

USAGE OF ENERGETIC CROPS AS ALTERNATIVE SOURCES OF ENERGY IN CZECH REPUBLIC

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Abstract

Fifty percent of Czech agricultural lands was categorized to LFA. The energetic crops and raw grass biomass are a perspective industrial and energetic material. It is possible to utilize them by anaerobic digestion for methane, pyrolysis for syngas or fast pyrolysis for biooil, which all find exploitation in co-generation power units (energetic use) or in the chemical industry. They can be used for manufacturing alternative fuel for slow-running diesel engines, in “grass biorefinery”, for the production of “green or brown juice” in ethanol production biotechnology, manufacturing of lactic acid, isolation of saccharides, carotenoids and enzymes etc.

Key words

Energetic crops, alternative sources of energy, burning, anaerobic digestion, gasification, pyrolysis, green biorafinery

Introduction

The European commission of EU presented within the bounds of “Agenda 2000” its proposal for a reform of agriculture. This reform should especially provide for the competitiveness of European agriculture. Regions of LFA (less favoured areas) include mountain regions and regions with soils of low productivity, difficult cultivability, lower productiveness of soil environment, with low populations dependent predominantly on agriculture, and regions with specific problems, e.g. contamination with air pollutants (Kolář L. *et al.*, 2001). Within the whole EU approximately 51 % of all agricultural land is classified as LFA. The differences tend to be great, e.g. in Belgium 23 %, in France 40 %, in Spain 63 % and in Luxemburg nearly 100 %.

As an initial criterion for the evaluation of agricultural regions in the CR there was adopted the criterion of the productivity of the agricultural area, stated for individual land-valuation soil-ecological units /BPEJ/ (Ministry of Agriculture of the CR 1998). As a boundary limit for regions with favourable and unfavourable conditions there became the value of productivity of 35 points, i.e. 75 % of the whole-state average. In the CR, the average productivity is 108.4 EURO per hectare of agricultural land, and it is 46.2 points. In the CR, this conclusion was made after analysis of all natural and social-demographic criteria, as in general required by EU (Ministry of Agriculture of the CR 1999).

In the CR, 48.83 % belongs to LFA.

The ecologic and economic aspects of optimal activity of agriculture in LFA will be fulfilled only under the condition that agriculture will at least for a temporary time produce not foodstuffs, but energy or raw materials for chemical and the other processing industries. Crops from LFA produce in average 72.64 GJ.ha⁻¹ of energetic gain, which is dependent on cattle units per hectare in the system (Kudrna and Šindelářová 2001). Then energy released from biomass, thus accumulated solar energy, from unfertilized but harvested areas, can be exploited (Kudrna 1986). In this way there will be fulfilled also the demanding ecological and social-economic conceptions for proper exploitation of these regions.

The present state of the problems

Energetic plants can be processed to produce energy sources in five different ways (Ust'ak, 2001). By burning in a combustion energetic apparatus. It is admittedly the cheapest, but the minimally ecological optimum way of use (Sladký, 1996). By anaerobic digestion, in which methane gas is the resultant product, and where the wastes can be used to produce organic and organomineral fertilizers (Straka, 2003; Schulz, 1996). Methane from anaerobic digestion can be used directly as a fuel for burners of different heating systems, but it is more advantageous to use it in a gas engine or a microturbine for the production of electric energy by co-generation (Šurovský, 2003). By thermal decomposition, so called “gasification”, which is carried out in reactors with no

or limited access of air at temperatures of 500 – 900 °C. The result is a mixture of gases (syngas), where carbon monoxide and hydrogen form the main part (Claudet, 2001). This mixture can be transformed in fuel cells to electricity or burnt in gas engines. By a known process it is possible to transform syngas using water steam to a mix of hydrogen and carbon dioxide (Dermirbas, 2002). The main problem of this way of processing is the development of about 5 – 10 % toxic tars and liquidation of the solid residual, for which there is no suitable exploitation. This way of processing of grass mass is better than direct combustion due to the development of a lesser quantity of undesirable products (dioxins, dibenzofurans), cheaper maintenance of the equipment, approximately twice as big energetic gain and even such difficult combustible materials as grass biomass can be gasified. Modern gasification equipment is offered by the German company TAF from the CHOREN group. It concerns CARBO-V technology, which is two-step, and which includes a fluid gasification reactor. In the CR in Skotnice in the Odra basin there has been built a gasifier of the ATEKO joint-stock company, producing gas, which is burned in two gas engines from the company TEDOM Třebíč (Šurovský, 2003).

Also by fast pyrolysis, which can be considered as most perspective and also most modern of technologies. It concerns heating of organic material the without access of air. The main products of pyrolysis include a solid residue and pyrolysis gas, after which cooling a quality pyrolysis oil is gained, and real gas products (Bridgwater 2002). Time of delay in pyrolysis space is 2 s at temperatures about 500 °C, without air access. Material must be flash dried (<10 % humidity) and floured (particles <2 mm). If the product of gasification was cca 80 – 85 % gas and 5 – 10 % low-temperature tars, the product of fast pyrolysis is only cca 13 % gas (again mix CO + H₂) and 75 % tars, with a somewhat different composition, than in the case of gasification. The tars can be used as a raw material for chemical processing, eventually as an alternative fuel for slow-running diesel engines, similarly as low-quality diesel fuel oil. An obstacle for their adequate usage as a fuel there is a too high quantity of nitrogen compounds (Manabe et al., 1992). Heating value of bio-oil is 15 – 20 MJ/kg, thus a half of the heating value of fuel oil from mineral oil (petroleum). It is a brown, well pumpable liquid, containing 20 – 25 % water, 20 – 25 % lignin, 5 – 12 % organic acids, 5 – 15 % hydrocarbons, and other substances, and it is acidic (ph 2.2 – 3.3). A disadvantage is: bio-oil is difficult to store. After some months it begins to decompose and its heating value also decreases. That is why its production should be in harmony with the speed of processing.

Proposal of energetic use of phytomass in LFA regions

In the present, the interest of entrepreneurial subjects, as distinct from Europe and the world, is oriented by this time more to the near future than to the distant future. That is why, it is as yet more perspective to be in business in trade and finance than in the production sphere, especially in branches with high demand on investments, as renewable energy resources.

Joining EU and opening up to the world forces the regions in the CR with less favourable conditions for competitive agricultural production to look for a solution. It is necessary to keep agriculture, the inhabitants must find a job, which secures them an adequate economic income and at the same time will fulfill demanding ecological and land-forming aims, all this with minimal costs.

A solution exists. It is the anaerobic digestion or decay of decomposable organic matter. It is a well-known technology, developed thoroughly in sewage disposal. No larger sewage plant works nowadays without decay of sludge under anaerobic conditions. Methane gas and an easier processibility and use of the decomposed sludge in comparison with the raw sludge are the gain.

This technology was applied on other organic materials low in lignin. At first it was stable manure (Žilka, 1979), later slurry (Váňa and Šlejška, 1998), wastes from fruit-and-vegetable processing plants, later on the other wastes from the food industry, and finally also the mass of planted “energetic” crops (Graf, 2001). The way of solution is a as cheap as possible way of energy production, so that it could be produced by a farmer himself without a high technical education, so that most of the produced energy would be used in his own farm and the surplus would be sold. Energy is produced from wastes from agricultural production and from grass mass in this case of course has a lower energy efficiency. A farmer has enough energetic crops and waste grass mass. Low production cost and especially low capital cost are decisive. Of course, a look at an old engine of an OPEL 2000 motorcar, driving an electric alternator, arouse a smile in comparison with a nice co-generation unit of the Třebíč company TEDOM, the type PREMI or TWIN. At present, a Czech

farmer cannot even think of it, as he has not enough finances for on chemicals for plant protection, lime and fertilizers.

Though a modern anaerobic digestion should be of two steps, with a hydrolysis reactor in the first step and a fermentor with the circulation of the process liquid in the second step, the "Šumava unit" (Kolář and Kužel, 2002) is either the classical discontinuous BATCH-system or the continual DURCHFLUSS-VERFAHREN, with co-fermentation of grass mass and the excrement of cattle. This is of an indisputable advantage. Grass mass has a too low buffering ability (Kužel and Kolář, 2003 b), excrements on the contrary have a high one, their combination stabilizes the process and creates a great advantage (Kolář *et al.*, 2005). This is presented by the minimal operation of the unit. Wastes are processed to cheap organomineral fertilizers (Kolář, 1997). Organic or organomineral fertilizers (Kužel *et al.*, 2001a) produced from wastes will be applied in the place of production or will be sold to the regions under intensive agricultural production. These cheap fertilizers will increase potential soil fertility and decrease production cost by replacing expensive and less productive purely mineral fertilizers. Šumava conception presupposes replacing a heavy concrete by light PE/EVA foils. From a foil there is not only the ceiling of digestion tanks, but also the gas receiver. Bags with the volume of 1000 m³ and bigger supplies the Czech company BIOGAS TECHNOLOGY joint-stock company Pardubice. The plastic gas receiver enables operation of gas engines (a positive pressure of 0.5 – 1.0 mm of water column is sufficient) but not operation of burners (necessary positive pressure at least of 40 mm of water column). Technological heating is thus realized by the cooling water of gas engines (Kužel *et al.*, 2001b).

If, in the first step, basic financial resources will be created by the sale of electric energy from anaerobic digestion of energetic plants and waste grass mass and animal excrements (mainly of cattle), it will become possible to modernize and increase existing plants.

Here we recommend acting according to the patent of Váňa and Slejška and the publication of these authors from 1998 (Váňa and Slejška, 1998). From the companys, e.g. Biogas Technology Pardubice and Tedom Třebíč can be recommended.

Even the most modern gas engines for driving alternators, producing electric energy, are noisy, demanding on operational and service care, have high emissions, are of large dimensions and heavy. In the course of time they will be replaced by micro-turbines (Šurovský, 2003). Their advantages consist in low emissions, low noisiness, minimal operation and service care, minimal number of moving parts and repair parts, low weight, small dimensions, perfect control of the burning process. As a fuel, natural gas, biogas, gas from gasification and bio-oil from fast pyrolysis can be used.

A micro-turbine is actually a gas boiler, wich also produces electricity with a power to 200 kW. For power of 200 kW – 1 MW we need to speak about mini-turbines. It concerns combustion turbines, where unlike steam turbines the driving medium is not steam but a current of burned gases from burning natural gas, biogas or even bio-oil from fast pyrolysis. Micro-turbines unlike engines with more than 100 moving parts have in most cases only one moving part (a joint shaft of radial compressor, radial turbine and generator of electric current). High-revolution machines (up to 120 000 revolutions per minute) have air bearings and do not need lubricating.

Micro-turbines are developed and manufactured already by many companys. The best known is the micro-turbine of the company CAPSTONE from the USA. A micro-turbine can be seen in the boiler house JAHODIŠTĚ for heating flats in Český Brod, where it is operated by the company MTH Kotlín Ltd., with power of 30 kW, using by natural gas. The company CAPSTONE started the sale of micro-turbines in 1998 and manufactures them also for other fuels. There are also micro-turbines from ELLIOT, INGERSOLL-RAND from USA, TURBECAB from Sweden, GENERAL ELECTRIC (USA) or the Czech micro-turbine PBS Velká Bíteš (Šurovský 2003).

There exist also two-shaft burning turbines, connected only by a current of burned gases. They are especially suitable for the burning of biogas and bio-oil, also bio-ethanol and methanol can be burned. Their advantage is the additional possibility of compressed air production. The advantages of micro-turbines are a high effectiveness (total efficiency 70 – 80 %, electric efficiency 24 – 30 %) and also the fact, that they accept sulfane from biogas, unlike gas engines. They are independent of the fluctuation in biogas quality, which is a problem for gas engines.

In a long-term perspective there will be suitable, besides the modernization of anaerobic digestion, to extend mainly gasification and fast pyrolysis of grass mass; driving electric generators

should be replaced by micro-turbines combusting biogas and bio-oil. Fast pyrolysis of grass mass requires a dry fuel. For the drying of grass, waste heat from combustion gas from micro-turbines can be ideally used (Šurovský 2003).

Energetic plants or grass mass, as well as other crops, e.g. meadow clover, can be processed in the so-called green bio-refinery. Using squeezing or other technologies, we gain so-called "vegetal juice" containing sugars. These sugars can be fermented and it is thus possible to produce bioethanol for energetic purposes (an additive to engine or two-shaft combustion turbine fuels) or lactic acid (Andersen and Kiel, 2000) for the production of biodegradable packings. From vegetal juices it is possible to isolate chlorophyll (Kolář *et al.*, 2007 a), enzymes, proteins, amino acids or other biologically active substances (Starke *et al.*, 2000). From plant fibres, isolation materials can be manufactured or plant wastes can be palletized and burned (Kolář *et al.*, 2007 b) or processed to biogas. As an example there can act the functioning "Grass refinery" supplying energy for the town of Schaffhausen (Janzig, 2001). Grass from 600 hectares (4 400 t converted dry matter per year) will be energetically upgraded to cca 3 millions kWh of electric current, one million kWh of gas and 4 million kWh of heat. The company "2B Biorefineries" from Dübendorf in Switzerland delivered the equipment for immediate use. This company operates from 1998 the main prototype in Märwil in Thurgau. The fermentation of grass proceeds without solid organic substances. At first, plant fibers are being isolated in a process without chemicals. They are later used as heat insulation, a filling agent for fibrous materials with fire- and insulating properties as wool from glass- or mineral fibers. At the same time, proteins are separated and are sold as a fodder for animals. Vegetal juice, containing predominantly sugars, remains for energetic use. These sugars are fermented at 35 °C to biogas. From 1 t grass mass it is possible to gain 380 kg fibers, 190 kg proteins, 615 kWh electric current, 900 kWh heat and 269 kWh of energy in the form of biogas for introduction into the gas-distribution system. 6.7 million Switzerland francs have been invested in building and beginning the operation. The plant shall already in the second year of operation bring economical profit (Janzig, 2001).

Building units of modern anaerobic digestion and fast pyrolysis of grass mass in the LFA region should, besides enhancing the development of bioenergetics and chemical industry, create a basis for a more distant perspective of our energetics – the generation of electricity in fuel cells (Šurovský, 2003). As a basic fuel there is hydrogen, which can be gained by the transformation of natural gas, biogas and gases from gasification and the fast pyrolysis of the grass mass.

A fuel cell changes directly the chemical energy of a fuel to an electric one, without reciprocating or rotation motions, without limitation of efficiency by Carnot's cycle. It is spoken about so-called "hydrogen energetics". Fuel cells have practically no emissions and e.g. a pressure fuel cell with a micro-turbine enables the increase of electric efficiency even to 70 %. Fuel cells are ceramic (SOFC), carbonate (MCFC), of phosphoric type (PAFC), with a plastic polymer membrane (PEM). Fuel cells are already being developed and tested by the companies SIEMENS, UTC Fuel Cells (a new, so-called "alkaline" type, is also mounted in American space shuttles), Ballard (Canada), Plug Power (USA), SULZER HEXIS (Switzerland), ONSI (USA), application and research works proceed also in the CR (Šurovský, 2003).

At present, the price of fuel cells is excessive in the CR, but abroad they practically work in sewage treatment plants (Renton, USA, Köln am Rhein, Germany), in electric power plant Chugach Electric (Alaska, USA), in hospitals (Bad Neustadt, Germany) etc.

Conclusions

The goal-directed cropping of energetic plants and the use of waste grass mass from meadows and pastures will provide raw material for the energetic and chemical industries. It will enable the fulfilling of obligations of the CR in relation to use renewable energy resources. It will support the development of the processing chemical industry. It will create work opportunities for the inhabitants and the development of rural regions in the LFA.

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