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Bioenergy production in Ukraine: The competitiveness of crops and other raw materials from agriculture and forestry

Disclaimer:

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1. Executive Summary

The use of bioenergy is an important issue with regard to overall energy security given the fact that world energy prices are on the increase. From a Ukrainian perspective, this paper deals with various crops and agricultural raw materials and their technical and economic potential to serve as renewable energy sources (RES). Special emphasis is put on the economic costs and benefits of energy production based on biomass.

In the first part of this paper we focus on **agricultural commodities commonly used to produce biofuels such as bioethanol and biodiesel**. Because relevant prices, technologies and institutions undergo rapid changes, there is need for a dynamic approach to answer at which cost one can produce a single litre of biofuel. In this respect, high world energy prices and an increasing demand from the food, feed and energy industries determine high prices for agricultural commodities like grain, oilseeds and corn, which exert special influence on the profitability and competitiveness of bioenergy production.

Today, rapeseed production in Ukraine is competitive with other countries. At current production costs farmers achieve good profits with rapeseed production. It is predictable that sooner or later the domestic crushing industry will invest in rape seed processing to increase its share in the value chain. However, the question whether rape seed oil will be further processed into biodiesel within Ukraine or whether it is exported remains open. At current levels of energy and raw material prices biodiesel is not profitable without subsidies. This is also the case for bioethanol using grain. Taking into account the current crude oil price level, there are no incentives to produce bioethanol from corn or wheat.

Is this also true for ethanol produced from sugar beet? The analysis below shows that cost of producing bioethanol in Ukraine with sugar beet at 428 US$/$m^3$ is not competitive with fossil fuels. The calculated production cost of 428 US$/$m^3$ is more efficient than that in the European Union but not competitive with the low cost producer Brazil that is producing ethanol from sugar cane.

An important way to increase the productivity of biofuel output is to use the whole plant instead of processing only parts of it. This is the second generation of biofuels. Using second generation materials is still in research and development and Ukraine should keep in mind that there are new technologies to produces biofuels at low cost in a more efficient way.

Ukraine's agricultural sector has the potential to supply raw materials that are needed to produce bioenergy. In a best-case approach, this could result in lower green house gas (GHG) emissions and benefits for soil and water quality as well as an enhanced biodiversity. However, it is economic efficiency that determines whether such an approach should or should not be realised.

In addition, there are yet **other renewable energy sources (RES) to produce bioenergy**. Any analysis of renewable energy sources would be incomplete if particular residuals of agricultural activities such as straw, wood and bark residues or liquid manure were not included. The price for straw pellets is cheap in comparison with other raw materials and even the use of wood residues could be an alternative to produce energy. Using straw for heating systems is cheaper than using agricultural raw products that are traded on a high-price-level food market. Straw is available in most parts of Ukraine and because of the low production costs is suitable for energy production systems.

Biogas production from livestock organic waste could also provide new opportunities for some agricultural industries and rural areas. Local energy generation using biogas plants can improve the energy supply in remote areas where imported energy is especially expensive.

For further **strategic options for renewable energy in Ukraine** we conclude that at current price ratios of energy and raw materials biodiesel and bioethanol production in Ukraine is not yet profitable. Hence, exporting grains and oilseeds **to benefit from high demand on international commodity markets until price ratios in Ukraine substantially change** seems the better strategy. The applied technology is rather simple and investors would quickly react on changing price ratios. As sugar beets are even more costly raw materials than grains and oilseeds, the production of bioethanol using sugar beets as raw materials would also need huge subsidies and does not present a strategic option with high profit potential. The EU's and US's political decisions on the use of biofuels so far have had an inflating effect on world grain and rapeseed prices. In this respect Ukrainian farmers, grain traders and oilseed processors may benefit from the EU's and other countries highly subsidised biofuels sector by increasing exports and thus raising profits. At the same time policy makers should **take into consideration renewable energy that is based on low-cost raw materials**, such as straw and wood residues for heating as well as manure and communal waste for biogas to support energy supply in rural areas of Ukraine.

2. Introduction, background and objectives

Renewable energy offers interesting opportunities for agriculture and forestry in Ukraine. Besides, energy security and the use of bioenergy are important topics. Prices for fossil fuels have grown and so have discussions about greater independence from imported energy. However, conditions and potentials for the use of renewable energies differ from country to country. The production of biofuels is just one way to use biomass for energy production. But renewable energy sources (RES) offer more possibilities. In each case it is necessary to compare the market prices or opportunity costs of agricultural commodities and raw materials that are used for producing renewable energy. After all it is the costs of RES that largely determine the price of bioenergy. High world energy prices and an increasing demand from the food, feed and energy industries result in high prices for agricultural commodities like grain, oilseeds and corn. As a consequence, higher prices of raw products do have direct influence on the profitability of energy production.

The agricultural sector has the potential to supply raw materials that are needed to produce bioenergy. In a best case approach, this could result in lower green house gas (GHG) emissions and benefits for soil and water quality as well as an enhanced biodiversity. However, it is economic efficiency that determines whether such an approach should or should not be realised.

This paper deals with various crops and agricultural raw materials and their technical and economic potentials to serve as RES. Special emphasise is put on the economic costs and benefits in connection with energy production based on biomass.

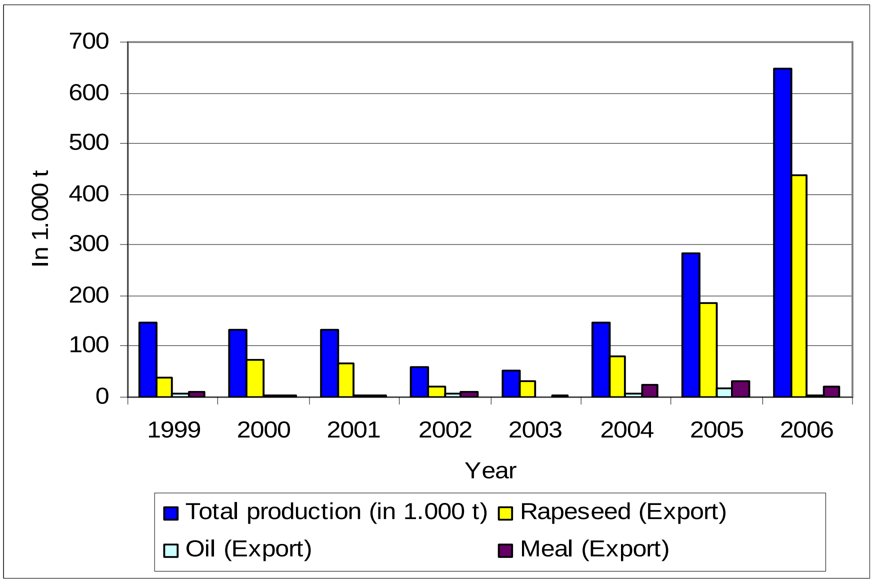
3. Crops that can be used for biofuel production

In this part we focus on agricultural commodities to produce biofuels such as bioethanol and biodiesel. Because relevant prices, technologies and institutions undergo rapid changes, there is need for a dynamic approach to answer the question at which costs one can produce a single litre of biofuel. In this respect, high world energy prices and an increasing demand from the food, feed and energy industries determine high prices for agricultural commodities like grain, oilseeds and corn, which exert special influence on the profitability and competitiveness of bioenergy production.

3.1 Rapeseed

In Europe, rapeseed has been cultivated since the beginning of the 19th century. Both spring and winter types have been developed. Although the market is dominated by winter rapeseed but the spring type is also cultivated in many regions. In Ukraine farmers produce winter and spring varieties but the share of winter rapeseed reflects a steady growth (from 63 % to 82 % over the last three years). In general, crops of the winter-hardy cultivars realize higher yields than the spring type. Only in case of an extremely hard winter lasting until late springtime, farmers growing spring rapeseed are realizing a benefit as those plants with the winter growth habit suffer from winterkill and do not meet their theoretical yield potential. Other reasons for spring rapeseed are site-related factors and natural local conditions concerning the vegetation period or operational sequences on the farm (e.g. a lack of time when winter rapeseed should be sown in late summer but capacity for sowing in springtime). Rape seed is a comparatively ambitious crop. The seedbed must be well prepared and quality seeds, fertilizer and several pesticides are needed to achieve high yields. For crop rotation it is advisable to cultivate rapeseed every 4-5 years. An important advantage is the positive effect rapeseed has on the following crop. In Ukraine, the area cultivated with rape seed has been increased rapidly since 2003. From 2004 till 2006 the volume of the rapeseed production has more than doubled from 148.300 t to 647.100 t, as depicted in Figure 1.

Figure 1: Total production of rapeseed in Ukraine and export share of rapeseed, rapeseedoil and -meal (1999-2006)



Source: Ukrainian Ministry for Agricultural Policy; Official USDA Estimates

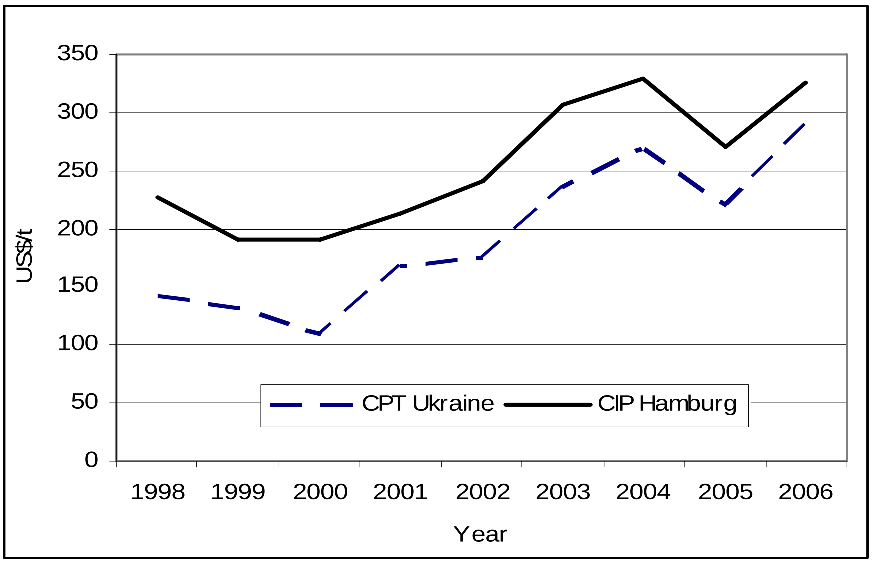
Rapeseed as an agricultural commodity is exported to the world market. This booming trend for rapeseed production and export is based on a growing worldwide demand. Especially the EU with its rising biodiesel production makes a market for rapeseed and rapeseedoil. The following Table 1 shows the global increase in oilseed production since 2001/2002. The worldwide production of oilseeds is dominated by soybeans, followed by cottonseed, peanuts and rapeseed.

Table 1: The world vegetable oil production

Source: USDA, Toepfer, December 2006

The Ukrainian farmers benefit from this international trend that is based on the increasing biofuel demand. In the past, the Ukrainian oilseed market was dominated by sunseeds. The production and domestic crushing of rape seeds and soybeans have been on the rise during the last years. In the case of soybeans this increase has been caused by growing demand from the livestock sector, mainly from Asia.

Figure 2: Prices paid for rapeseed on the world market and for Ukrainian exports (1998-2005)



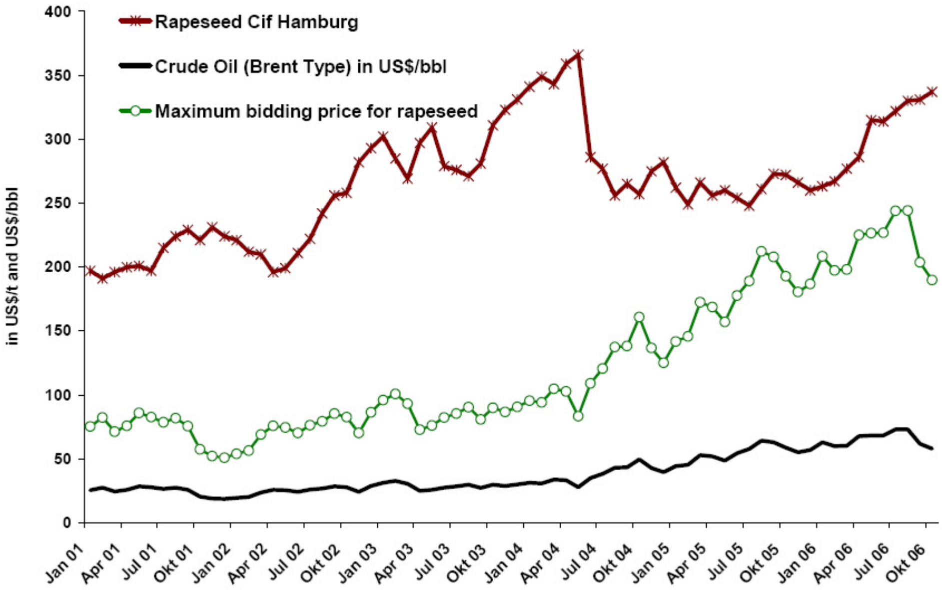
Source: State Statistics Committee of Ukraine (2006); Lembke (2005)

Figure 2 shows that the price paid for exported rapeseed from Ukraine (CPT Ukraine) follows the world market price (CIP Hamburg). The price level line on the world market runs above the Ukrainian price. However, the decreasing spread between international and domestic markets indicates decreasing transaction costs in Ukraine due to considerable domestic and foreign investments in market infrastructure and port logistics.

In a detailed analysis Lakemeyer (2007) concludes that rapeseed production in Ukraine is competitive with other countries. At current production costs, Ukrainian farmers achieve good profits with rapeseed production. It is predictable that sooner or later the domestic crushing industry will invest in rapeseed processing installations in order to increase the share in the value chain for Ukraine. However, the question whether rapeseed oil will be further processed into biodiesel within Ukraine or whether it is exported elsewhere has to remain unanswered for the time being. At current price ratios of energy, commodities and raw materials domestic biofuel production is not profitable. Thus, it seems to be a better strategy to sell rather than process domestically produced commodities and thus benefit from participation in international markets until price ratios substantially change.

Figure 3 presents the results of a model calculation for the investment and running costs of biodiesel production to deduct the maximum bidding price for rapeseed paid by biodiesel plants in Ukraine under market conditions. It becomes clear “that the maximum bidding price for rapeseed used for biodiesel production has continuously been lower than the market price since 2001.” (IER:2007).

Figure 3: The crude oil price, the maximum bidding price for rapeseed used for biodiesel production and the market price for rapeseed



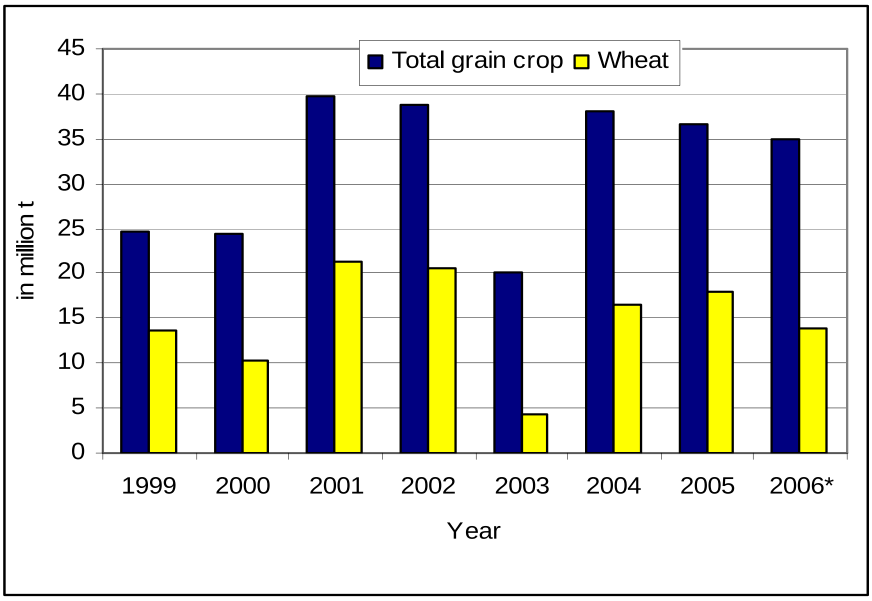
Source: IER (2007)

The EU's political decisions on the use of biofuels so far have had an inflating effect on world market rapeseed prices. In this respect, the competitiveness of using rapeseed for biofuel production in Ukraine is questionable, given that biodiesel production has never been competitive without subsidies. However, Ukrainian farmers and oilseed processors may benefit from the EU's highly subsidised biodiesel sector by realising increasing exports and thus rising profits.

3.2 Grain (wheat and maize)

Figure 4 shows the production of total grain crops and wheat for Ukraine over the last 6 years. In the Ukrainian market, wheat is the most important grain.

Figure 4: Ukrainian crop and wheat production (million tons)



Source: Own presentation with data from AgroPerspectiva (2007) and UkrAgroConsult (2006).

The curve progression reflects the production results from 1999 to 2006. Last year's harvest was well below previous years because of bad weather conditions, which reduced harvest acreage and yield. But this is not as drastic as it was in 2003. Prices for wheat on the world market have displayed an increasing trend since last autumn.

Following reduced harvests in some regions of the world as well as increased feed demand (mainly in Asia) and increased demand from the bioethanol industry (mainly in the USA) prices for wheat and corn traded on the world market has increased drastically in the course of the year.

Table 2: Calculation of the maximum bidding price for corn

2.	**Calculation of the max. bidding price for corn**		
a	Price of crude oil in US$/bbl	$60,00	
b	Price of gasoline in US$/bbl	$78,00	= a * 1,3
c	Price of gasoline in US$/m3	$490,61	= b / 0,1589873
d	Maximum price of bioethanol in US$/m3	$323,80	= c * 0,66
e	**Production cost**		
f	Capital cost in US$/m3	$58,42	
g	Variable cost in US$/m3	$151,00	
h	Total production cost net of corn in US$/m3	$209,42	= f + g
i	By product credit in US$/m3	$64,00	= 0,8 * P DDGS
j	Total production cost minus by product credit in US$/m3	$145,42	= h - i
k	Price of ethanol minus production costs in US$/m3	$178,38	= d - j
l	Maximum bidding price for corn in US$/t	$69,57	= k * 0,39
	Prices and conversion factors		**Assumed Parameters**
	Price of crude oil in US$/bbl	$60,00	Ethanol prod.out of corn in m3/t
	Price of DDGS in US$/t	$80,00	Energy density of ethanol/gasoline
			DDGS prod.per m3 ethanol

Source: IER (2007)

Under these assumptions the maximum bidding price for corn is 69 US$/t, which is relatively low in comparison to the actual world market price for corn. The crude oil price exerts the most important influence on the maximum bidding price as is also supported by IER (2007). Taking into account the current crude oil price level, there are no incentives to produce bioethanol with corn. In the next chapter we calculate the bioethanol production with sugar from sugar beet.

3.3 SUGAR

Assuming that Ukraine considers producing ethanol from domestically produced sugar we calculate again the production costs.

Table 3: Cost calculation for bioethanol production based on sugar beet

1. Capital cost assumptions		**Unit**
Investment cost of 200.000 m3 plant	90.000.000	US$
Cost of a plant in US$ per m3 production capacity	450	US$/m3
Interest rate in %	6	%
Depreciation period in years	10	Years
Yearly capital cost per m3	57,2	US$/m3
2. Variable cost assumptions		
Energy cost	67,00	US$/m3
Transportation cost in US$/m3 ethanol	90,00	US$/m3
Other costs in US$/m3 ethanol	37,50	US$/m3
Total variable costs in US$ per m3	194,50	US$/m3
3. Raw material cost assumptions		
Price of sugar in US$/t	118,00	US$/t
Conversion ethanol per t of sugar in m3/t	0,62	m3/t
Conversion t of sugar per m3 ethanol	1,62	t/m3
By products	0,10	t/m3
Cost of sugar for ethanol production in US$/m3	191,05	US$/m3
By product credit	140,00	US$/t
4. Total cost calculation in US$/m3		
Capital cost	57,15	US$/m3
Variable cost	194,50	US$/m3
Raw material cost	191,05	US$/m3
By product credit	13,72	US$/m3
Total cost	**428,98**	**US$/m3**

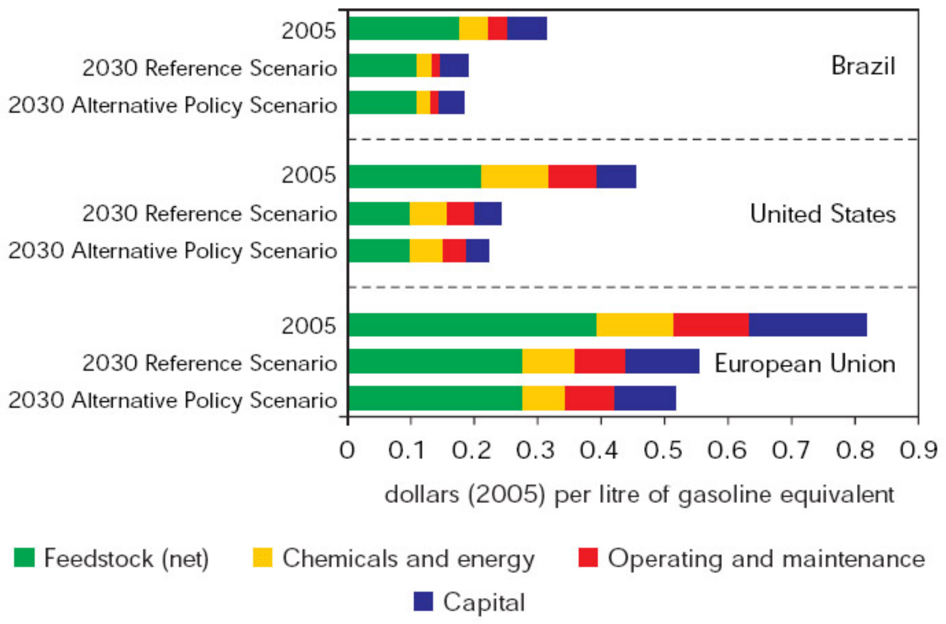
Source: Own calculation based on Data from IER (2007), FNR (2006), Langwost (2002), DMH (2007) and Südzucker (2007).

Due to high production costs it becomes clear that producing bioethanol from domestically produced sugar is not competitive. At the current price level agricultural raw products are too precious to produce biofuel that is not competitive with fossil fuels at given market prices.

This calculation starts with the capital costs. We assumed rather optimistic capital cost of 90 mln US$ with an annual ethanol production capacity of 200.000 m^3. The variable cost includes energy cost, transportation cost and other cost (e.g. the enzymes that are used for the fermentation). The transportation costs are higher for sugar beet because of a lower rate of yield in comparison to wheat for bioethanol production. The raw material cost show the price of sugar (118 US$/t) calculated on data from the London International Financial Futures and Options Exchange and Ukrainian sugar prices. Conversion cost are at a reduced rate because of the plant size and technical possibilities by using sugar beet instead of wheat. The by-product credit is assumed in a more pessimistic way. Vinasse (fermented molasses) contains nutrients such as nitrogen, phosphate, potash and sucrose. In concentrated form it could be applied as a fertilizer on the field or the clarified vinasse is used as an additive in animal feed. The market price for vinasse is about 140 US$/t. Vinasse is the only by-product credit that is allowed for in this calculation. There are other by-products that can be taken into account like sugar beet pulp. Sugar beet pulp is a carbohydrate-rich co-product generated by the table sugar industry and therefore it is more a by-product in the sugar plant than in the ethanol production process. That is the reason why we do not calculate with a by-product credit for sugar beet pulp that is often used in the animal feed-industry.

Under these assumptions the cost of producing bioethanol in Ukraine with sugar beet totals 428 US$/$m^3$, which is not competitive with fossil fuels. Compared internationally, it can be seen in the next figure, that the calculated production cost of 428 US$/$m^3$ are more efficient than those in the European Union but not competitive with the low cost producer Brazil that is using sugar cane as raw material. Sugar cane is a perennial tropical crop and therefore less costly than annually planted sugar beets.

Figure 5: Production cost of ethanol in Brazil, the European Union and the United States



Source: (Costs including current rates of subsidy to crops and ethanol production[1]) OECD 2006

Due to a combination of climate, soil and relatively low labour and land cost, Brazil is currently the world's lowest-cost producer of sugar cane and, therefore, ethanol. In comparison, the production costs for producing ethanol are the lowest worldwide (Figure 5). This underlines the importance of raw product cost that is used for biofuel production. Sugar beet and also grain are traded at high world market prices on the food market. Therefore their prices are currently too high to allow for their competitive use as RES. In 2005, roughly 50 % of the produced sugar cane output in Brazil was used for ethanol production, the output of which reached 8.2 Mtoe – an increase of 51 % over 2000.

3.4 POTENTIAL OF SECOND GENERATION RAW MATERIALS

An important way to increase the productivity of biofuel output is to use the whole plant instead of processing only parts of it. This is the second generation of biofuels. It means converting ligno-cellulosic biomass into biofuels. This process of gasification of the feedstock produces synthetic gas (so called syngas) – a mixture of carbon monoxide, hydrogen and other compounds. The syngas can then be converted to diesel (via Fischer-Tropsch synthesis), methanol or dimethyl ether – a gaseous fuel that is similar to propane. Alternatively, the hydrogen can be separated and used as a fuel. Currently, most interest exists in production of diesel via Fischer-Tropsch-synthesis (FT diesel). As yet, there is no commercial production of biofuels through gasification, because of the high cost compared with conventional technologies. However, a considerable amount of research and development is under way to devise commercially-viable processes. To achieve economies of scale, very large plants will probably be needed for the production process. This will require extensive logistical systems for gathering and transporting the biomass raw materials (Hamelinck and Faaij, 2005). Demonstration plants have been built in Germany. The current production cost of FT diesel from biomass is about $0.90 per litre, based on a woody biomass feedstock price of $3.6/GJ. The cost could decline to $0.70 to 0.80/litre in the long term (IEA, 2006).

[1] For further details with regard to different assumptions about the Reference and Alternative Policy Scenario please refer to OECD World Energy Outlook 2006.

4. Other renewable energy sources to produce bioenergy

There are various other energy sources in agriculture and forestry that may be used to produce bioenergy. Some of them are rather cheap and therefore auspicious. It is obvious that biofuels are not in every case the most efficient way to use agricultural products as RES. While the use of (domestically produced or imported) RES could clearly improve energy security in Ukraine, the key question is: At what economic cost? It can be seen that the cost for producing biodiesel and bioethanol are comparatively expensive because of the possible alternative use of the raw materials for high prices on the world food markets. Therefore it makes sense to look at raw materials that may be available at lower cost in Ukraine. This could be crop residues like straw, manure or communal waste to produce biogas and – last but not least – wood.

4.1 STRAW

After harvesting, the straw stays on the field if it is not needed for livestock farming. To conserve humus for the soil-fertility, straw is often ploughed into the field, but this is not mandatory every year in a well planned crop rotation. The straw surplus differs with the different crops. The average energy content of straw as RES is 4-4,5 kWh/kg. Straw can be used as fuel in small farm straw-fired boilers and in straw-fired DH plants. The amount of straw that is possibly usable for energy production can be calculated with a look to the current crop production in Ukraine (e.g.: on average of four years of Ukrainian grain production there are 12.8 million ha). Assuming of a low yield on average, the biomass that can be harvested would amount to approximately 23 GJ/ha (e.g. in Germany we calculate higher yields and a more intensive grain production with finally 70 GJ/ha energy from the straw yield). In case the whole Ukrainian straw would be used for energy production, 300 PJ or 7.2 mtoe could be gained annually. This calculation is a first step to get an impression about the idle energy potentials in Ukraine. Zhovmir and Zhelyezna (2005) upgraded this calculation with the knowledge about currently used straw volumes in livestock farming. They come to the result that even if only a certain amount would be used for livestock farming, there will be still 2,5-4 mtoe for energy use available. This is a "cautious" calculation. Given the current developments in the agricultural sector, grain production is becoming more intensive and remaining straw will increase with the grain yields.

Table 4: Price for humus and nitrogen contained in straw.

Price for humus and nitrogen contained in straw:		
Value of humus	3,68	USD/t straw
Value of nitrogen, phosphate and others	7,36	USD/t straw
Sum	11,04	USD/t straw
Yield of straw	1,90	t/ha
Value/ha	**20,98**	**USD/ha**

Source: Own calculation based on data from IER (2006) and KTBL (2005) (2006)

The production of heat from straw is competitive because the value of straw is comparatively low. The value of grain as the proceeding crop is around 13 US$/t for Ukrainian grain producers. With a yield of around 3 t/ha the value per ha is 39 US$/ha wheat. For straw we can assume a yield of 1,9 t/ha that should be estimated by the contents of nitrogen, phosphate, potassium, magnesium and others. Approximately 20 US$/ha should be calculated as value that should be credit against the humus and fertilizer balance of the field. For example a farm sells straw to a heating plant to burn that straw, the minimum price for the straw is 11 US$/t because this is the value that can be credited for humus and nitrogen-contents.

The prices that can be taken into account for straw as raw material for heating can be calculated in comparison with heating oil or gas. The calorific value of straw (4,7 kWh/kg) is around 50 % lower than that of heating oil (10 kWh/kg).

Heating oil prices paid by consumers are determined by the cost of crude oil. Adding on the cost to produce the product, the cost to market and distribute the product as well as the profits (sometimes losses) of refiners, wholesalers and dealers determine finally the consumer price. Actually heating oil price is about 50 €/100l. Conseur (2006) analysed the costs of different heating systems with raw products like gas, heating oil, wood pellets or straw in Germany. The database is not identical in every detail with a Ukrainian database but it can be seen as an example for price tendencies.

Table 5: Comparison of different raw products for heating use

Raw product	Price	Energy consumption	Degree of efficiency	Price in ct/kwh
Heating oil	81,9 ct/l	9,8 kWh/l	90 %	9,2
Gas	67,6 ct/m3	9,2 kWh/m3	95 %	7,7
Wood pellets	261,3 USD/t	4,9 kWh/kg	90 %	6,0
Straw pellets	**195 USD/t**	**4,5 kWh/kg**	**90 %**	**4,8**

Source: Based on Conseur[2] (2006)

As can be seen in Table 5, the price for straw pellets is cheap in comparison with other raw materials. This means that farmers could gain profits from selling straw to heating companies and Ukrainian consumers – mainly in rural areas - would benefit from lower heating cost.

4.2 Manure, sludge and communal waste for biogas production

Producing energy in biogas plants is one of the most flexible ways to provide energy either in small sized plants for households and villages or in modern huge plants securing the energy supply of thousands of people. Today, advanced biogas technologies are available and the investment cost decline. Biogas production is a natural and essential biological process with different types of bacteria that are in involved in a digestion process.

A huge number of plants differing in size are built in Europe, but most of them are using agricultural raw products such as corn or crop silage (e.g. of rye or triticale). This is a comparatively expensive way to produce renewable energy, because of the production cycle of the raw material and its opportunity cost as it can be sold for high prices on the food markets.

In other countries, e.g. China, agricultural residues (e.g. manure, straw, sugar beet pulp, sewage sludge, organic waste) are used for biogas generation. Estimates of potential and projections must be interpreted with caution because they can vary widely depending on the different assumptions made. For manure, the available data is often the numbers of livestock. The manure available from households can be estimated on the basis of experience in many other countries. The amount of manure produced by animals depends on amount and type of fodder, some average figures exist for most countries. We try to give a first impression on the potentials that could be realised by livestock farms in Ukraine.

Our own calculations that are based on national cattle and swine herds of roughly 9 and 8 million animals respectively, suggest that Ukraine could by a very conservative estimate produce 8,4 billion m^3 of biogas per year from manure, for a potential of 137,3 PJ of energy.

This calculation shows that the largest potential for biogas at low cost is in manure related to agricultural activities. Other potential raw-materials are:

- sludge from mechanical and biological waste-water treatment (sludge from chemical waste-water treatment has often low biogas potential)

- organic household waste

- organic, bio-degradable waste from industries, in particular slaughter-houses and food-processing industries

Hence, agriculture could provide the manure from livestock and the resulting sludge at the end of the production process could be used as fertilizer. Liquid manure from livestock has a high value to farmers because of the nitrogenous content. One cubic metre liquid manure transform into an average of 4 kg N, that is 2,4 US$ based on the nitrogen content. But

[2] All calculations are based on German database and experiences.

farmers do not lose the nitrogen during the gasification process so that finally energy could be produced and the liquid manure is still a high valuable fertilizer.

The calculation of the profitability of a biogas plant consists of substantial investment cost, some operation and maintenance cost, mostly free raw materials (e.g. manure and waste), and income from sale of biogas or electricity and heat. Other values for farmers like the value of sludge that can be used as a fertilizer on the fields can be added.

The production of renewable energies can replace fossil fuels to a considerable extent. CO_2- and methane- emissions are reduced and make this RES attractive for Joint Implementation investments. Experiences over a long period show that smell and hygiene problems of sludge and manure are reduced. In economic terms, renewable energy and by-products in the form of liquid fertiliser and soil conditioner are produced.

4.3 WOOD: USING RESIDUES AND SHORT ROTATION COPPICE

Finally, we present the potentials that can be developed in the forestry sector. In saw mills, pulp mills and all wood processing industries, residues are left that can be used for energy purposes. From saw mills it is mainly bark and saw dust. Pulp mills (e.g. cellulose and paper production) leave black and sulphite liquors as well as wood and bark residues. From sawmills come edgings, chips, sawdust, bark and other residues that are RES at low prices. Some of these residues could be used for pulping or particle- and fibreboard. The residues in forms of larger pieces can be made into wood-chips for wood-chip boilers, while sawdust can be burned in special furnaces or compressed into wood pellets or brickets that can be used in smaller furnaces and ovens like it is already done in many households. Often wood industry uses its wood residues to meet own energy demands for heating, steam production and eventually electricity.

Besides the energy use of wood residues from mills, there is another possible use in the forestry sector. Plantations of fast-growing trees can be grown. This is already done on a larger scale in Sweden using willow and poplar. With an average yield of 10 tons/ha of dry biomass, 500 thousand tons of biomass can be harvested annually. There is a possibility to use the silt of the effluent from the water treatment plants to fertilize these plantations. Such investigations have recently been initiated in other countries, Lithuania e. g.

Experiences from Sweden show that these plants do not exhaust the soil, as they keep the nitrogen in the soil. As experiments by Block (2004) show the usual agricultural machinery and equipment is suitable for harvesting.

Wood and especially fairly unused residues from millings are predestined for energy use in Ukrainian households or in production plants to produce renewable energy at low costs. As depicted in Table 5, the costs of using wood for energy production are low in comparison with fossil raw materials like heating oil or gas. Due to high energy efficiency wood offers realistic perspectives in rural areas of Ukraine.

5. Strategic options for renewable energy in Ukraine

Biofuel and bioenergy production clearly offer advantages for the agri-rural sector. However, some disadvantages can be identified as well. The calculations in chapter 3 show how important the competitiveness of produced renewable energy is. In Table 6 the gross energy yield per ha is compared taking into account different types of biofuel.

Table 6: Gross energy yield per ha

		Biodiesel (rapeseed)	Bioethanol (sugar beet)	Bioethanol (corn)	Bioethanol* (sugar cane)	BtL	Biogas (maize)
Fuel Equivalent		0,91	0,65	0,65	0,65	0,97	1,4
Heating value	MJ/l	33,1	21,17	21,17	21,17	33,45	50
Biomass	t/ha	3	35	4,1	73,8	15 t atro	45
Biofuel	l/t Biomass	401,5	65,1	240,4	88,0	269	79 kg/t
Biofuel	l/ha	1204,4	2280,2	985,7	6494,3	4028	3555 kg/ha
l Fuel Equivalent/ha		1096,0	1482,1	640,7	4221,3	3907	4977
Gross fuel yield	GJ/ha	39,9	48,3	20,9	137,5	135	178

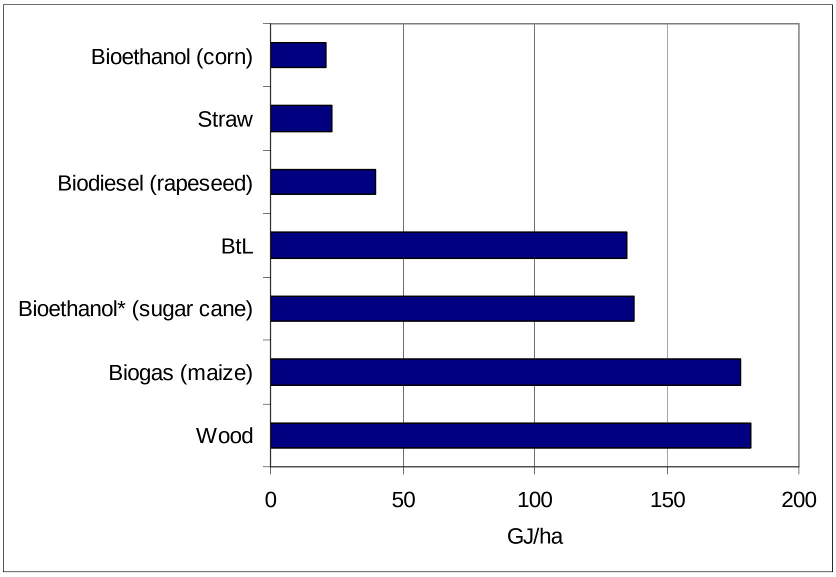
*) Bioethanol produced in Brazil

Source: Own calculations based on data from FNR and IEA.

It can be concluded that the gross fuel yield from bioethanol produced with corn is relatively low. Bioethanol made of sugar beet involves a higher productivity than biofuel made of rapeseed but best gross fuel yield per ha is to achieve with biogas from maize. These days the discussion about acreage competition for food – and energy-use shows how important the gross energy yield per ha will become. Ukraine has to keep in mind not only the production costs but also to use the acreage as efficient as possible to produce raw products for food- and energy- use.

In Figure 6 the gross energy yield from different energy sources is compared. This yield and the related production costs mainly determine the competitiveness of raw materials for energy production.

Figure 6: Gross energy yield from different energy sources



*) Bioethanol produced in Brazil

Source: Own calculations.

Producing biodiesel on the basis of rapeseed as raw product becomes questionable in Ukraine because of high rapeseed world market prices. Biodiesel production vis-à-vis high commodity cost has never been competitive without subsidies in the past. The better option is to produce rape seed and rape seed oil and sell this on the world market.

Producing bioethanol with corn brings similar results as for biodiesel. Grain is well traded on high world market prices and even in most modern plants bioethanol made of wheat or corn can only be produced if it is subsidised at current price ratios. Hence from economic perspective it is better to produce corn and grain for the world markets.

High production costs for bioethanol production with domestically produced sugar beets makes clear that at current price levels agricultural raw products are too precious for a competitive ethanol production. Sugar cane is a cheaper raw product and hence more competitive.

Biogas production with organic waste from livestock production could provide new opportunities for some agricultural industries and rural areas. Local energy generation with biogas plants can also improve the energy supply of remote areas where imported energy is especially expensive.

Using straw for heating systems is cheaper than using agricultural raw products that are traded on a high-price-level food market. Straw is available in most parts of Ukraine and because of the low production costs suitable for decentralized energy production systems.

Wood produced in short rotation coppice and especially fairly unused wood residues from millings are predestined for energy use in Ukrainian households or in production plants to produce renewable energy at low costs. Due to a high energy efficiency wood offers realistic opportunities for rural areas in Ukraine.

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