad S_{rad} = \int_{(A)} r \cdot q \, dA = \frac{2\pi}{3} \cdot q \cdot \left(R^3 - {R_0}^3\right).$$

Table I: Estimated parameters of biomass fuel supply of power generation(0.3≤η≤0.6)

electric output, P (MW)	mass of the fuel, m (10^3 tons/year)	radius of the region, R (km)	radial component of freight ton kilometres, S_{rad} (10^3 tkm/year)
5	15-30	1.73-2.45	2.2-6.2
50	150-300	6.9-9.8	700-2000
800	2400-4800	22-30	44000-125000

4. Conclusions

Numerous aspects were reviewed in this short study concerning the application of coal and biomass as fuel for power generation. Finally the question arises: can biomass be considered as an alternative fuel in power generation? Sophisticated equipment is available for the economic utilization of biomass in certain situations. However, considering emission, haulage and storage, coal seems to be more economic for higher outputs.

Acknowledgements

This work was carried out as part of the TÁMOP-4.2.1.B-10/2/KONV-2010-0001 project in the framework of the New Hungarian Development Plan. The realization of this project is supported by the European Union, co-financed by the European Social Fund.

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