National University of Life and Environmental Sciences of Ukraine
Institute of Forestry and Landscape-Park Management
Scientific-Engineering Centre "Biomass"
International Institute of Applied System Analysis

Energy potential of biomass in Ukraine

Biomass Energy Europe

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Authors:

Petro Lakyda, Roman Vasylyshyn, Sergiy Zibtsev, Ivan Lakyda – National University of Life and Environmental Sciences of Ukraine

Georgiy Geletukha, Tetyana Zhelyezna – Scientific Engineering Centre “Biomass”, Ukraine

Hannes Böttcher – International Institute of Applied System Analysis, Austria

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The results of assessment of energy potentials of forest and agricultural biomass are presented in the book. Study was made in a framework of FP-7 project “Biomass Energy Europe” (Grant Agreement №213417).

For researchers and specialists in energy, forestry, natural protection and students studying forestry, ecology, biology and technical sciences.

INTRODUCTION

Energy crisis prompts European countries for searching an alternative sources of renewable energy. Important part of those efforts is conducting of integration research and development of road maps for sustainable energy use for whole continents. The "Biomass energy Europe» Project (BEE - Biomass Energy Europe), funded under the European Commission Seventh Framework Programme, aims at harmonizing estimates of biomass resources in Europe and neighboring countries. The results will enhance consistency, accuracy and reliability of estimates of biomass potential, which will facilitate transition of these countries to renewable energy.

The goal of the project is to improve the accuracy and comparability of the results of future assessments of biomass energy resources by reducing diversity of technical approaches, harmonization of procedures and information sharing. Based on experience of project participants and results of their ongoing research, the main attention was paid to harmonization of evaluation techniques for assessing biomass potentials and choosing source data. In addition, it was possible to ascertain possibilities for combined use in order to assess biomass potentials based on "on-ground" data as well as data obtained from satellites. The following components of energy potential were assessed: forest biomass, energy crops, residuals from traditional agricultural activities and other waste.

To achieve the goals set by European countries in renewable energy sector, reliable information about the energy potential of biomass in Europe is required. However, the results of different existing assessments of biomass resources for fixed geographic areas vary significantly. The most significant reason for variance in results is difference of approaches to selection of general assessment methodology, source data, methods of determining of potential of land available for growing energy crops, factors and assumptions regarding production and utilization of biomass. Also, sometimes some empirical data were missing (such as conversion rates, waste composition, productivity). In addition, existing biomass resource assessments are often very different among themselves in terms of time range and depth of analysis, and by types of potential.

Ukraine is represented in the BEE project with two organizations which have substantial experience in bioenergy sector – they are professionals of Education and Research Institute of Forestry and Landscape Architecture, National University of Life and Environmental Sciences of Ukraine and Scientific and Technical Centre "Biomass".

Ukraine has great potential of biomass available for energy use. By bringing this potential to energy production it is possible to satisfy 13-15%

of the country demand in primary energy in the nearest perspective. Development of bioenergy sector in Ukraine should be conducted consistently and reasonably, taking into account possible impact on national economy and environment. Harmonized method of estimation of energy potential, which was obtained as a result of the project, was used to assess the Ukrainian bioenergy sector. The main findings of the assessment are presented in this booklet. The basic components of biomass potential are agricultural residuals and forest biomass. Agricultural biomass is concentrated in the central, southeastern and southern regions, in places with the most fertile soils, while forest biomass may be produced in the northern parts of the country, which is by 25-30% covered with pine forests, and in the western part - Ukrainian Carpathians, where the dominant forest species are spruce, beech, fir and oak.

Estimation of energy potential was done for the country in whole as well as for administrative regions (oblasts). Conclusions contain the major legislative, technological and economic issues of sustainable use of biomass energy in Ukraine and possible way-outs.

The authors of the brochure will be grateful for critical comments, suggestions and proposals on the content of and perspectives for its improvement.

1. FOREST BIOMASS

1.1. Overview of forest resources of Ukraine

The forests of Ukraine are distributed very irregularly over the country (Fig. 1) as a result of climatic conditions and anthropogenic impacts over a long period of time. The largest forest territories are concentrated on the north and on the west parts of country, in Polyssja (mixed forests) zone and in the Ukrainian Carpathians. Coniferous forests occupy 42% of the total forested area, including pine (*Pinus sylvestris* L.) that dominates on 32% and spruce (*Picea abies* Karst.) and Silver fir (*Abies alba* Mill.) that cover ~10%. Hardwood species cover 43%, of which European oak (*Quercus robur* L.) and common beech (*Fagus sylvatica* L.) dominate at 32%, and almost 15% of the forest area consists of softwood broadleaves and shrubs.

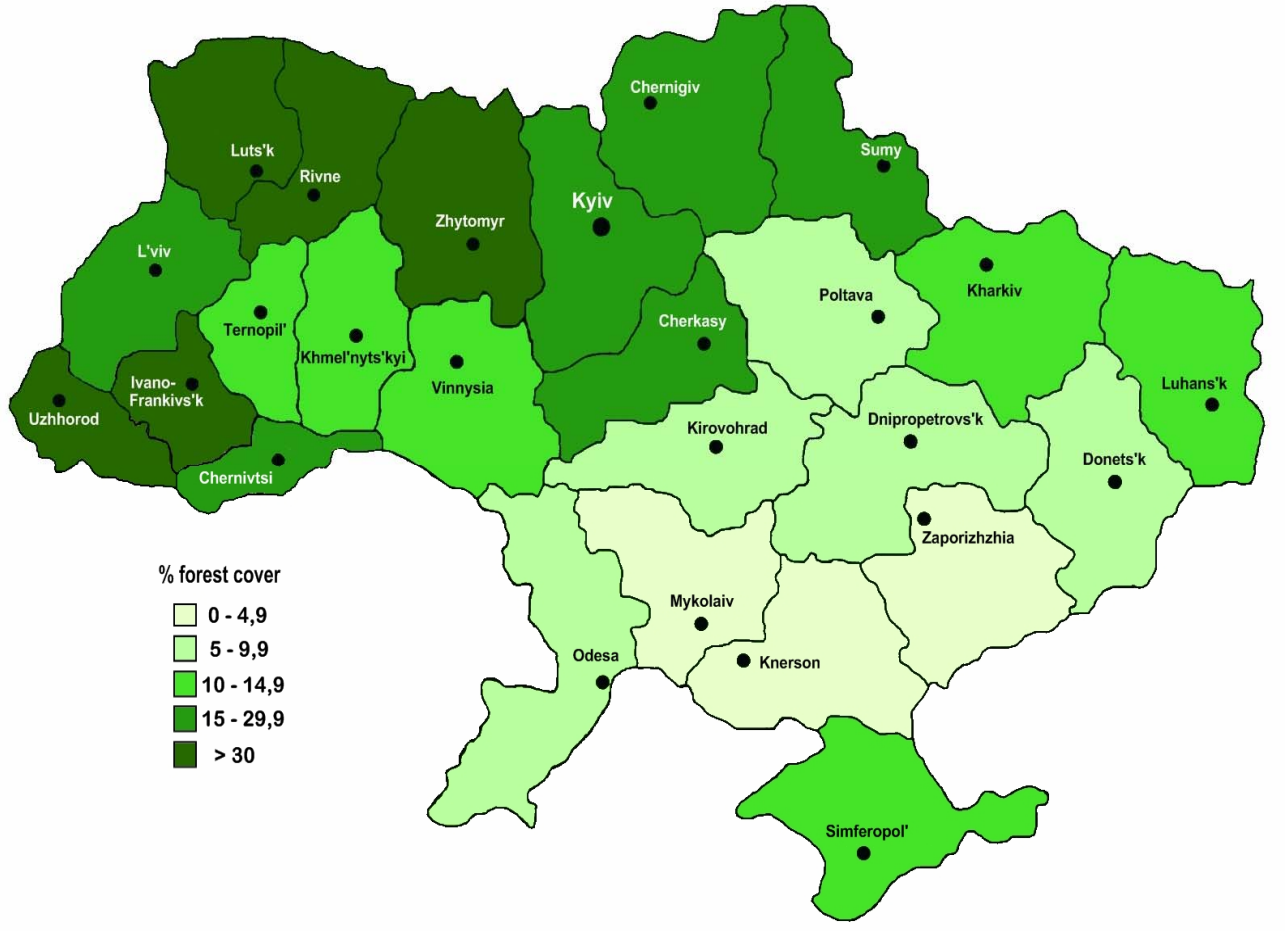

Figure 1. Percent of cover in Ukraine by oblasts (administrative region)

Age structure of forest stands is as following: young forests – 32%, mid-aged – 44, immature – 13, mature and overmature – 11%. The overall average age of forest stands is 54 years. Artificial stands (planted forests) make up an amount near 50 % of the total area. Average growing stock per 1 ha of forested area is 186 $m^{3.} \cdot ha^{-1}$, average change of growing stock volume

(net growth) is 4.0 $m^3 \cdot ha^{-1} \cdot year^{-1}$ and varies from 5.0 $m^3 \cdot ha^{-1} \cdot year^{-1}$ in Carpathians to 2.5 $m^3 \cdot ha^{-1} \cdot year^{-1}$ in the Steppe zone. The total growing stock exceeds 1.8 billion m^3. Ukraine takes the 7th place in Europe in wood stock after Russia, Sweden, France, Germany, Poland and Finland (TBFRA-2000).

During the last 50 years forested area in Ukraine increased at about 1.5 fold basically due to extensive reforestation and afforestation programs during the period. However, amount of forests in some zones (particularly, in Steppe) is far from optimal in order to provide successful protection of environment, soil and water. From this point of view no essential biomass potential should be expected in Steppe zone due to needs to be in line with sustainability criteria.

Wood is a major industrial forest product in the country. Annual harvest of merchantable wood comprises about 15 million m^3 (including 12 million m^3 harvested in forests under jurisdiction of the State Forestry Committee of Ukraine (SFCU)), of which final felling comprises 6.5 million m^3 (5.6 million m^3). The distribution of harvested wood by tree species is presented in figure 1. The major categories of wood usage after final felling are displayed in figure 3.

Annual maximum allowed harvest (final felling) for better sustainability is limited by Annual Allowable Cut. AAC is assessed during forest inventory and planning for every forest enterprise. During the last decade, the AAC comprised from 5.2 to 5.7 million m^3 of commercial wood. Taking into account the current distribution of Ukrainian forests by age classes and number of activities which are planned by the government it is expected that during next decade, AAC will increase by 10-15%.

In general, intensity of harvest is substantially less than in other European countries - the rate of use of annual average increment (net growth) in Ukraine is about 40-50%. Annually only 0.9% of the total growing stock is harvested.

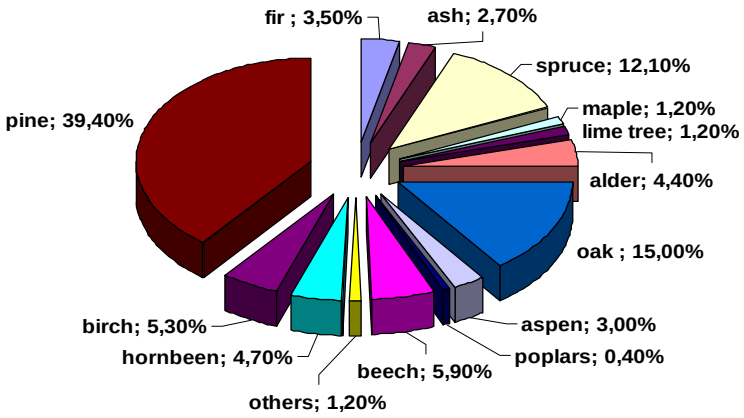

Figure 2. Distribution of harvested wood by tree species

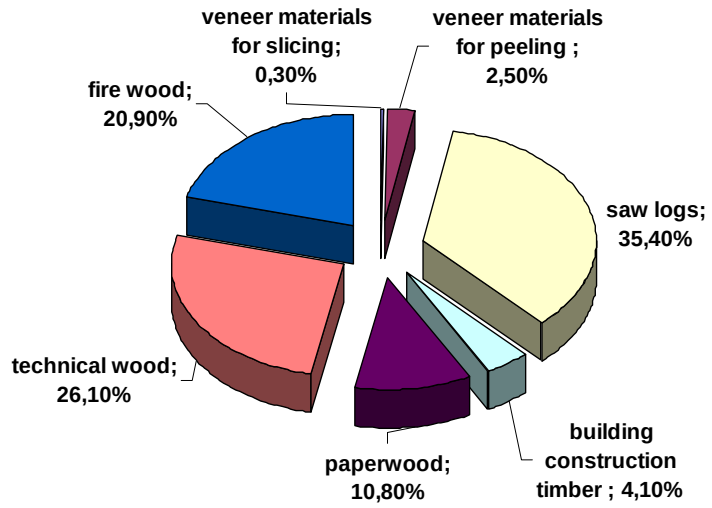

Figure 3. Major assortments of wood harvested by all felling

1.2. Methodology of forest biomass potentials assessment: Resource-focused statistical method

For calculation of potential of forest biomass in Ukraine BEE method handbook definitions were used (BEE 2010):

- *Woody biomass* – The mass of the woody parts (wood, bark, branches, twigs, stumps and roots) of trees, alive and dead, shrubs and bushes, measured to a minimum diameter of 0 mm (d.b.h.) Excludes: Foliage.
- *Stemwood* – Part of tree stem from the felling cut to the tree top with the branches removed, including bark.
- *The primary forest residues* (wood harvest residues) include several types of woody biomass – biomass from pre-commercial thinning (often the whole tree), logging residues (branches, tree tops and leaves or needles) and stumps.
- *The secondary forest residues* (wood processing residues) include various types of biomass originating during industrial processing of timber: sawdust & cutter chips, bark, slabs, lump wood residues, black liquor.

1.2.1. Stemwood

Stemwood is one of the most important forest biomass types in the country. Stemwood for energy purposes accumulates after main kinds of harvesting activities like final harvesting, sanitary felling (for improving forest heath condition) and pre-commercial and commercial thinning. Forest biomass potentials were assessed accordingly to methodology from BEE Methods Handbook and theoretical and technical potentials were obtained as a result. Both types of potentials were calculated per region

(oblast), natural climatic zones and for the country as a whole. Sources of the data for calculations are given in the BEE Data Handbook.

Due to peculiarities of available statistical data for forest sector of Ukraine, basic statistical method was modified for calculations of technical potential of stemwood. In particularly, amount of industrial wood that comes after certain type of harvesting were calculated not as share of industrial wood in the total volume of *i*-commercial thinnings or final felling in country x in year y, like it is described in the Handbook, but based on actual volumes of harvesting of industrial wood and firewood (2008) that were provided by State Forestry Committee of Ukraine (SFCU) for forests that is under its authority (68% of all forests of Ukraine). Due to absence of reliable statistics about harvesting in forests of other constant users (Ministry of Agrarian Policy, Ministry of Military, Ministry of Natural Protection etc) for calculations were used coefficients that reflect relation between forest cover area of SFCU and other users for every oblast.

1.2.2. Primary forest residues

Primary forest residues are that part of forest residues that practically not in use for energy now in Ukraine. Brushwood and small diameter trees cut during first silviculture interventions and, accordingly to current forest management practice, retained for decomposition, while crown components, brunches and other biomass that produced during final harvesting burnt up. This kind of practice is not appropriate at current conditions from economical point of view taking into account increase of forest biomass demand on the market.

Primary forest biomass residues assessment was made with use of basic resource oriented statistical method (Handbook), which allows obtaining figures for both theoretical and technical potentials for all oblasts, natural climatic zones and for Ukraine as a whole. In particularly, biomass expansion factors were used obtained from data base of field experimental data “Phytomass of forests of Ukraine”. Detail descriptions of sources of the data are given in the BEE Data Handbook. Biomass expansion factors were used for calculation of forest biomass potentials for forests of State Forestry Committee (68%), while for other forests, where there are no reliable statistics, extension coefficients were used that reflects relation between areas of forests of State Forestry Committee and forests of other users for every oblast.

1.2.3. Secondary forest residues

Not long time ago, forest processing industry ignored use of secondary forest residues that related with low price of imported natural gas. During last period situation dramatically changed and much more attention is paid to energy potential of residues generated by wood processing industry. For

secondary forest residues assessment method that combined resource–oriented approach and simple statistical one were used.

Assessment of technical potential of secondary forest residues was calculated based on BEE Methods Handbook. Assessment of theoretical potential was made based on statistical data about total volume of produced in the country residues by timber processing industry (BEE Data Handbook). Due to a number of reasons in Ukraine there is no statistics related to timber consumption by wood processing industry and effectiveness of timber processing (ratio of volume of produced production and volume of consumed timber). Among reasons of this kind of situation could be mentioned next: numerous users of forests in Ukraine (Ministry, agencies etc – totally more 50) that often have their own processing enterprises which do not submit any statistics; decreasing of internal timber products market during last period; prevailing of export oriented tendencies in timber trade. That's why use of method proposed in the Handbook we consider as incorrect under this circumstances. In the same time, it should be underlined that in case of availability of proper statistical data the Handbook method could be applied completely effectively in Ukraine as well. Theoretical and technical potentials were calculated also for all oblasts, natural climatic zones and for country as a whole.

1.3. Potential of forest biomass

The forest biomass potentials were assessed for total area of forested lands in Ukraine (closed canopy forests) that consist 9.4 million ha or 15.7 per cent of the Ukraine's territory. The theoretical and technical potentials for forest biomass consist 312,24 and 89,08 PJ accordingly (Table 1, Table 2, Fig. 4).

Analysis of obtained results shows that potential of forest biomass in Ukraine largely determined by regional features, which reflect uneven distribution of forests over the territory of the country. For example, near 35% of all forest biomass for energy purposes are concentrated in Polissia (Forest zone), near 30% in Carpathians M-s and in Forest-Steppe zone and only near 5% in Steppe zone of Ukraine. It should be underlined, that from economical point of view most favorable energy biomass resources are concentrated in Carpathian region. Forests of the Carpathians M-s are characterized by the maximal density of energy biomass – 457,2 KJ per square meter, while in the other natural zones these indices are significantly lower: in Polissya – 255,8 KJ per square meter, Forest-Steppe – 144,2 KJ per square meter, and Steppe – 36,5 KJ per square meter. At the same time, a major part of forest resources in the Carpathians are technically inaccessible due to lack of forest roads.

Table 1

Potential of primary forest residues in Ukraine (2008)

Type of primary forest residues	Theoretical potential		Technical potential	
	*PJ**	*Mt***	*PJ*	*Mt*
Logging residues	19.73	1.23	17.65	1.10
Thinning residues	8.97	0.56	4.98	0.31
Total	28.70	1.79	22.63	1.41

*1 *PJ* = 10^{15} joules, **1*Mt* = 10^{6} tons.

Table 2

Potential of forest biomass in Ukraine (2008)

Type of forest biomass	Theoretical potential		Technical potential	
	PJ	*Mt*	*PJ*	*Mt*
Stemwood	263.72	14.7	49.95	2.79
Primary forest residues	28.70	1.79	22.63	1.41
Secondary forest residues	19.82	1.11	16.50	0.92
Total	312.24	17.6	89.08	5.12

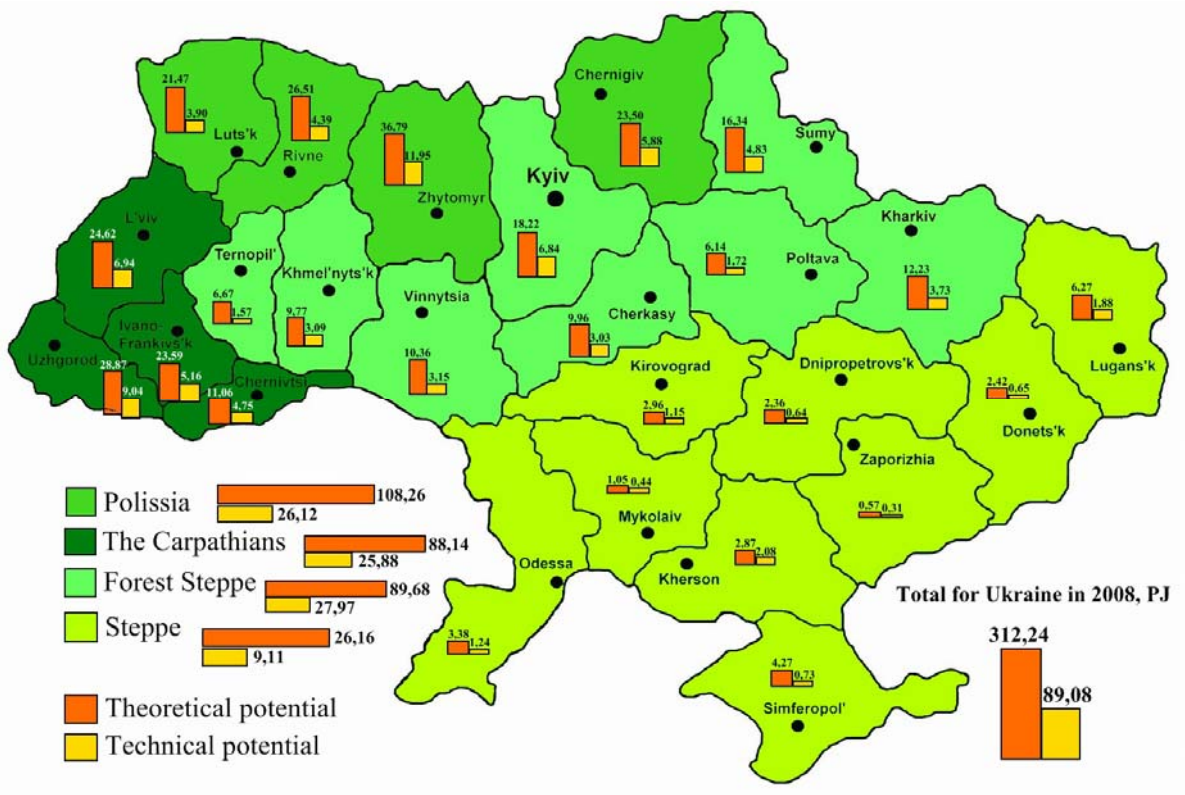

Figure 4. Potentials of forest biomass in Ukraine (2008)

In other regions, availability of transport network is better, but problem of technical capacity for effective use of potential of forests arises there. Taking into consideration age distribution of forests in Ukraine, it should be underlined that during next 10-year period share of mature stands will increase dramatically, that consequently will lead to increasing of available volumes of forest biomass for energy. So, Ukraine should be ready for this kind of positive changes in terms of securing proper legislation base and technological capacity for effective use of future potentials.

In order to access applicability of harmonized BEE Handbook method of forest biomass assessment, alternative assessment with stand-wise method were applied to one oblast. The method based on use of stand-wise database "Forest Fund of Ukraine" produced by National Forest Inventory Enterpise “Ukrderzhlisproekt”. State Enterprise Dobrians'ke Forest Economy of Chernihiv region served as a model forest enterprise within implementation of this evaluation. Obtained potential of forest biomass of the enterprise was extrapolated to the region level by means of ratios by volume and forest area.

The results of the potential assessment are presented in Table 3, Table 4. The results show theoretical and technical potentials (in PJ/Mt). Analysis of obtained results of alternative stand-wise assessment allow to conclude that basic statistical method (Handbook) provides a good level of accuracy and could be used for forest biomass assessment in both regional and national scales in Ukraine under conditions of essential biomass potential, low use and insufficient data that do now allow using more advanced methods.

Table 3

Results of assessment of potential of forest biomass in State enterprise “Dobryanka forest economy” based on stand-wise method (2008)

Type of forest biomass	Theoretical potential		Technical potential	
	PJ	*Mt*	*PJ*	*Mt*
Stemwood	1.18	0.066	0.23	0.013
Primary forest residues	0.14	0.009	0.13	0.008
Secondary forest residues	0.12	0.007	0.11	0.006
Total	1.44	0.082	0.47	0.027

Difference in theoretical potential assessment between two methods reach near 20% which determined with fact that during using of stand-wise method better accounted category of forest land, that exclude any possibility to harvest timber for energy purposes on lands with high

conservation or other values. Close results obtained in technical potential assessment could be explained by fact that in both methods real (statistical) volumes of harvesting were used.

Table 4

Compare of results of forest biomass potential assessment by using basic statistical method (BEE method handbook) and alternative stand-wise method in Chernigiv region (2008)

Type of forest biomass	Theoretical potential				Technical potential			
	basic Statistical method (Handbook)		alternative stand-wise method		basic Statistical method (Handbook)		alternative stand-wise method	
	PJ	*Mt*	*PJ*	*Mt*	*PJ*	*Mt*	*PJ*	*Mt*
Stemwood	20.10	1.124	15.31	0.856	2.85	0.159	2.90	0.162
Primary forest residues	1.80	0.112	1.76	0.109	1.70	0.106	1.69	0.105
Secondary forest residues	1.60	0.089	1.54	0.081	1.34	0.075	1.36	0.076
Total	23.50	1.325	18.61	1.046	5.88	0.340	5.96	0.343

Stand-wise methods that were used in a case study has more practical importance because it allows to make long-term forecasts of forest biomass potentials (in case of availability of growth models of main tree species), while basic statistical method allows to make national or regional assessment only for certain year when statistical data are available. Negative feature of stand-wise method in compare with basic statistical method is limitation in access to and to use of forest inventory information.

1.4. Implementation issues

Positive feature of current status of energy biomass use is that certain legislative framework already has created in Ukraine. In 2009 Parliament of Ukraine approved the law of Ukraine “About alternative type of fuels”. The law provides all need legislative conditions and economical incentives for implementation of modern technologies of use of forest biomass for energy purposes. In parallel, by order of Cabinet of Ministries of Ukraine 25 millions of Ukrainian HRN (2.5 mln Euro) were designated from stabilization fund of Government for purchasing 10 technological complexes for harvesting and utilization forest residues and low diameters timber to energy (fuel) pellets and its transportation to boilers of municipal or regional levels. This kind of decree shows that the issue now is in the level of national priorities and policy and Government is trying to create some legislative and economic environment for developing of use of biomass for energy purposes.

Current economical condition, in particular, world financial crisis does not create favorable conditions for large scale utilization of secondary forest residues into bio fuel. There is a lack of large wood processing enterprises where economically feasible volumes of residues can be processed, while costs of delivering of raw material from numerous middle and small size enterprises is too high and reduce of potential profitability of pellets production.

At the moment, only few wood processing enterprises are left in Ukraine that can process 25 000 cub m of timber per year and more. It happens because of number or reasons such as low average percentage of forest cover lands in Ukraine (15.7%) (except Carpathian and Polissya regions), reduction of timber import from Russia, high level of fragmentation of forests, deterioration of forestry infrastructure etc. All these factors play negative role in process of implementation of modern technologies of fuel production from biomass like wood pellets, briquettes and liquid biofuels.

Taken into consideration abovementioned, development of large and complex wood processing enterprises with annual volumes of processing more 100 thou cub m and production of modern fuel types from residues should be approved as a strategic policy goal in Ukraine. Important feature of this kind of production should be a creation of closed technological cycle of wood processing starting with harvesting and ending in pellets or other type of fuel. Production process should start from forest site and forest road, including all logistics and other stages that guarantee high economical efficiency, low production costs and, in the end, highly competitive price in compare with oil and gas.

Lack of forest road network density and low quality of forest roads, absence of internal production of special machines for timber harvesting and transportation are other important reasons that make negative impact on intensity of development of market of biomass for energy purposes. Accordingly to expert estimations, for ensuring proper availability of forest recourses of Ukraine, 500 km of new forest roads of high quality should be constructing annually, based on use and implementation of modern innovative approaches and technologies that substantially can reduce costs for road construction.

Systems of informational, legislative and technological measures in forestry and wood processing industry, including processed during execution of this project will facilitate sustainable growth of share of renewable energy from forest biomass in production of industrial products.

2. AGRICULTURAL BIOMASS

2.1. Overview of agriculture in Ukraine

Ukraine has 60.35 mill hectares of land. Of this, 70% is agricultural land, 17% is used for forestry, the rest is for housing, industrial and other purposes (used as state reserves, for recreation etc). Ukraine's agricultural sector employs 23.1 percent of the work force, but comprises only 6.5 percent of GDP.

Fertile soil makes it possible to grow a variety of crops. Ukraine has a perfect climate for growing small grains throughout the country and is excellent for corn or soybeans in the north. Among all the European countries, Ukraine is the leader in growing sugar beet, buckwheat and carrot; the country is on the second place in growing wheat (after Russia) and tomato (after Poland). Ukraine is geographically the best situated of all the European countries for marketing with easy access to the Black Sea, China and all of Western Europe to feed a growing population. Ukraine, overall, has the best port access in this region of the world.

Farms in Ukraine employ a variety of crop-rotation schemes, some including four or more crops, some only two. A six-year crop rotation in the winter grain region often includes two consecutive years of wheat and one season of "clean fallow," during which no crop is sown. The chief reason for including fallow in the rotation is to replenish soil-moisture reserves, and it is more widely used in south-eastern Ukraine where drought is not uncommon. The production of grain and oilseed crops is dominated by large agricultural enterprises which were established when Ukraine's agricultural sector was restructured in April, 2000. In contrast, nearly 90 percent of the country's vegetables and virtually all of the potatoes are grown on private household plots. Average size of agricultural enterprises in Ukraine is more than 1000 ha of land. Changes in production volumes of some agricultural crops over two past decades are presented in tables 5-8.

Table 5

Wheat production in Ukraine

Items	Years							
	1995	2000	2003	2004	2005	2006	2007	2008
Sown area, th. ha	5509	5619	2828	5674	6665	5583	6288	7116
Harvested area, th. ha	5479.4	5161.6	2456.4	5533.7	6571.0	5511.0	5951.3	7053.6
Yield,100 kg/ha	29.7	19.8	14.7	31.7	28.5	25.3	23.4	36.7
Production quantity, th. t	16273.3	10197.0	3599.3	17520.2	18699.2	13947.3	13937.7	25885.4

Table 6

Sunflower production

Items	Years							
	1995	2000	2003	2004	2005	2006	2007	2008
Sown area, th. ha	2020	2943	4001	3521	3743	3964	3604	4306
Harvested area, th. ha	2007.6	2841.6	3810.0	3427.0	3689.1	3911.7	3411.4	4279.5
Yield, 100 kg/ha	14.2	12.2	11.2	8.9	12.8	13.6	12.2	15.3
Production quantity, th. t	2859.9	3457.4	4254.4	3050.1	4706.1	5324.3	4174.4	6526.2

Table 7

Sugar beet production

Items	Years							
	1995	2000	2003	2004	2005	2006	2007	2008
Sown area, th. ha	1475	856	773	732	652	815	610	380
Harvested area, th. ha	1448.5	747.0	665.6	696.5	623.3	787.6	577.0	377.2
Yield, 100 kg/ha	204.7	176.7	201.2	238.3	248.2	284.7	294.2	356.2
Production quantity, th. t	29650.4	13198.8	13391.9	16600.4	15467.8	22420.7	16977.7	13437.7

Table 8

Rice production

Items	Years							
	1995	2000	2003	2004	2005	2006	2007	2008
Sown area, th. ha	22	26	22	21	21	22	21	20
Harvested area, th. ha	22.0	25.2	22.4	21.3	21.4	21.6	21.1	19.8
Yield, 100 kg/ha	36.4	35.6	37.5	37.7	43.4	46.0	51.1	50.9
Production quantity, th. t	80.1	89.7	84.0	80.4	93.0	99.5	108.0	100.8

Being a large grain producer, Ukraine is one of the six world largest exporters, supplying to 80 countries worldwide. Rising world grain prices help make these exports even more viable. The total harvest of grain crops was 53.3 mill tonnes in 2008. The country is also the biggest exporter of sunflower oil and has substantial potential in growing and exporting rapeseed.

Ukraine's agriculture has been evolving since the country achieved independence in 1991, following the breakup of the Soviet Union. State and collective farms were officially dismantled in 2000. Farm property was divided among the farm workers in the form of land shares and most new

shareholders leased their land back to newly-formed private agricultural associations. The sudden loss of state agricultural subsidies had an enormous effect on every aspect of Ukrainian agriculture. Due to permanent decline of livestock, structure of the sawn area changed significantly: percentage of land under fodder crops decreased from 37% in 1990 to 10.1% in 2008, and percentage of land under industrial crops increased from 11.6% in 1990 to 25.0% in 2008 (Fig. 5). The transition of Ukraine's agricultural sector from a command economy to a more market-oriented system has introduced the element of fiscal responsibility, and farm managers are striving to make their enterprises as efficient as possible. Decisions on crop selection, fertilizer application, harvest method, grain storage, and all other aspects of farm management are made with an eye toward boosting farm profit. Ukraine's agriculture is going through a winnowing process whereby unprofitable, usually smaller farms will either collapse or join more successful farms.

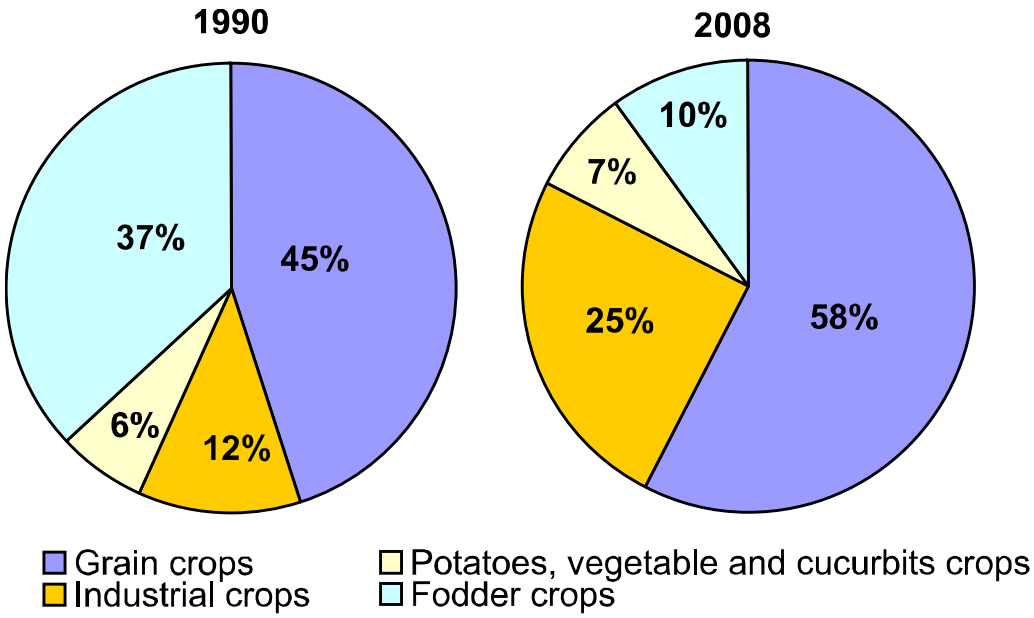

Figure 5. Change in the sown area structure under main agricultural crop

Animal husbandry. Ukraine's livestock sector includes cattle-breeding, pig-breeding, poultry farming and sheep-breeding. A powerful economy sector in Soviet Union time, it has been experiencing drastic changes the last decade. Especially it concerns cattle-breeding which is the most important branch of Ukraine's animal husbandry: since 2000 the livestock population has been decreasing constantly, and only the last two years one can see some tendency to its stabilization (Fig. 6). Pig-breeding is the second branch of Ukraine's livestock sector by its significance. At present the pig population is on the level of 2000 with rises and drops that occurred during this period (Fig. 7). Positive trends can be observed in poultry farming first of all regarding poultry factories. Total number of poultry heads there has been stably rising since 2000 (Fig. 8). Taking into account all the

mentioned factors one can expect rise in manure volumes and therefore biogas potential in Ukraine in the coming years.

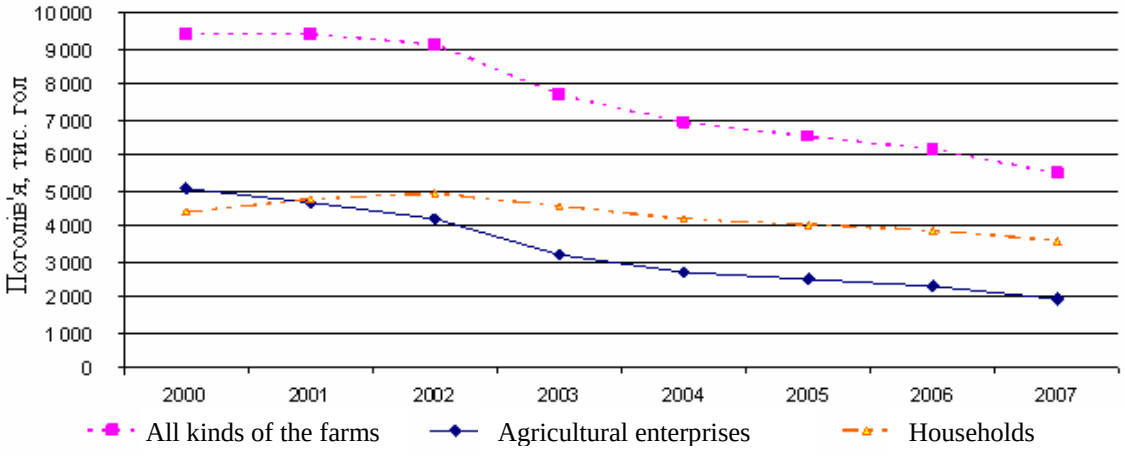

Figure 6. Change in the cattle population, thousand heads

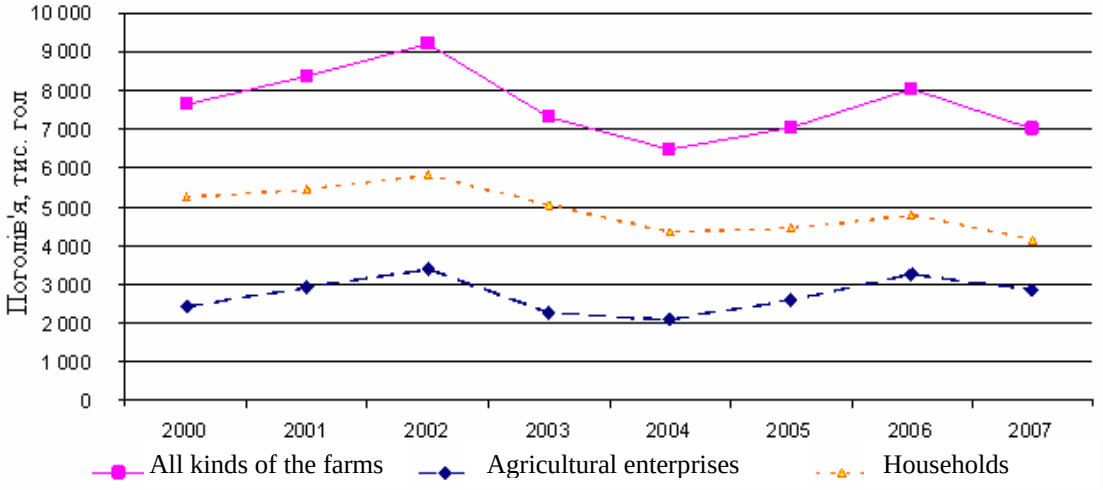

Figure 7. Change in the pig population, thousand heads

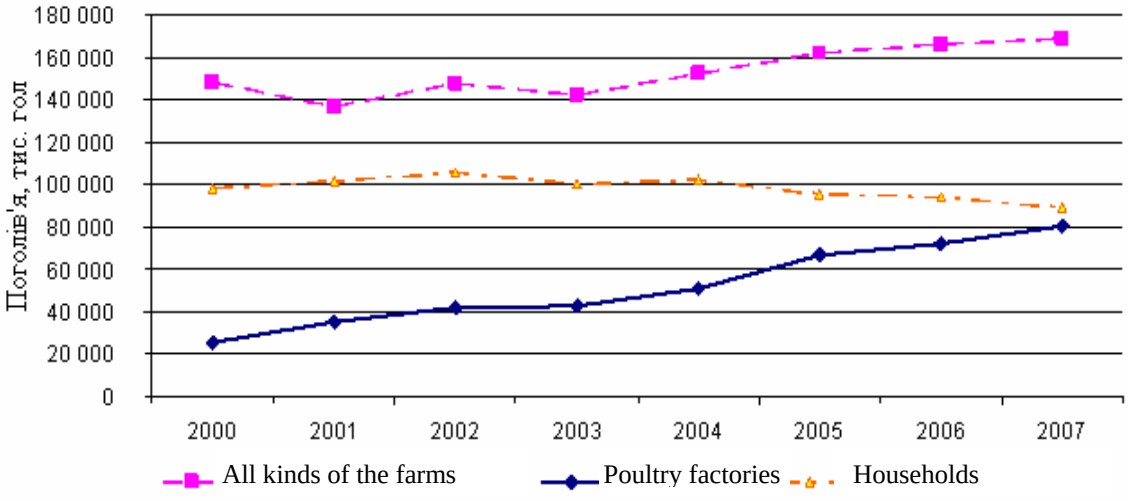

Figure 8. Change in the poultry population, thousand heads

2.2. Methodology of biomass potential assessment in agriculture: Resource-focused statistical method

According to definitions given in the BEE Methods Handbook:

- *Primary Agricultural Residues (PAR)* are those materials which remain in fields as by-products after the primary product of crops has been harvested. These include different materials like cereal grain straws, of wheat, barley, rice, etc., corn stover (stalk and leaves), etc.
- *Secondary agricultural residues (SAR)* are specific type of residues and include quite a wide variety of biomass types. SAR arise during processing of agricultural products for food or feed production. They are bagasse, sunflower husks, rice husks, nut shells, cocoa bean shells, kidney bean shells and other biomass of such a kind.
- *Manure* is organic matter used as organic fertilizer in agriculture. Animal manure includes farmyard manure or farm slurry (liquid manure).

2.2.1. Primary agricultural residues

Regarding PAR the most important type of agricultural biomass available for bioenergy is straw. It is produced after the harvesting of, mainly, cereals or other annual lignocellulosic crops and rape. The parameters which affect the straw potential are the area of land covered by these crops and the amount of straw produced per tonne of a crop. Competitive uses reduce the straw potential for bioenergy like the use for animal litter and feed.

Assessment of PAR potential is performed on the basis of the resource-focussed advanced statistical method described in the BEE Methods Handbook. The method gives opportunity to calculate theoretical and technical potential of biomass. Data items required for the advanced statistical method are: cultivated area of crops (ha), agricultural production of crops (t/ha), site specific product to residue ratio of the crops, availability of residues for the crops according to current harvesting system, sustainability factor (region specific), and availability of residues for animal husbandry (region specific). Sources of the data are given in the BEE Data Handbook. In this report, the data are taken and calculations are made not only for a country as a whole but also for the country's regions (oblasts).

The following agricultural crops are considered in the assessment of PAR:

- ✓ wheat;
- ✓ barley;
- ✓ maize for grain;
- ✓ other cereals as a whole (rye, oats, millet, buckwheat, rice);
- ✓ rapeseed;
- ✓ sunflower.

2.2.2. Secondary agricultural residues

In fact SAR are generated and collected at the enterprises which process agricultural crops for food/feed production. The parameters which affect the residues potential are the processed volumes of agricultural crops and the amount of residues produced per tonne of a crop. Competitive uses reduce the SAR potential for bioenergy like the use for animal feed.

Assessment of SAR potential is done by means of the resource-focussed basic spatially explicit method described in the BEE Methods Handbook. The method gives opportunity to calculate theoretical and technical potential of biomass. It is based on regional statistical data that is plotted in a spatially explicit way. Data items required for the basic spatially explicit method are: actually processed volumes of agricultural crops (t), product to secondary residue ratio of the crops, availability factor and use factor of the crops. Sources of the data are given in the BEE Data Handbook.

In Ukraine's conditions, the following types of secondary agricultural residues are taken into account:

- ✓ sugar beet bagasse;
- ✓ rice husks;
- ✓ sunflower husks.

2.2.3. Manure

Assessment of manure potential is performed by applying statistical method described in the BEE Methods Handbook. The method gives opportunity to calculate theoretical potential of biomass. It is based on regional statistical data that is plotted in a spatially explicit way. Data items required for the method are (for different types of livestock): number of heads, amount of manure (t/head), and biogas yield for livestock manure (m^3/t). Sources of the data are those given in the BEE Data Handbook.

Comment. In this assessment, the availability factor (*Av*) is additionally applied with the purpose to evaluate also the technical potential of manure. For Ukraine, manure of three categories is assessed:

- ✓ cattle manure;
- ✓ pig manure;
- ✓ poultry manure.

2.3. Potential of agricultural biomass

The results of the potential assessment are presented in Table 9 and Figures 9-11. The results show theoretical and technical potentials (in PJ).

Table 9

Potential of agricultural residues in Ukraine (2008)

Type of agricultural residues	Theoretical potential, *PJ*	Technical potential, *PJ*
Primary agricultural residues	1135.52	415.05
Secondary agricultural residues	32.9	18.29
Manure (biogas)	90.87	68.09
Total	1259.29	501.43

It is obvious that primary agricultural residues make up the lion's share of the technical potential (83%) followed by manure recalculated into biogas (14%) and secondary agricultural residues (4%). Distribution of agricultural residues over the country is rather unequal depending mainly on sawn areas and animal livestock in the regions. The major part of the potential falls upon central regions of Ukraine.

Two sustainability issues may arise here: 1 - potential competition between the use of residues for energy purposes and for animal husbandry; 2 – possible depletion of organic matter in the soil and nutrients in agricultural lands because of removal straw from fields. These issues are taken into account while calculating the technical potential through sustainability factor, availability of residues for animal husbandry, and use factor.

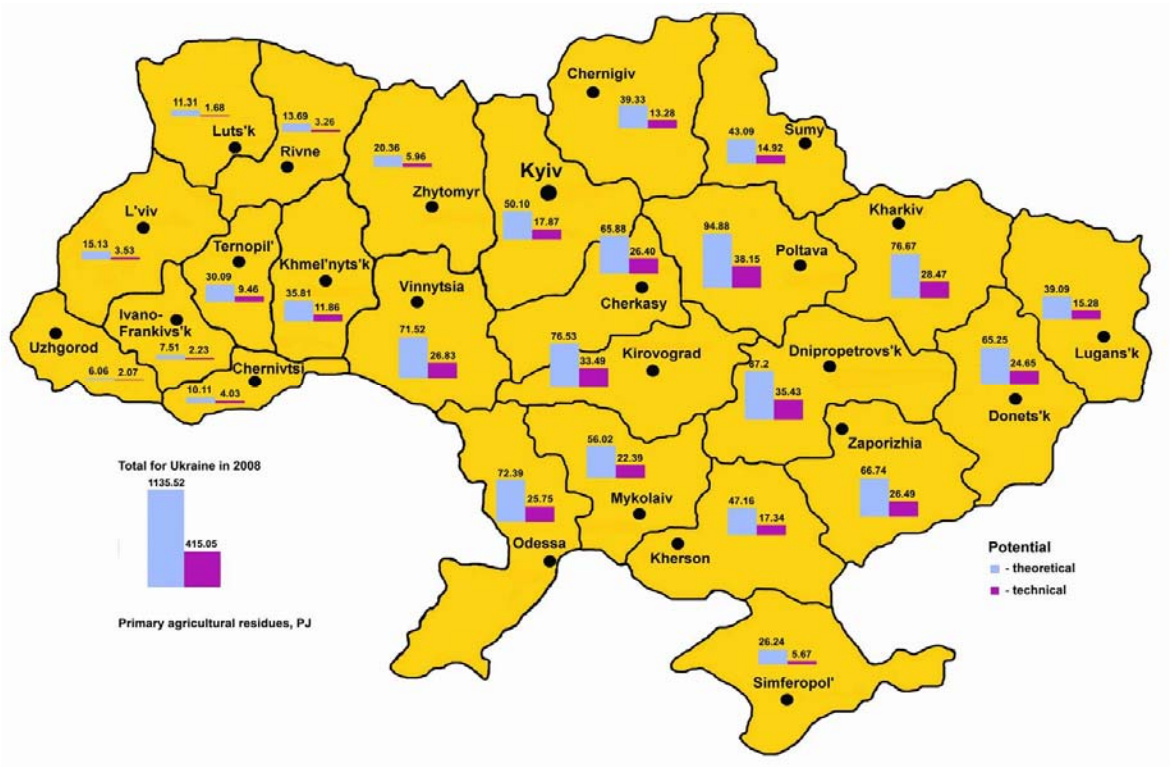

Figure 9. The potential of primary agricultural residues in Ukraine (2008)

Figure 10. The potential of secondary agricultural residues in Ukraine (2008)

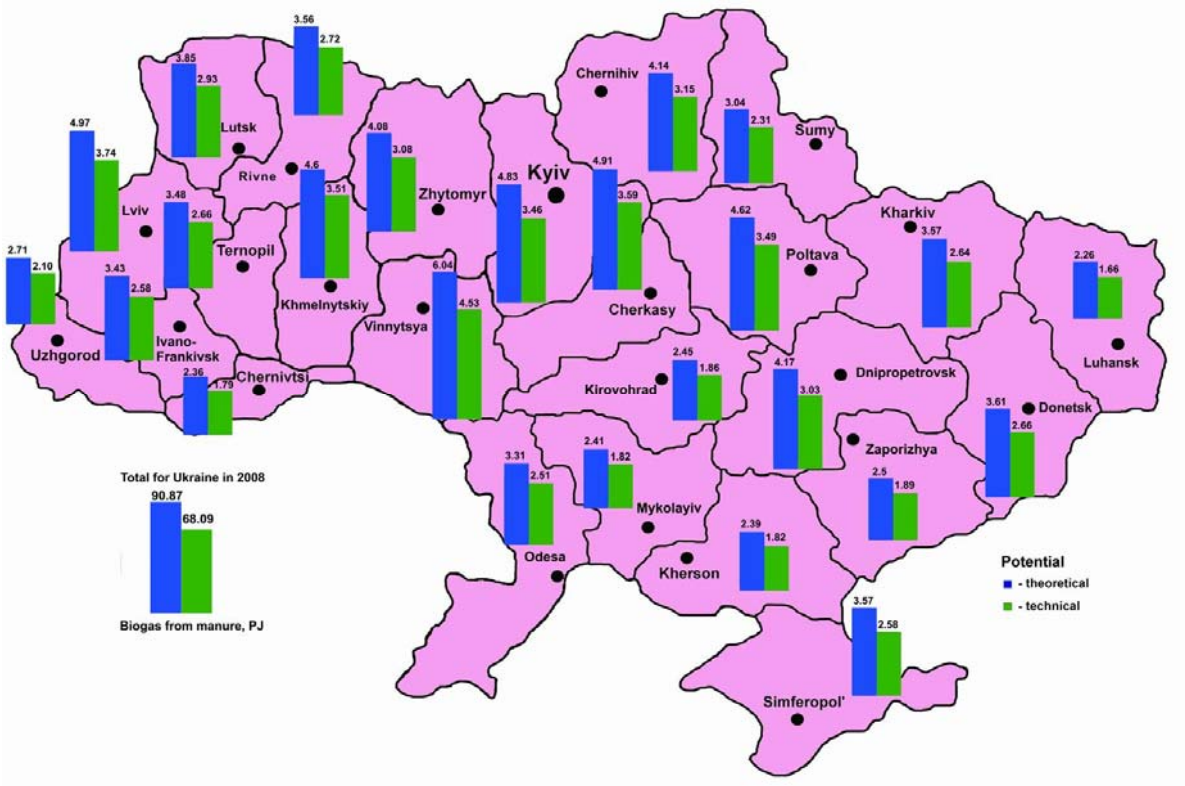

Figure 11. The potential of biogas from manure in Ukraine (2008)

2.4. Implementation issues

Currently, woody biomass in the major type of biomass which is used for energy production, mostly heat - about 30 PJ/yr. It is firewood (domestic boilers in households) and wood waste/wood chips (industrial boilers at forestry and woodworking enterprises). Besides some amount of straw, manure and sunflower husks is also utilized for energy purposes but their contribution to Ukraine's energy balance is negligible. At present more than 60 straw fired boilers are in operation at agricultural enterprises and schools in rural areas. Practically all the oil-extraction plants have boilers which produce heat from sunflower husks. Three large biogas plants generate power from manure. In addition, there are a few experimental plantations of energy crops which belong to different institutions/organisations, but there are no officially arranged production and utilisation of energy crops. Up to 200 small and medium-scale installations produce pellets and briquettes from wood and agricultural residues.

One of the main barriers to wide utilisation of straw potential in Ukraine is rather high cost of straw fired boilers. This applies to the boilers of foreign manufacture as well as to the boilers of domestic production. Currently there is a monopolistic manufacturer of straw fired boilers in Ukraine, and it keeps prices which are high for most potential consumers. Another important problem is unstable supply of straw. Practice of long-term contracts for biomass supply is not established in Ukraine yet. An owner of a straw fired boiler is aware that there is possibility of problems with straw supply unless it is his own straw. Two ways can be suggested to solve these problems:

- introduction of a 20% state subsidy for the purchasers of biomass boilers;
- establishment of companies which business would be providing secure and stable supply of biomass to consumers.

3. GENERAL CONCLUSIONS AND RECOMMENDATIONS

As a result of the research, it was found that in Ukraine in 2008 theoretical and technical potentials of forest biomass are 312.24 and 89.08 PJ respectively, agricultural waste - 1259.29 and 501.43 PJ respectively. Currently, technical potential of forest biomass is about 1,5% of the total consumption of all types of energy in Ukraine.

Today about 30% of technical potential of wood biomass is used for energy, first of all this is production of heat form firewood in private households and social infrastructure in rural areas; use of wood residuals in order to obtain thermal energy for heating and technological needs on wood processing plants, production of wood briquettes, pellets (fuel pellets), charcoal, etc. Over 60% of these amounts of wood biomass is annually exported (sawdust briquettes, pellets, fuel wood chips, charcoal, firewood).

It is also worth noticing that almost one fifth of the technical potential of forest biomass in the form of logging residuals, wood residuals on small-scale wood working enterprises, wood residuals in households, communal sphere is being rotten, thrown out, taken out as trash, burned or disposed in other way of without any beneficial effect.

Currently, to ensure rational use of energy potential of forest biomass, regional target programs for replacement of fossil fuels with biofuels from wood are essential. When implementing those programs attention should be paid to resolving the following issues:

- ✓ to ensure harvesting, gathering, processing and transportation to boilers existing wood biomass, which originates on logging areas of final felling and areas, where formation and forest health-enhancement fellings are carried out;
- ✓ to establish plantations for growing energy wood;
- ✓ to ensure gradual systematic increase of planned logging taking into account changing age structure of stands of main forest forming species;
- ✓ to construct forest roads in order to ensure transport access to wood biomass resources, especially in mountainous regions;
- ✓ to ensure deep wood processing that will allow for more efficient use of forest resources and residuals.

Ukraine has quite a big potential of agricultural residues which mainly consists of straw from cereals and production residues from sunflower and maize from grain. At present, less than 1% of the PAR potential is used for energy purposes (combustion in boilers, production of pellets and briquettes). This is because of the poorly developed infrastructure and logistics system for a reliable feedstock supply in Ukraine. These factors prevent a lot of potential customers from installing straw fired boilers.

Taking into account the current situation in the biomass market, it is expected that in the near future some companies will come forth whose business will be the reliable delivery of biomass feedstock to a final customer. This may lead to the introduction of long-contract system and much wider use of agricultural residues for energy production.

The situation with SAR is much better though their technical potential is incomparably less than PAR. 77% of sunflower husks is used in boilers, another 20% is used for pellets production. Almost all the oil extraction plants have biomass boilers for useful utilization of generated sunflower husks.

Regarding biogas from manure, LFG and sewage gas, expert opinion is that utilization of the technical potential will be more brisk after introduction of feed-in tariff for electricity produced from biogas. At present, the feed-in tariff for green electricity covers biomass but does not include biogas.

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Head. Publishing Center of NUBiP of Ukraine A.Kolesnikov

Partner of the project:

Web-Address:
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