BIOGAS OBTAINED FROM CORN SILAGE AND/OR COW MANURE IN THE REPUBLIC OF SERBIA AS A ROAD TRANSPORT FUEL

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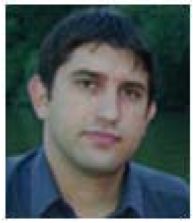

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Abstract: *Serbia has great potential for the production of the biogas, due to growing energy crops and livestock are the greatest potential of its agriculture. The use of biomass through anaerobic digestion to get the biogas, would reduce the need for the state to import energy, environmental protection should be raised to a higher level, the economy would be improved, unemployment in rural areas would be reduce and prevent migration of population from these regions. If we add to the fact that the European Union set itself the goal to 2020 year 20% of energy provided from renewable energy sources (at least 25% of bioenergy in the future can come from biogas produced from organic materials such as corn silage or animal manure), anaerobic digestion is imposed as a very acceptable technologies. In this paper, viewed as a potential production of biogas as a transportation fuel in the Republic of Serbia, which are the barriers that impede greater development of this branch of industry and suggestions on the experience of other countries to promote or encourage the same.*

1. INTRODUCTION

It is a great dissonance between bombastic statement, of *new* or *renewable* fuels and their benefits, because under these are implying pure components. A typical replacement thesis is related to the natural gas that, and without it, will be a fuel of this century. Optimistic studies of natural gas in vehicles operate with pure methane. Unfortunately, pure methane has nowhere in nature. He is still in mixture with other admixtures in different percentages. The main point is that natural gas and biogas should be accepted as a technically superior quality raw material for motor fuel [1].

In order to biogas could be used as a transportation fuel, it has to percolate, so that the volume of the methane is at least 95%. Only then biogas can be used as fuel in vehicles that were originally modified to operate on natural gas.

The technology of biomass and utilization of animal manure by anaerobic digestion (AD) is a superb and safe technology for obtaining biogas. If we add the fact that Serbia has a large farming area with agriculture crops (corn soya, sunflower, rapeseed…) and great potential in livestock, we can say that this is a good basis for the production of such renewable transportation fuels.

2. BASIC PARAMETERS OF ANAEROBIC DIGESTION

Anaerobic digestion is the decomposition of organic material under the influence of microbial populations that exist in the environment without oxygen. During anaerobic digestion (fermentation) organic materials are decomposing under the influence of methane bacteria and occurs biogas is composed mixture of methane CH_4 (40-75%), carbon dioxide CO_2 (25-60%), a small percentage of other gases such as hydrogen H_2, hydrogen sulphide H_2S (0-1%) and carbon monoxide CO (2%). Biogas is lighter than air, no smell and no colour. Ignition temperature is between 650 -750 ºC and it burns with clean blue flame. Caloric value is about 20 [MJ/Nm^3] [2].

Anaerobic digestion can treat a wide range of organic material originating from agriculture, industry or municipal wastewater. Basically any liquid or solid organic waste from food and agricultural industry (whey, waste from slaughterhouse, used oil, grease and food waste from restaurants, liquid manure or municipal water) can be treated by anaerobic digestion.

Animal manure is a potentially large biomass resource. Dehydrated manure has the same energy content as a wood, and when it used for heating, the efficiency is only 10%. About 150 million tons of dry manure is used as fuel throughout the world. The conversion efficiency of animal waste can be increased up to 60% if it's in the process that produces biogas through anaerobic digestion.

Production of biogas only from animal manure is unviable, but adding cosubstrate (e.g., corn silage) increased profitability. As a contribution that can be specified by the fact is that almost 85% farm scale plants for the production of biogas in Germany used cosubstrate in anaerobic digestion.

It is important that each biogas plant must to have a clear picture what kind of energy needed to produce and to see what type of energy to match potential customers as well as costs of delivery of such energy. In this sense, input of organic matter is an important operating parameter, which indicates how much corn silage or liquid cow manure can be entered depending on the volume of digester in unit time [2].

3. ANALYSIS OF CORN PRODUCTION IN SERBIA

In assessing the energy potential of plant residues from husbandry, it was discussed only corn production in Serbia, Central Serbia and Vojvodina. Figure 1 shows the trend in the yield of maize in Serbia. As for total production expressed in [kg] it is characteristic that from year to year changes, which can be prescribed only by rely the manufacturer of atmospheric precipitation and low foliar. This is especially pronounced in central Serbia.

Yields of maize in 2007 were a slight increase but still below the yield, which reached a maximum value in 2005 year, while the trend of corn price is increasing since 2005 with falling prices in 2009 year. This means that the price of corn can not be clearly related to the maize yield per unit area. Increase the price of corn can be attributed to global food price rise on the world market. This fact can also be explained by the increase in biofuels industry that is obtained from corn (especially bioethanol) and growth of this industry increases demand for corn.

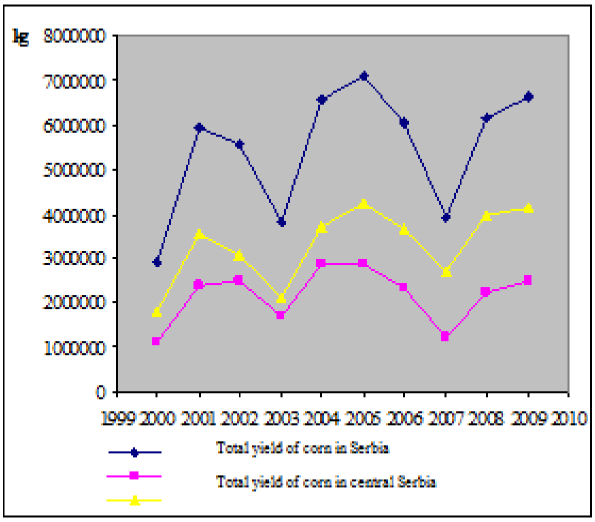

Fig. 1 Trend of the total yield of corn in Serbia

3.1 Potential of Serbian biogas production from silage corn

In Serbia the most important form of biomass are plant remains in husbandry. After harvesting corn on the processed ground remains corn (stalks with leaves). Since the average ratio of grain and weight 53%: 47%, it appears that biomass has nearly as much as grain [3]. It was created that part of the biomass must be back into the ground (recommended plough between 30% and 50% of the mass), which means that energy remains can be use at least 50%. When considering the energy potential of corn it can be classified into the following categories:

1. The whole plant (corncob and the stalk) for silage and biogas production (first-generation technology);
2. Grain maize for bioethanol production (first-generation technology);
3. The whole plant (corncob and the stalk) for the production of bioethanol (second-generation technology);
4. Stalk without corncob for silage and biogas production.

Corn is C_4 plant which means that produce directly the C_4 sugar and not through C_3 as they do other plants. For this reason, corn very well use the sun's light, producing high levels of sugar which is very important for the production of biofuels. The lower parts of the plant (stalk) contain enough fibre to using second-generation technology so whole plant can be is used in the process of fermentation. So the corn plant can be extracted as the best characteristics for biofuel production per unit area [2].

In addition, this plant requires much less energy and water investment in breeding compared to other energy crops. Corn also has practical benefits in the form of storage compared to other cultures that can be easily spoil during storage period. All these advantages of maize compared to other energy crops make it very flexible and reliable raw material for the production of biofuels in particular for the production of biogas. Another reason for the benefits of using corn as well as for obtaining biogas lies in the concentration of solids (between 30 and 40 %). Cultures that have this percentage below 20% result in very poor silage and a small production of biogas [2].

Analyzing these parameters can be defined model for determining the amount of biogas from corn silage. The amount of biogas can be determined on the basis of dry matter, organic fraction of dry matter and the theoretical maximum amount of biogas that can be obtained by 1 kg of corn silage (Table 1):

Table 1. Characteristics of silage maize [4]

Substrate	**DM [%]**	**OM [%]**	**Amount of biogas [m^3/tODM]**
Corn silage	15-40	75-95	500-900

Note: DM - dry matter, OM - organic matter; tODM - tons of dry organic matter; Amount of biogas = [amount of substrate (t) x DM (%) x OM (% of DM) x maximum amount of biogas produced (m^3/tODM)] (m^3)

Based on Table 2, which shows the ratio of grain production and the quantity of plant remains and data with a total yield of maize per unit area, it is possible to define the actual amount of yield potential of biogas per hectare area under maize in Serbia (Table 3).

Table 2. Relationship between grain and the rest of the plant [5]

Energy plant	**Grain : Rest of plant**
Wheat	1:1
Corn	1 : 1.1
Sunflower	1 :2.5
Soybean	1:2
Barley	1 : 0.8

Based on these results we see that Vojvodina surpasses in relation to Serbia and central Serbia. We should not forget that the analysis carried out for the corn silage with corncob and the rest of stalk. Analyzing the results previously obtained, increasing use of corn silage for energy purposes can be expected in those places that have enough raw materials. In Serbia, a problem the corn yield per unit area is directly reflected in the potential amount of biogas produced, and that far behind the yield of silage in the EU 25 [t/ha].

Table 3. Potential quantity of biogas generated by [ha] of corn silage

Year	Potential quantity of biogas in Vojvodina [m^3/ha]	Potential quantity of biogas in central Serbia [m^3/ha]	Potential quantity of biogas in Serbia [m^3/ha]
2000	1037	678	861
2001	1971	1433	1714
2002	1759	1527	1647
2003	1206	1033	1122
2004	2075	1771	1931
2005	2308	1753	2049
2006	2090	1505	1814
2007	1431	799	1146
2008	1941	1401	1705
2009	2135	1670	1932
average	1795	1357	1592

As opposed to central Serbia, Vojvodina has the potential for the development of these projects primarily because of higher yield per hectare, the larger farms that every year more and more becomes the property of farms and different domestic awareness of population and manufacturers.

4. GENERAL CHARACTERISTICS OF MANURE FROM FARM MILK COWS

Process of anaerobic digestion is not converted total content of organic waste materials into biogas. Anaerobic bacteria do not have the capability of degradation of lignin, and other hydrocarbons. If the digestion is treated waste material with a high content of nitrogen and sulphur, it can produce unwanted toxic concentrations of ammonia and hydrogen sulphide. In Table 4 are lists the daily amount of [kg] and composition of manure extracted from a dairy cow weighing 630 [kg].

Table 4. The amount and composition of cow manure [6]

Dairy cow manure	50.8
Total solids (dry manure) -TS	6.1
Total volatile solids (dry manure) -VS	5.4
Total phosphorus	0.044
Total potassium	0.16
Organic carbon	5.7

As can be seen from Table 4 the most volatile solids and cellulose makes hemi cellulose. Both components can be easily converted to methane gas by anaerobic bacteria. However, lignin does not degrade during anaerobic digestion. Since a significant part of indissoluble substances in cow manure is lignin, the percentage of volatile organic solid material that can be converted to gas is much lower compared to other types of manure and organic waste. Percentage of production CO2 and CH_4 depends on the characteristics of manure. From the manure of dairy cows in most cases it is possible to produce biogas which content CH_4 between 55-65% and 35-45% CO_2.

In 2008 the EU member states produced biogas equivalent of 7 [Mtoe], and in the period 2012-2015 the EU predicts the production of 15 [Mtoe]. Animal manure has the potential of 18.5 -20 [Mtoe] (Table 5).

Table 5. The energy potential of the total swine and cow manure in EU-27 [7]

Total animal manure	Biogas	Methane	Potential	
[10^6 tona]	[10^6 m^3]		[PJ]	[Mtoe]
1,578	31,568	20,519	827	18.5

4.1 Number of dairy cow in central Serbia

Ministry of Agriculture, Forestry and Water Management was in 2007 entrusted the Institute for Animal Belgrade-Zemun job reporting on the state of animal husbandry in the territory of central Serbia. One of the reports was the number of milk cows per farm districts of Central Serbia, the number of conditional livestock (CL) for each registered farm.

In order to obtained data with number of districts with CL milk cows in the Republic of Serbia and be able to process statistically, it was necessary to define the number of classes. Given that we have 118 measurements, the numbers of classes are between 9 and12 with a space of 150 CL. In this way we found Figure 2.

First results were given by the fact that 42.4% belongs to a group of 0-150 CL, and 25.4% of the group 151-300 CL. This point to the qualitative assessment of a large number of small farms which number up to 150 CL.

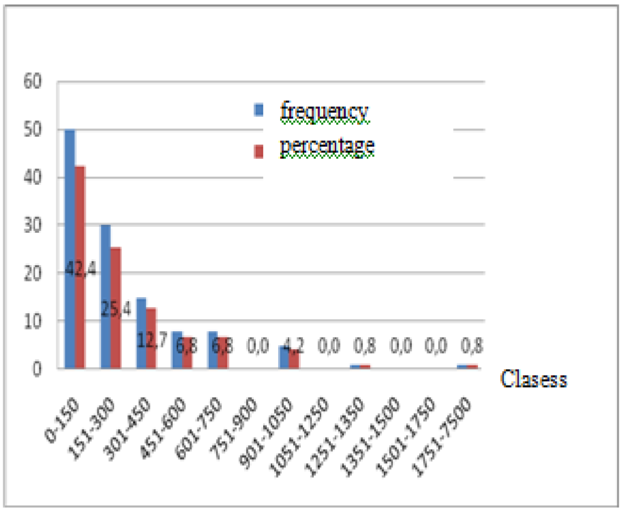

Fig. 2. Milk cows number in CL classes and percentage in central Serbia

4.2 Biogas production from dairy cow farm in central Serbia

Calculation methodology of construction costs and potential revenues from anaerobic digestion of cow manure was taken from eminent professional handbook for engineers in planning and building bioenergy systems, written by the German Association for Solar Power 2005, [4]. Baseline data in the calculation was that one cow in lactation, weight 630 [kg], for one year produces 27 [t] of manure (contain 10% dry matter and the biogas yield between 0.2-0.4 [m^3/kgDM]). Methane content in biogas was between 50-80%. Operating digestion temperature is mesofilik (35 °C) with manure temperature of 15 °C. Storage of fermented material in post digesters are two months.

The existing experience from Germany show that in case of energy crops as feedstock, biogas plants with installed el. power of 250 [kW] require special efforts to ensure the economic viability [8]. In this analysis substrate is cow manure and corn silage as co substrate in the appropriate percentage of the energy crop. It makes no sense to do a complete calculation of biogas plants equipped for 2, 4 or 8 cows, because in this case, quite realistically possible is to use, „Chinese bio reactor" type which is the most common underground digester volume of 60-20 [m^3]. This type of reactor is semi-automatic and the plant is necessary to spend much less resources, again depending on the percentage co substrate (Table 6).

Table 6. AD cow manure with small number of CL

No. CL	Production of biogas [m^3/year]				Total cost of the project [€]			
	Part of co substrate [%]							
	0	9	20	30	0	9	20	30
2	1,080	1,579	2,327	3,216	2,035	2,585	2,915	3,240
8	4,320	6,316	9,310	12,862	2,640	3,388	3,895	4,390

Exceptional biogas purification is necessary if the biogas is placed in the gas distribution network system or when it is used as fuel for the vehicle. With such actions concentration of methane in biogas with 50-70% are increases to 95% and biogas becomes bio methane. It should be noted that the bio methane in vehicles can be used in the same manner as natural gas.

Figure 3 is shown function in biogas production depending on the percentage of cosubstrate (e.g., corn silage).

It can be concluded that with an increase in the percentage of cosubstrate representation exponentially increase the production of biogas. The basic reason may be specified by the fact that cow manure (if it's self-fermentation) has a very low conversion VS rate to the biogas because of the high undesirable lignin content. Therefore, when you add cosubstrate (in this case corn silage), containing a high percentage of cellulose and production of biogas increases exponentially.

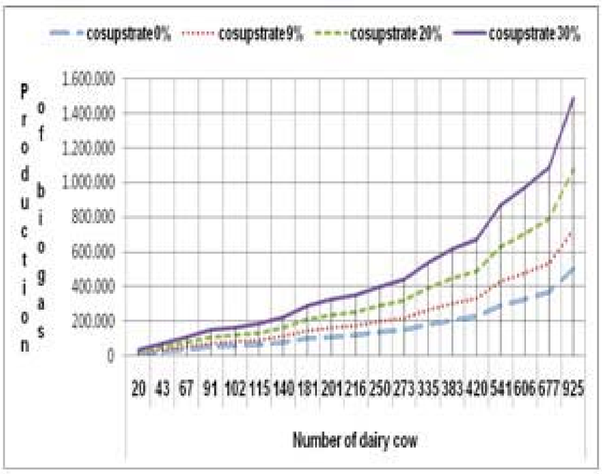

Fig. 3. Biogas production depending of cosupstrate percentage (eg, corn silage) and milk cows number (CL)

An example is obvious if you look at production of biogas with 200 CL, which amounts to 108,540 [m^3], and with the same number and CL, and cosubstrate share of 20% amounts to 233,904 [m^3]. So we get an increase of 115%. Table 7 provides an overview as possible of the total production of biogas and electricity (without heat).

Table 7. Possible annual production of biogas and electricity in central Serbia (12.630 CL)

Cosubstrate percentage (corn silage)	0%	9%	20%	30%
Biogas production [m^3/god]×10^3	16,809	30,128	44,410	61,357
Amount of biogas [m^3/CL]	440	789	1,164	1,608
Electricity production [GWh_{el}]	34.3	50.2	74	102.2
Electricity production [TJ]	123.5	180.7	266.4	368
Electricity production [Mtoe]	0.0029	0.0043	0.0064	0.0088
Substitute imported natural gas in Serbia (2008.) [%]	0.7	1.3	1.9	2.6
Substitute imported natural oil in Serbia (2008.) [%]	0.00011	0.00016	0.00024	0.00034
The value of substituted oil[€]×10^3 (1barel = 59 €)	**1,078**	**1,598**	**2,379**	**3,272**

5. BIOGAS AS FUTURE ROAD TRANSPORT FUEL IN SERBIA

Biogas can be used in both heavy-duty and light duty vehicles. Light duty vehicles can normally run both on natural gas and biogas without any modifications whereas heavy-duty vehicles without closed loop control may have to be adjusted if they run alternately on biogas and natural gas.

Biogas has to be upgraded to natural gas quality in order to be used in normal vehicles, designed to use natural gas. There are today tree European countries with approved standards for biogas (Switzerland, Germany and

Sweden).The development of the biogas vehicle sector has been undertaken in close co-operation between natural gas distributors and biogas distributors.

The most common technologies for biogas upgrading are the water scrubber technology and the Pressure Swing Adsorption (PSA) technology. Gas upgrading is normally performed in two steps where the main step is the process that removes the CO_2 from the gas. Minor contaminants (e.g. sulphur compounds) are normally removed before the CO_2-removal and the water dew point can be adjusted before or after the upgrading (depending on process).

For biogas as transport fuel no common standardisation in the European Union exists. This is attributed to the low level of applications and on the lower complexity of biogas compared to bioethanol or biodiesel. Biogas consists, after different purification treatments, mainly of methane (> 80% Vol.) and CO_2.

Nevertheless there is a Swedish Standard (SS) on biogas **SS 155438** “Motor fuels – Biogas as fuel for high-speed Otto engines” as a reaction to the growing demand of biogas in Sweden. The methane content of biogas according to this standard is 97 % (+/- 1-2 %). This Swedish standard was developed by STG Technical Group number 85 (TK 85). It is applied for the use in Otto engines, which includes converted diesel engines provided with glows or spark plugs. Biogas manufacture on the above standard may be used in engines to natural gas without modification. Standard specification provides two biogases: Biogas A (engines without λ control) and biogas B (engines with λ control) (Table 8).

Table 8. Characteristics of biogas per SS 155438 [9]

Features	Unit	Biogas A	Biogas B	Test method
Wobbe index	MJ/m^3	44.7-46.4	43.9-47.3	SS-ISO 6976
Methane	%	97±1	97±2	ISO 6974
Octane number		130	130	
Water content	mg/m^3	32	32	SS-EN ISO 10101-1, -2, -3
$CO_2+O_2+N_2$ (max)	%	4	5	ISO 6974
O_2 (max)	%	4	1	
Sulphur	mg/m^3	23	23	ISO 6326-1, -2, -4 SS-EN ISO -3, 5
NH_3	mg/m^3	20	20	ISO 6974

In the Swedish Gas Council report 20, Swedish Biogas AB are quoted as estimating a cost range for the production of biogas used in vehicles, reflecting different production conditions, in the order of 26-33 [peni/Nm^3] *(Note: peni=1.3 dinara)*. This range also includes crop based biogas. The higher feedstock cost when using crops is partially compensated for by lower treatment costs for upgrading in the biogas plant. The pre-tax market price for biogas used as a vehicle fuel in Sweden is claimed to be about 70% of the total consumer price of gasoline (including tax). Hence with the full tax rebated, biogas in Sweden can be competitive with gasoline or diesel fuels. The estimated cost range from this Swedish data is equivalent to 36-46 [peni/kg] including compression costs. However, for use in vehicles, the biogas would also need to be delivered to the refilling station, with additional costs for transportation from the CAD *(Centralised anaerobic digestion)* plant, and the retailing and other operating costs at the filling station. A detailed report for the Californian dairy industry has also examined the production and use of biogas as a vehicle fuel and other energy applications. A hypothetical anaerobic digestion and upgrading plant producing upgraded biogas using feedstock from a dairy herd of 8,000 cows. The methane produced from the feedstock is assumed to be approximately 1 [m^3] per cow per day. The operating costs in the Californian report are based on actual cost data from the *Linkoping plant* and the capital costs are based on actual costs at the *Boras plant*. The estimated total cost of 23.2 [p/Nm^3] from the US study is equivalent to 32.3 [p/kg] at a pressure of 1 bar, and at 15 ^oC. For use in vehicles, the biogas would need to be compressed. Applying the compression costs from the Swedish study of 7 [p/Nm^3] to the US data gives an overall cost of 30.2 [p/Nm^3], equivalent to 42 [p/kg]. Furthermore, as with the Swedish estimates, there would be additional costs associated with delivery to the refilling station, comprising the costs of transportation, retailing and operating costs at the filling station. From the evidence of these two studies, it is suggested that biogas from a CAD plant can be produced, upgraded and compressed for use as a vehicle fuel at a cost of between 36- 46 [p/kg], at the plant gate.

There are today more than 4000 vehicles in Sweden running on natural gas and biogas and several local fleets (e.g. Linköping, Uppsala, Kristianstad) where the major part of the urban public transports are operated on biogas.

Biogas vehicles have special benefits in many Swedish cities as free parking, lower tax on biogas vehicles when used in commercial traffic, no tax on biogas as vehicle fuel, exemption from city gate tolls for biogas vehicles, special lanes for biogas taxis and financial support for investment in biogas vehicles. Some 15% of the large Volvo vehicle sales are now CNG bi-fuel vehicles.

When it comes to passenger cars all the major manufacturers have ready-made solutions to natural gas, and it meets the American left (*Ultra Low Emission Vehicle*) emission values for the application of appropriate catalytic technology. Table 9 presents characteristics of vehicles Volvo V70, bivalent".

Table 9. Volvo V70 „bivalent’’ [1]

Features of vehicle	Super unleaded	„Bivalent’’: natural/bio gas
Power kW (KS), [rpm]	103 (140) on 5400	103 (140) on 6100
Consumption in the city on 100 km	13.2 [L]	14.4 [m^3]
Suburban driving consumption on 100 km	7.2 [L]	7.5 [m^3]
Average consumption on 100 km	9.4 [L]	10 [m^3]
Emission CO_2	225 [g/km]	179 [g/km]
Tank volume	68 [L]	95 [L] - (23 m^3)

All the above mentioned data and analysis show the significant economic and environmental benefits from the development of the gas as transportation fuel, but it is clear that there are numerous obstacles. As to what extent is anaerobic digestion technology developed in Serbia (corn silage and liquid cow manure) and what the fleet vehicles operated on natural gas, it will be more specific time for the wider use of biogas.

The barriers to wider use of biogas in Serbia can count: limited experience with the application of anaerobic digestion technologies, and usually believes that there is a large investment risk; currently is more cost-effective to use a gas to produce electricity because of the cost of processing the gas and the lack of distribution network for this fuel, the consumers limited awareness of natural gas as a fuel in vehicles (environmental awareness); potential users believe that additional capital expenditures are greater than the possible savings in fuel cost above.

Serbia has adopted international regulation of natural gas as "motor fuel". There are a few stations for raising pressure in bottles of natural gas to 200 bar in Serbia. Belgrade has a compressor station in the circle "Ikarbus (primarily for passenger cars), and in Novi Sad within „NIS". Natural gas is not prepared beforehand by the standard as "a natural gas" vehicle but taken directly from the pipeline.

6. CONCLUSIONS

Natural gas is a fossil fuel that has many advantages (high security of supply, low emissions, established distribution grid etc.) compared to liquid fuels like diesel and gasoline and has also been pointed out as a major alternative in the changeover to sustainable fuels. Upgraded biogas has the same advantages as natural gas but is in addition a sustainable fuel that can be manufactured from local waste streams thereby also solving local waste problems.

Production of biogas is a mature technology that is well established in many European countries and the biogas potential is considerable, especially when taking into account the possibilities to use set aside land for production of crops for biogas.

Upgrading of biogas is a relatively new technology but experience from Sweden and other countries shows that it now is possible to upgrade biogas with high reliability and to reasonable costs. The Swedish experience shows that biogas can be an economical sustainable fuel with a potential to drastically reduce emissions in urban transport.

Serbia has not yet created conducive environment for the development of anaerobic digestion projects. Without the help of state subsidies for production every attempt is doomed to failure. Production of the biogas only from corn silage is unviable because of the traditional use of the corn for feeding livestock, of a small yield per unit area and poor agricultural policies.

Serbia not using the resources given by the nature, and when we add the rapid progress of science and technology (anaerobic digestion is one of them), the situation is even more difficult. Small agricultural holdings are one of the major problems. Given that 43% of all registered farm milk cows belong to the category of 0-150 CL, it is not favourable for a loan repayment for such a small number of milk cows. Therefore, it is the biggest problem in investing in systems for the production of the biogas.

Gradual introduction of any new fuel in general use is always going a similar way: first, in conjunction with conventional liquid fuels, and only after the branch distribution network of large-scale use. In that way we should see future use of the natural and the biogas for motor vehicles.

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