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Biomass in Montenegro

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ACKNOWLEDGEMENTS

The study analyses the current state in the bioenergy sector in Montenegro in terms of supply, demand and related policy framework. It has been prepared in the framework of the Hellenic Aid – USAID programme: SYNENERGY by a CRES team comprising Calliope Panoutsou (team leader), Christoforos Perakis, Vassilis Papandreou and Stefanos Ntoulas. External consultants included Vesna Nikcevic and Branko Glavonjic .

EXECUTIVE SUMMARY

The aims of this study were:

- to evaluate potential biomass supply from agriculture, forest and municipal waste;
- to map and examine geographical patterns of biomass potentials;
- to assess possible market sectors that could actually exploit the biomass resources that have been identified and quantified by this study.

The results of this study show that indigenous biomass feedstocks in Montenegro could make a material contribution towards national primary energy demand despite the fact that, due to growing population and relatively rapid economic development (from a relatively low base), energy demand is forecasted to rise rapidly in coming years.

Potential biomass feedstocks were found in all the areas that were covered by this study. Key potentials, and anticipated ways of exploiting these resources, are summarized as follows:

Forest based biomass. The results from this study indicate annual Technical Potential of forest based biomass is 3,3 PJ. From this 0,33 PJ comprise of forest residues. In the study is is assumed that 50% of this resource could be used for co-firing this would result in the production of 29 *'green'* GWh within existing solid fuel power facilities.

Fuelwood is considered to have high value for local, small scale energy use, i.e. stoves, open fires and ovens. While this is clearly neither efficient nor perhaps environmentally optimal use of resource, it is nevertheless an essential, low cost resource for large numbers of rural people. From the 1,54 PJ estimated by this study, it is assumed that 20% will be available for new, efficient small scale wood fired boilers, stoves, etc. This would account for 68GWh heat production annually.

Biogas from agriculture. Based upon livestock data (pigs, chickens, cattle), the amount of slurries and manures produced has been estimated. This could be exploited via anaerobic digestion (AD). The Theoretical Potential is 0,83 PJ biogas production. However, it is assumed that much of this resource could not be aggregated between farming units to provide sufficient feedstock that a typical AD unit may require. It is assumed that 30% of theoretical potential could be realised, or 0,25 PJ. The installed capacity would be 3 MWe and annual output would be 24 GWh of electricity. Given both the remote, rural location of AD units, it is assumed that the amount of heat used would be negligible.

Landfill gas. Municipal Solid Waste (MSW) production expected to reach 0,5 t/person/year (the EU 15 average) though it is currently only half this level. It is disposed and methane is captured and used to generate power. This assumes that, due to the location of the landfills, there are no local uses for heat. The theoretical biogas potential estimated in this study is 0,7 PJ.

Energy crops. In common with other resource assessments, the potential for energy crops is, in theory, large. It is also highly dependant on which crops are deemed to be most likely to be grown, what type of land is converted to their cultivation, and the areas of land

used. This study makes a reasonably conservative scenario, ie. that 10% of land currently used for grazing/pasture plus 5% of fallow land are used to grow perennial grasses. The respective Technical Potentials is estimated to be 7,44 PJ resource. If half of this resource would be available for bio-energy industry, or medium-scale CHP installations (individual capacity 5 MWe plus) delivering power to grid and heat to residential / commercial / industrial users. This would support 52 MWe installed capacity that would generate 362 GWh electricity and 517 GWh heat annually. The other half of the resource would support local small scale energy crop fired baled fired boilers or energy crop pellet boilers supplying residential properties with heat. This would equate to 827 GWh of useful heat production per year.

Agricultural biomass is far less significant in Montenegro, nevertheless significant quantities of vineyard prunings can be found in the region of Podgorica. On the other hand animal farming is more widespread.

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A. AIMS AND APPROACH

The aims of this study were:

- to evaluate potential biomass supply from agriculture, forest and municipal waste;
- to map and examine patterns of biomass potentials;
- to assess possible market sectors that could actually exploit the biomass resources hat have been identified and quantified by this study.

The study employed both bottom-up and top-down approaches to collate and analyse data. Data sources were varied and included: official statistics from national and international governmental organisations; published and unpublished surveys and studies; direct communication with local experts. The process of gathering data was time-intensive. Moreover, considerable effort was taken to assess the credibility or otherwise of data, through carrying out numerical cross-checks as well as more subjective (but no less important) "sense-checking" by team members in consultation with colleagues and peers.

Data were analysed using spreadsheet-based models and a Geographical Information System (GIS). The reference year for all calculations was 2008. Appendices 1 and 2 contain data and a note on methodological approach respectively.

This study considered five main sources of biomass feedstocks:

1. **Agriculture field crop and arboricultural residues**
2. **Livestock residues**
3. **Energy crops**
4. **Forest-based biomass**
5. **Municipal Solid Waste (MSW)**

The agriculture sector is a source of varied biomass feedstocks. Field crops produce residues – mostly in form of straw-type materials - that can be collected to be exploited for energy. Trees cultivated on farms are a source of wood through prunings etc, or arboriculture residues. Different types of farm livestock produce manures, slurries etc. that have generally have high moisture contents but nonetheless also represent energy resources. Finally, there is the possibility to use agricultural land to grow dedicated energy crops, which include a number of wide-ranging plant species. All the fore-mentioned were considered within this study.

The processing of agriculture crops also gives rise to residues / by-products that can be exploited for energy. These are collectively termed agro-industrial residues. However, these were not included in this study due to the facts that data on industries is scant and there is little empirical evidence for the proportions or coefficients of production of by-products for the Montenegro agro-industrial sectors.

The forest sector is clearly also a source of biomass feedstock. A key issue is the role played by different types of forest, different ownership types, and competing uses for wood.

This study collected and analysed data for this sector giving due consideration to these and other factors during the analysis.

The fifth source of feedstock considered by this study was municipal solid waste (MSW) i.e. waste produced by residents and commercial organisations. EU legislation considers energy produced from the biodegradable fraction of MSW to be renewable. Thus, the organic fraction, paper, cardboard and textiles are a source of biomass.

The study considered two types of biomass supply potential as follows:

Theoretical Potential: The total quantity of biomass that can be produced annually from a specific crop or waste / residue / by-product. Theoretical Potential is the quantity grown or disposed, constrained only by macro-factors such as land availability and growth yield.

Technical Potential: This considers important issues around “practical availability” and is invariably a proportion of Theoretical Potential. Thus, calculation of Technical Potential considers factors such as other competing demands, the need for residues to stay on the land to replenish soil nutrients, etc.

Theoretical Potential can be considered a step on the way to calculating the Technical Potential. The Technical Potential provides, in a sense, the useful data, because this shows how much resource could actually be exploited. Assumptions on availability are made explicit, so this allows sensitivity analysis to be done, showing what the quantitative impact of varying the assumption is. Also, at a later date, if evolving circumstances lead to different assumptions, recalculation of Technical Potential is straightforward.

It is important to note that neither of these potentials considers financial / economic factors. Neither Theoretical nor Technical Potentials make judgements on whether or not exploitation would be commercially viable. This would be a third step and involve a further and indeed much more complex and dynamic set of assumptions. This was beyond the scope of the current study.

It should also be stated that the potentials presented in the study for the five different sources described above are mutually exclusive, i.e. the supply potentials do not overlap one-another and can be summed to derive total biomass potential.

The final part of the analysis was to study how agriculture and forestry biomass resources could actually be exploited. Approaches to use biomass resources include cofiring with fossil fuels; combustion in new build combined heat and power (CHP) units; anaerobic digestion; combustion at smaller scale ranging from individual stoves and ovens in households to larger, modern boilers for heat provision to buildings etc. The focus was on conversion technologies that are proven commercially and are already widespread elsewhere in Europe. More advanced conversion technologies such as pyrolysis and gasification were not included. It is possible that such technologies may become preferred over the time-frame to 2030, but that is speculative.

The main market sectors were as follows:

1. Small scale stoves, boilers, ovens for heating and hot water in domestic properties and other buildings including schools, hospital, municipal offices etc.
2. Existing coal fuelled power plants that cofire wood.
3. Existing coal fuelled district heating plants that cofire wood.
4. New build medium scale combined heat and power (CHP) units that use wood and / or straw and / or energy crops.
5. Anaerobic digestion units using manures and slurries from livestock.

B. COUNTRY BACKGROUND

Figure B.1: Geographical Position of Montenegro [CIA 2010].

Montenegro is a country located in Southeastrern Europe,on the Balkan peninsula. It has a coast on the Adriatic Sea to the south-west and is bordered by Croatia to the west, Bosnia and Herzegovina to the northwest, Serbia to the northeast, Kosovo to the east and Albania to the southeast.Montenegro is divided in 21 municipalities. The capital city is Podgorica.

Montenegro covers a total area of 1.381 mill. ha. It is a small country with a very diverse terrain configuration. Terrain in Montenegro ranges from high mountains in the northern part of the country, through karst segment in central and western part, to a narrow coastal plain. The coastal plain disappears completely in the north. The coastal region is noted for active seismicity. Montenegro's lower areas enjoy a Mediterranean climate, having dry summers and mild, rainy winters.Mountainous regions receive some of the highest amounts of rainfall in Europe. [Wikipedia 2010]

Based on national census for 2003 the population in Montenegro was 620 thousand. persons with an average population density of 44,9 persons / km^2.Almost 37% of them is aged under 25 years old. The estimation for July 2010 is 627 th. persons[MONSTAT 2009a].

Economy of Montenegro is mostly a service based economy, currently in process of economic transition. The GDP in 2007 was 5.135 bill. Euros (in current prices) with 6% of it in the agricultural activities.

In 2008, total employed persons were 166 th. with less than 2% working in agriculture and forestry sectors. The unemployment rate is around 14,7%. (2007 est.).

C. LAND USE

Montenegro is dominantly a mountainous country incised by river gorges and deep valleys. Plains are found only in the southern parts of the country, while the proportion of the land whose slope is smaller than 5% amounts to about 3,7% of the total area [Danon et al. 2010].

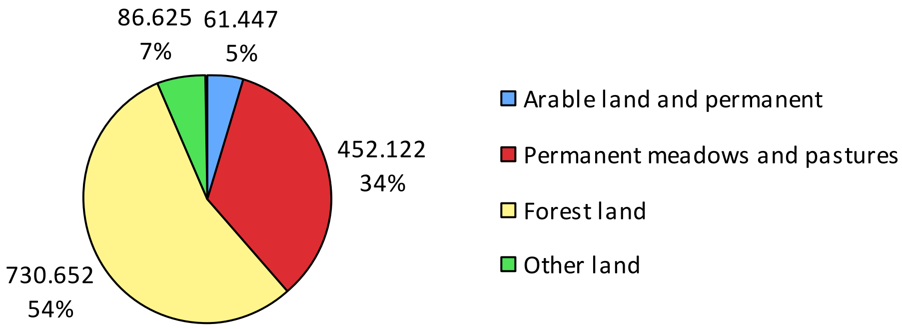

Figure C.1 Major land use types in Montenegro 2008 [MONSTAT 2009a].

Agricultural land covers the 37% of the total land area in Montenegro. The major part of the agricultural land is characterized as permanent meadows and pastures (grassland), while the area dedicated to the cultivation of various crops was just 3,4% of the total land in Montenegro in 2008 (Figure C.2).

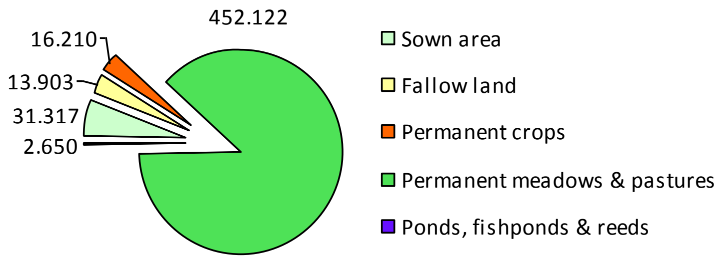

Figure C.2 Structure of agricultural land in Montenegro by category of use in 2008 (ha). [MONSTAT 2009]

The main crops producing considerable quantities of field crop residues in Montenegro are maize, wheat, rye and barley.

The main arboricultural residue resources in Montenegro are vineyards, olives, apples, plums, pears and citrus fruits prunings.

Total forest area in Montenegro amounts to 730.652 ha, which is 53% of the total land. 67% of the forest land is public, while the rest is private. The forests are located mainly at the northern part of the country

D. OVERVIEW OF BIOMASS FEEDSTOCKS

Potential biomass resources in Montenegro sum up to 12.030.126 GJ, which is equivalent to 26% of the country's total primary energy supply (TPES). There is a big potential in Montenegro for energy crops cultivation. According to a conservative approach, perennial grasses cultivation in 10% and 5% of the country's grassland and fallow land respectively, could provide 7.441.176 of energy, which is two thirds of the total potential. Forest based biomass is also a significant biomass resource in Montenegro amounting to 3.312.210 GJ, while almost half of it comes from industrial wood processing.

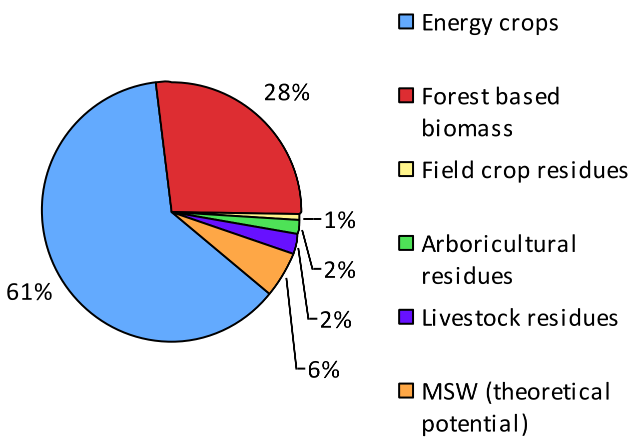

Figure D.1 Relative contribution of each biomass resource to the total potential.

Agricultural biomass is far less significant in Montenegro, nevertheless significant quantities of vineyard prunings can be found in the region of Podgorica. On the other hand animal farming is more widespread.

Table D.1 Estimated technical biomass potential in Montenegro (2008).

	Potential (GJ)
Total	**12.030.126**
Energy crops	7.441.176
Forest based biomass	3.312.210
Agricultural biomass	566.936
Field crop residues	72.157
Arboricultural residues	246.615
Livestock residues	248.164
MSW (theoretical potential)	709.804

In the following sections, a detailed analysis of technically available biomass potentials is presented for agriculture and forest based biomass along with a conservative scenario for energy crops cultivation in Montenegro is analysed. Regarding the biodegradable fraction of municipal solid waste (MSW) the study estimated only the theoretical potential.

E. CURRENT USE OF BIOMASS IN THE ENERGY MARKET

In the period 1997-2006 total consumption of primary energy grew at the average rate of 3,7%. Total primary energy consumption in 2006 amounted to 46,11 PJ. Major share is of petroleum products (32,3%), coal (30,1%), hydro-energy (19,6%) and wood and wood waste (5,3%) (Figure E.1).

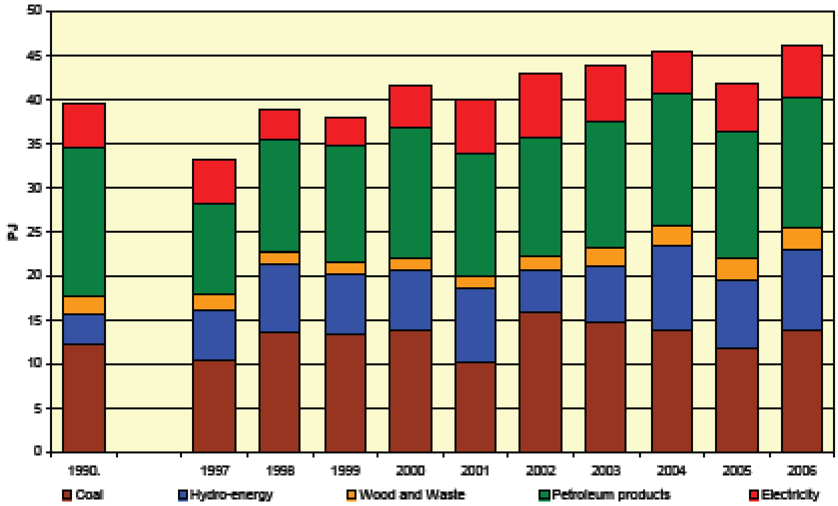

Figure E.1 Total primary energy supply in Montenegro (1997-2006). [MED 2007]

In 2006 domestic production of primary energy amounted to 24,59 PJ or 54% of total energy consumption ("energy independence"). Montenegro imports petroleum products, more than a third of the required electricity needs, and a very small amount of lignite. Therefore, Montenegro depends largely on foreign energy sources.

Consumption of firewood and wood waste for energy production amounted to 2,45 PJ in 2006 or 10% of the total primary energy production, which means that wood is a significant domestic source of energy. Some of the wood-processing industry companies use wood waste to cover their own energy needs. Wider use of biomass for energy purposes currently practically does not exist in Montenegro.

F. BIOMASS SUPPLY POTENTIALS – DETAILED RESULTS AND ANALYSIS

F.1 Agriculture field crop & arboricultural residues

Total quantities of residues were estimated using recent statistical data for the production of the main product for each crop as well as specific coefficients indicating the ratio of residues to main product.

For each crop i cultivated in region j, the annual energy theoretical potential $Erescrop_{i,j}$ is calculated based on the following formula:

$$Erescrop_{i,j} = c_i P_{i,j} H_i \qquad (F.1)$$

c_i country specific ratio of residue over main product [t/t]

$P_{i,j}$ annual production of main product i cultivated in region j [t]

H_i country specific lower heating value of residue [GJ/t]

> ***Field crop & arboricultural residues***
>
> Two large categories of field agricultural residues can be defined: field crop residues and arboricultural residues.
>
> Field crop residues are the residues that remain in the field after the crops are harvested. Depending upon the crop, the harvesting method and other parameters, field agricultural residues may include various plant parts such as stems, branches, leaves, chaff, pits, etc. varying in composition, moisture content and energy potential.
>
> Arboricultural residues are the residues that remain in the field after farming activities performed during the cultivation of perennial crops (prunings of vineyards and trees).

Data for crops production and harvested area in 2008 were obtained form the Statistical Office of Montenegro [MONSTAT]. The coefficients used to estimate the quantities and the energy potential of agricultural field residues derived from local experts' estimations and references. The calculated quantities of the main crops residues are given in Table F.1.

The estimation of the quantities of agricultural residues available for energy production is based on the degree of availability which is different for each crop, varies from year to year and depends on several factors such as:

- ✓ the harvesting method
- ✓ the moisture content
- ✓ the demand of agricultural residues for non-energy purposes (cereal straw, for example, is used for animal feeding, animal bedding, etc.).
- ✓ the need for some residues to remain on the soil to maintain the level of nutrients (sustainability reasons).

As it is shown in Table F.1, the availability factor for arable crop residues is 30%. The same factor is estimated at 90% for arboricultural residues, mainly due to technical difficulties in collecting them [Stojiljkovic 2010]. For olive trees prunings a factor of 50% was assumed, since bigger branches are already used for household heating. Since these quantities cannot be easily registered or estimated, the factor for olives was estimated based on our previous experience in Greece [Mardikis et al. 2003].

Table F.1 Crop residues available for energy production in Montenegro (2008).

Crop	Production (t)	Residues (t)	Degree of Availability (%)	Residues available for energy exploitation	
				Quantity (t)	Energy potential (GJ)
TOTAL	**81.881**	**35.236**		**20.991**	**318.773**
Field	**15.306**	**15.878**		**4.763**	**72.158**
Maize	9.626	10.589	30	3.177	49.237
Wheat	2.858	2.858	30	857	12.347
Barley	2.245	1.796	30	539	7.813
Rye	577	635	30	190	2.761
Arboricultural	**66.575**	**19.358**		**16.228**	**246.615**
Vineyards	43.991	10.998	90	9.898	148.470
Citrus	7.136	2.141	90	1.927	28.901
Apples	5.066	1.773	90	1.596	23.937
Plums	5.942	1.486	90	1.337	20.054
Olives	2.402	2.450	50	1.225	18.375
Pears	2.038	510	90	459	6.878

Based on the above it is estimated 20.991 tons of field crop and arboricultural residues could be annually exploited for energy purposes (reference year of analysis 2008). This is equivalent to 318.773 GJ of energy or 0,7% of the total primary energy supply in 2006 [MED 2007].

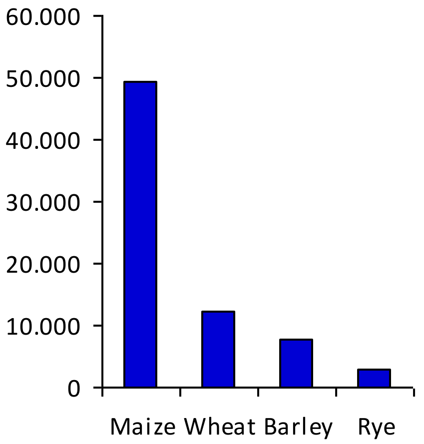

Figure F.1 Arable crop residues technical potential in Montenegro (GJ).

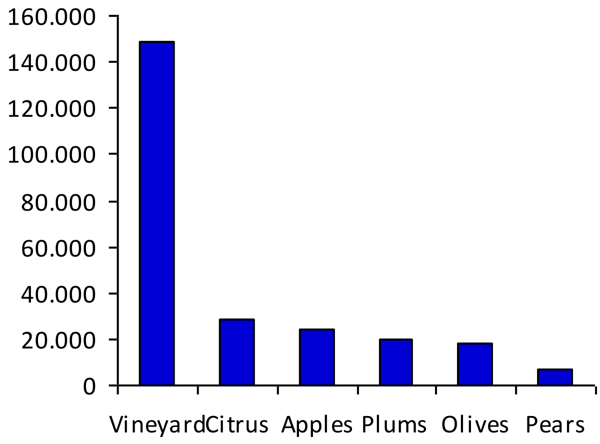

Figure F.2 Prunings technical potential in Montenegro (GJ).

Figures F.1 and F.2 present the potential of the most significant crop residues. Vineyards prunings are the most significant source of biomass contributing almost by half (47%) to the total crop residues potential. Furthermore, citrus fruits, apples, plums, olives and pears contribute also significantly to the arboricultural residues potential. As far as field crop residues are concerned, the most abundant source of biomass are maize residues, while small grain cereals residues (wheat, barley and rye) are also significant sources. By and

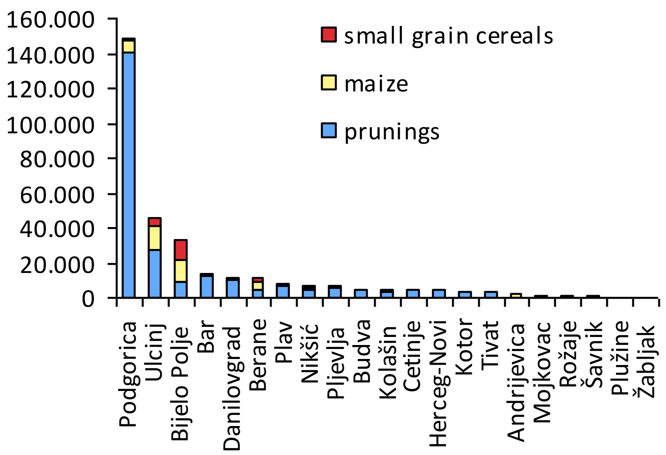

Figure F.3 Regional field crop and arboricultural residues technical potential (GJ).

large, field crop residues are less significant and their potential is around 1/3 of the arboricultural residues potential.

Crop residues are mostly found in the municipality of Podgorica as it is shown in Figures F.3 and F.4, while the potential in this municipality contributes to the total potential by 47%. Furthermore, 89% of the produced residues in Podgorica come from the vineyards prunings. Significant amounts of residues are found also in the municipalities of Ulcinj and Bijelo Polje, where field crop residues make a significant contribution.

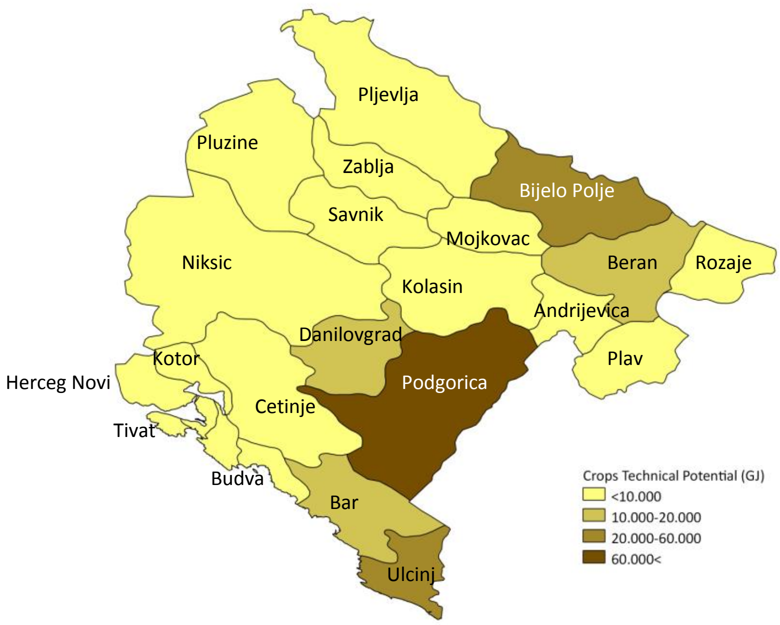

Figure F.4 Field crop and arboricultural residues technical potential map.

F.2 Livestock residues

In Montenegro according to official statistics [MONSTAT 2009a] there were 89.194 cattle (heads), 3.315 pigs and 236.688 poultry in 2008. Then the energy potential $Eresanim_{i,j}$ for anima l species i in region j was evaluated based on the formula:

- Energy can be derived from livestock residues as long as they are collected in lagoons or large tanks and can be considered feasible only in in-stall livestock systems, excluding therefore sheep and goats from such practices since their breeding is extensive making collection of manure impossible.
- Since animal manure is of a high water content, it can be digested anaerobically for the production of biogas, which can be burnt for heat or/and electricity production.

$$Eresanim_{i,j} = p_i C_{i,j} Y_i H_i \qquad (F.2)$$

$C_{i,j}$ number of animal species i nurtured in region j [heads]

p_i country specific manure generation factor for species i [t/head/yr]

Y_i country specific biogas yield [Nm^3/t manure]

H_i country specific lower heating value of biogas [GJ/Nm^3]

Based on local expert's estimations [Stojiljkovic 2010] regarding the residues produced on average per animal and the biogas yield per tone of produced residues, the amount of biogas that could be theoretically produced amounts to 38,11 million Nm^3, which is equivalent to 827.214 GJ or 1,6% of total primary energy supply of Montenegro in 2008 Table F.2).

Table F.2 Livestock residues theoretical potential in Montenegro (2008).

	Cattle	Pigs	Chicken	Total
Animal heads	89.194	3.315	236.688	329.197
Residues (t) (dry)	144.494	995	4.971	150.460
Biogas potential (million Nm^3)	35,45	0,43	2,24	38,11
Theoretical Potential (GJ)	**765.608**	**9.268**	**52.339**	**827.214**
Technically available				**30%**
Technical Potential (GJ)				**248.164**

Residues from cows contribute the higher share to the total potential (93%). Regional distribution of the theoretical potential is given in Figure F.5 and Figure F.6. The municipality of Plijevlja exhibits the highest potential, while also in the municipalities of Bijelo Polje and Niksic significant amounts of residues are produced. In general, livestock residues are found in several municipalities in the continental part of the country.

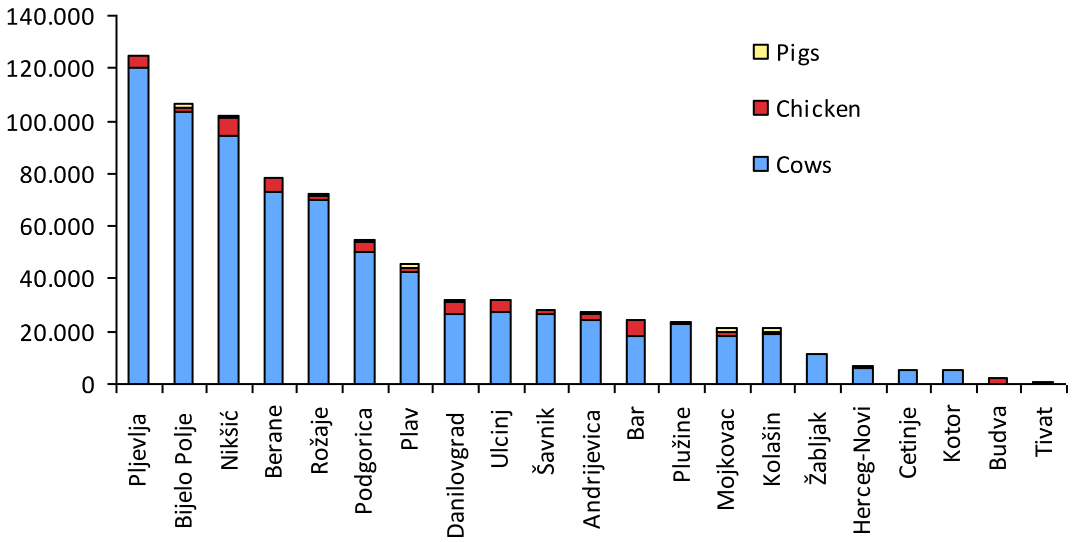

Figure F.5 Regional distribution of the theoretical potential of livestock residues (GJ).

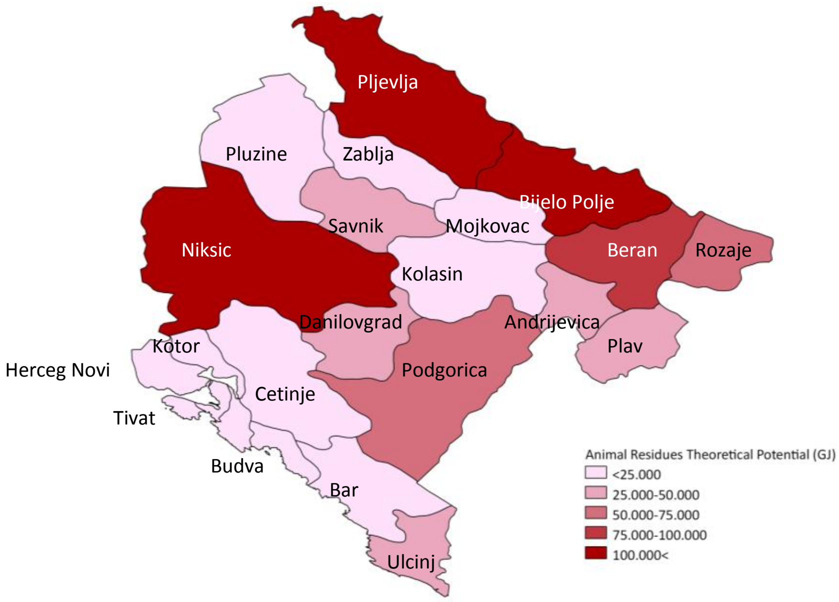

Figure F.6 Theoretical potential of livestock residues map.

The exploitation of livestock residues for energy production through anaerobic digestion process would be feasible only in cases of medium-large scale livestock units. According to a recent publication [Bogunovic et. al 2009], around 24%, 43% and 14% of cattle, pigs and poultry respectively are found in such installations in Montenegro. We assumed that the situation doesn't differ significantly in Montenegro and therefore, the technical potential was regarded equal to 30% of the theoretical value or 248.164 GJ. Data on the regional distribution of animal farms that are of adequate size for biogas production were not available and this field requires further analysis in the future.

F.3 Energy Crops

Two scenarios have been examined for the energy crop potential:

- ✓ Scenario A: 10% pastures + 5% Fallow
- ✓ Scenario B: 10% pastures + 25% Fallow

The total available land is 46.507 ha and 49.288 under scenarios A & B, respectively, since fallow land in Montenegro amounts to just 13.903 ha [MONSTAT 2009a]. Regional distribution of available land under Scenario A is shown in Figure F.7. Available land for energy crops cultivation is found all over the continental part of the country.

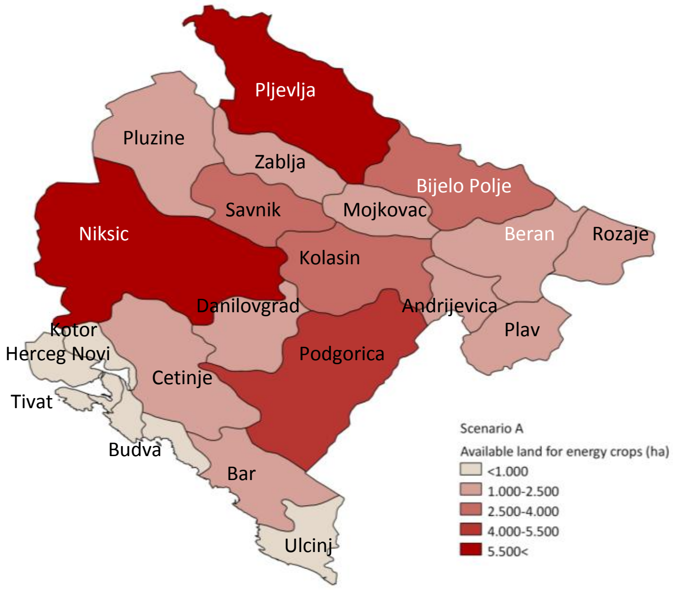

Figure F.7 Available land (ha) for energy crops cultivation in Montenegro according to Scenario A.

Table F.5 presents the energy crops considered in the two scenarios for Montenegro, their yields, main energy markets and the potentials of the available land in the two scenarios. The calculations are made for the whole land available in each case, e.g. if all the available land in Scenario A was used for biodiesel production with oilseeds the total potential would amount to 1.204.540 GJ, while if it was used for second generation bioethanol from SRC it would reach 10.045.588 GJ. These figures are outlining the different potentials based on the conversion efficiencies.

Detailed land use scenarios for energy crops were not analyzed as this would require a separate analytical approach for future land use patterns, direct and indirect land use impacts as well as other potential sustainability criteria (including soil, air and water) - this was outwith the scope of the current study.

Table F.3 Energy crops potential for biofuels (1st & 2nd generation) and bioenergy in Montenegro (2008).

Crop	Yield (2010)	End use	Energy potential Scenario A (GJ)	Energy potential Scenario B (GJ)
Oilcrops	2,70	1st gen Biodiesel	1.204.540	1.276.558
Sugarbeet	44,41	1st gen Bioethanol	55.250.732	58.554.085
Wheat	3,66	1st gen Bioethanol	4.595.856	4.870.635
Maize	4,67	1st gen Bioethanol	5.864.112	6.214.718
Perennial grasses	10,00	2nd gen Bioethanol	3.767.095	3.992.324
		Heat & Electricity	7.441.176	7.886.072
SRC	8,00	2nd gen Bioethanol	3.013.676	3.193.859
		Heat & Electricity	5.952.941	6.308.858

F.4 Forest Based Biomass

Total forest area in Montenegro amounts to 730.652 ha, which is 53% of the total land. 67% of the forest land is public, while the rest is private. The forests are located mainly at the northern part of the country in the municipalities of Mojkovac, Pluzine and Pljevlja as it is shown in Figure F.8. Nevertheless, forests are found all over the country. Total forest biomass of Montenegro is estimated at 70,9 million m^3 (41% conifers) with an average standing volume of 97 m^3/ha. Net annual increment is estimated at 1.431.000 m^3.

Forests intended for timber production involve 81% of all forests [LUX-DEVELOPMENT 2008]. Realized annual fellings according to official data [MONSTAT 2009a] were 595.195 m^3 for 2008 or 41% on the annual increase of the woodstock. Annual roundwood production in Montenegro was 485.038 m^3 in 2008 [MONSTAT 2009a], of which 156.181 m^3 were fuelwood (32%) and 328.857 m^3 were directed towards the wood industry. The remaining fraction, i.e. 110.157 m^3 were forest (logging) residues that remain at the forest.

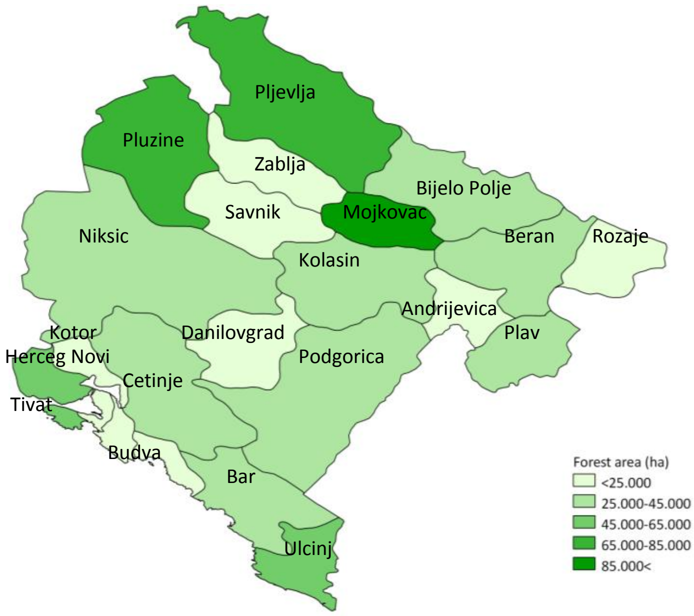

Figure F.8 Forest area in Montenegro.

Nowadays in Montenegro fuelwood is used for household heating. However, since energy demand increases and the prices of fossil fuels, soar, other forest based biomass resources apart from fuelwood are also considered for energy exploitation. These include forest residues and bark as well as residues/by-products coming from the processing of industrial wood.

Forest residues in Montenegro that can be utilized for energy production include tops, branches and stumps that are left over at the logging sites. According to Prof. Branko Glavonjic, forest residues that are available for energy purposes amount to 20% and 10% of the harvested volume of industrial roundwood and fuelwood respectively. Nevertheless, no more than 50% of these residues can be harvested due to difficulties in their collection.

Wood industries, apart from their products, produce residues, such as chips and particles, sawdust, slabs, edgings and shavings. These residues can either be used in particleboards production or used for energy purposes in industrial boilers and for densified wood fuels production (pellets and briquettes). When calculating the available sawmill residues it has been assumed that all the available technical wood is processed only into sawn timber [Danon et al. 2010]. Sawmill residues produced at the sawmills were calculated as 45% of the feedstock, while their availability is estimated to be around 80%. The recoverable quantities of bark from sawmills were taken equal to 7% of the feedstock [United Nations 2010], while their availability for energy production is 60-80%. We chose to remain on the safe side and adopted a 60% availability factor. Furthermore, according to [Glavonjic 2010], secondary wood industry residues, i.e. furniture, windows, doors, floorings and building wood industry, amounted to around 28.000 m^3 in 2008. There is no paper or pulp industry in Montenegro.

Energy potential for each wood fuel i in the region j was thus calculated as follows:

$$Eforest_{i,j} = M_{i,j}H_i \qquad (F.3)$$

$M_{i,j}$ quantity of wood fuel i produced in region j [t]
H_i lower heating value of wood fuel i [GJ/t]

For further details regarding definitions and lower heating value calculations see Annex II. The results are summarized in Table F.4.

Table F.4 Forest based biomass available for energy production in Montenegro (2008).

Source of Biomass	Biomass (m^3)	Degree of Availability (%)	Biomass available for energy exploitation	
			Quantity (m^3)	Energy potential (GJ)
Total	**436.391**		**349.937**	**3.312.210**
Fuelwood	156.181	100	156.181	1.535.530
Forest residues	81.390	50	40.695	331.175
Sawmill residues	147.986	80	118.389	1.122.458
Bark	23.020	60	13.812	110.436
Other wood industry residues	27.814	75	20.860	212.611

As it is shown in Table F.4 and Figure F.9, fuelwood and wood industry residues contribute equally to the forest biomass potential, while forest residues is not a negligible source of biomass (10%). Total potential equals to 3.312.210 GJ, which is 7,2% of the total primary energy supply of Montenegro.

Forest and wood industry residues are almost evenly distributed across the northern part of Montenegro. An exception is Pljevlja where almost 30% of the total primary wood industry (sawmill) residues is concentrated [Danon et al. 2010].

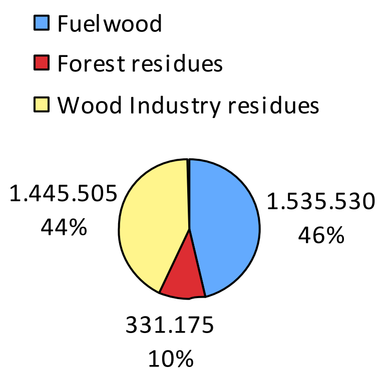

Figure F.9 Forest based biomass technical potential (GJ).

F.5 Municipal Solid Wastes

Municipal solid waste (MSW) refers to waste collected by or on behalf of municipalities; the main part originates from households, but waste from commerce and trade, office buildings, institutions and small businesses is also included.

The production and composition of MSW depends on various factors such as economic development, living standard and consumer patterns. A commonly used indicator for municipal waste generation is the waste per capita generation, which is expressed in kg per person and year. Since no data were available for Montenegro we have assumed that the waste per capita generation in Montenegro would be the same as in Serbia, where it equals to 312 kg/capita/yr [Faculty of Technical Sciences, Novi Sad 2008].

According to the EU legislation (Directive 2001/77/EC) energy produced from the biodegradable fraction of MSW is considered as renewable and therefore waste paper and textiles and organic waste are a source of biomass. Furthermore, the composition of MSW in Montenegro was also regarded to be the same as Serbia and it is shown in the next table [Statistical Office of the Republic of Serbia 2009].

Table F.5 MSW composition and lower heating value of biodegradable components.

	MSW Composition [Statistical Office of the Republic of Serbia 2009]	Lower heating value (GJ/t) [Smith et al., 2010]
Organic material	30%	3,98
Paper, paperboard	16%	11,5
Textiles	4%	14,6
Biodegradable fraction	50%	7,2
Plastics	13%	
Glass	5%	
Metals	6%	
Rubber	3%	
Construction waste	9%	
Other	14%	

Taking into account the population of Montenegro, the waste generated per capita and the fraction of the biodegradable part of MSW, the theoretical potential of biomass from MSW can be estimated according to the following equation:

$$E_{msw} = PpC_oH_o \qquad (F.4)$$

P population
p per capita waste generation [t/yr]
Co biodegradable waste fraction in MSW [%]
Ho biodegradable waste lower heating value [GJ/t]

The results for 2008 are summarized in Table F.6. The estimated theoretical potential amounts to 709.804 GJ or 1,5% of the country's total primary energy supply in 2006.

Table F.6 Theoretical potential of the biodegradable fraction of MSW in Montenegro in 2008.

	2008
Population [MONSTAT 2009]	628.804
Waste per capita (t/capita/yr)	0,312
Total Waste (t/yr)	196.187
Biodegradable fraction (%)	50
Lower heating value for bio-MSW (GJ/t)	7,2
Theoretical potential (GJ)	**709.804**

The main option for disposal of municipal waste is still landfilling, while in many cases existing facilities are inadequate, posing considerable risks to public health and the environment. Therefore, there is a potential for landfill gas exploitation for heat and/or electricity production. Evaluation of the technical potential of landfill gas production was out of the scope of this work.

G. HEAT AND ELECTRICITY MARKET OPPORTUNITIES

This section assesses how the biomass resources - that have been identified and quantified by this study in some detail - could actually be exploited. A number of assumptions are taken which are necessarily high-level and approximate, and are open for challenge. Despite this, this section shows that the resources represent varied, sizeable and replicable opportunities for investment in modern power and heat generation technologies. Use of indigenous, renewable resources would contribute to energy-independence and give environmental benefits notably - but not only - carbon reduction.

Ways of using biomass resources include cofiring with fossil fuels; combustion in new build combined heat and power (CHP) units; anaerobic digestion; combustion at smaller scale ranging from individual stoves and ovens in households to larger, modern boilers for heat provision to buildings etc. The focus was on conversion technologies that are proven commercially and are already widespread elsewhere in Europe. More advanced conversion technologies such as pyrolysis and gasification were not included. It is possible that such technologies may become preferred over the time-frame to 2030, but that is speculative.

The main options of biomass exploitation in the Montenegro heat, electricity and CHP market sectors are presented below. The results are summarised in Table G.1.

G.1 Heat & electricity generation

Based on the estimates on biomass technical potential the options considered for heat & electricity generation include:

G.1.1 Cofiring

Both literature and experts opinion suggests that cofiring 5 - 10% biomass feedstock with fossil fuel (on a weight basis) require relatively minor changes to the technology that is already in place, such as fuel feed systems, storage facilities, emissions controls etc and hence relatively low capital investment. Higher proportions of biomass fuel require more profound technical issues to be addressed and therefore higher investment. Power generation and district heating plant throughout the study countries is typically at an advanced age and is unlikely to merit substantial investment, therefore it was considered that the most likely approach would be to cofire at lower percentages.

Waste wood, forest and industrial residues as well as agriculture residues such as pruning and straw could be used for co-firing although wood chips is the preferable fuel. Forest residues, as estimated by the study, accounts for 0,33 PJ or 46.000 tonnes. If 50% of this could be used for co-firing this would result in the production of 29 ‘green’ GWh within existing solid fuel power facilities.

G.1.2 Decentralised bio-gas units:

Montenegro’s potential from livestock residue derived biogas account for 0,25 PJ. This can be utilized in small to medium bio-gas units installed near the breeding farms. Nearly 3 MW of such installations may be fuelled by the available bio-gas producing 24 GWh of electricity and 35 GWh of heat. The capacity and consequent energy production may be increased significantly in case of central co-digested units that could utilize agricultural residues (green biomass) or dedicated energy crops.

G.1.3 Small scale modern heating appliances

Currently biomass consumption comprises individual, traditional small stoves, ovens, boilers etc., with low efficiencies. The significant use of fuelwood indicates that there could be opportunities for the development of the market for modern biomass heating appliances. The study estimated that if 20% of the 1,54 PJ of available fuelwood could be exploited for this purpose this would result in generating 68 GWh of heat annually.

G.1.4 CHP using energy crops

The study makes a reasonably conservative assumption that 10% of land currently used for grazing/pasture is used to grow perennial grasses. The Technical Potential (for the low scenario), if perennial crops are used is estimated to be 7,44 PJ resource. It is assumed that half of this resource would be available for bio-energy industry, or medium-scale CHP installations (individual capacity 5 MWe plus) delivering power to grid and heat to residential / commercial / industrial users. This would support 52 MWe installed capacity that would generate 362 GWh electricity and 517 GWh heat annually.

G.1.5 Small scale heat with energy crops

In the study it is estimated that the other 50% of the 7,44 PJ for energy crops would support local small scale energy crop fired baled fired boilers or energy crop pellet boilers supplying residential properties with heat. This would equate to 827 GWh of useful heat production per year.

Table G.1: Montenegro - –Heat and Electricity market sectors fuelled with agriculture and forestry biomass							
Resource	**Key assumptions with regard to availability and production of resource**	**Technical Potential annual**	**Electricity generation annual**	**Heat generation annual**	**Electrical generation capacity**	**Heat generation capacity**	**Key assumptions with regard to the means of exploiting resource**
		PJ	GWh	GWh	MWe	MWth	
Forest residues and straw	0,33 PJ (46.000 tonnes) from forest residues, used wood and straw. 50% available for medium scale users.	0,3	29	-	4	-	Medium-scale CHP installations (5MWe+) delivering power to grid and heat to residential / commercial / industrial users
Wood from forestry	1,54 PJ (313.919 tonnes) fuelwood available: 20% available for local small scale energy use.	0,3	-	68	-	na	Local small scale wood fired boilers, stoves, fires etc.
Biogas from agriculture	Theoretical potential 0,827 PJ biogas production, 93% of which from cattle slurry. Assume that 30% of theoretical potential could be realised, or 0,248 PJ.	0,25	24	35	3	5	Small scale anaerobic digestion units (in range 1-3MWe) that aggregate residues from several farms, generating power to grid only. No significant heat uses given remote rural locations.
Totals excluding energy crops		**0,9**	**53**	**103**	**8**	**5**	
Energy crops	Assume that 10% of grassland and 5% of fallow land used to grow perennial grasses, provides 7,44PJ resource:						
	50% of above resource available for bio-energy industry larger users.	3,7	362	517	52	74	Medium-scale CHP installations (5MWe+) delivering power to grid and heat to residential / commercial / industrial users
	50% of above resource is available for bio-energy industry smaller users.	3,7	-	827	-	118	Energy crop bale or pellet boilers supplying residential and other buildings with heat.
Totals including energy crops		**8,3**	**415**	**1.447**	**59**	**197**	

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ANNEX I. AGRICULTURAL AND FOREST BASED BIOMASS POTENTIALS AND COEFFICIENTS

Table I.1 Field crop residues

Districts	Wheat	Maize	Rye	Barley	Total
					Technical Potential (t)
Andrijevica	0,00	178,20	0,00	0,48	179
Bar	2,40	60,72	0,00	0,48	64
Berane	138,60	297,00	7,59	17,28	460
Bijelo Polje	315,00	816,75	127,05	347,76	1.607
Budva	0,00	0,00	0,00	0,00	0
Cetinje	0,00	5,61	0,33	0,24	6
Danilovgrad	13,20	96,69	0,99	5,52	116
Herceg-Novi	0,00	1,98	0,00	0,00	2
Kolašin	0,00	82,17	3,30	8,88	94
Kotor	0,00	9,57	0,00	0,48	10
Mojkovac	2,10	23,43	5,94	18,48	50
Nikšić	13,50	92,40	28,38	24,96	159
Plav	0,00	98,01	1,65	0,48	100
Pljevlja	9,00	2,31	14,85	44,40	71
Plužine	0,60	0,00	0,33	0,96	2
Podgorica	93,00	476,85	0,00	13,68	584
Rožaje	0,00	1,65	0,00	31,68	33
Šavnik	0,00	0,00	0,00	5,76	6
Tivat	0,00	9,24	0,00	0,00	9
Ulcinj	270,00	924,00	0,00	0,00	1.194
Žabljak	0,00	0,00	0,00	17,28	17
TOTAL	**857**	**3.177**	**190**	**539**	**4.763**

Districts	Wheat	Maize	Rye	Barley	Total
					Technical Potential (GJ)
Andrijevica	0	2.762	0	7	2.769
Bar	35	941	0	7	983
Berane	1.996	4.604	110	251	6.960
Bijelo Polje	4.536	12.660	1.842	5.043	24.080
Budva	0	0	0	0	0
Cetinje	0	87	5	3	95
Danilovgrad	190	1.499	14	80	1.783
Herceg-Novi	0	31	0	0	31
Kolašin	0	1.274	48	129	1.450
Kotor	0	148	0	7	155
Mojkovac	30	363	86	268	747
Nikšić	194	1.432	412	362	2.400
Plav	0	1.519	24	7	1.550
Pljevlja	130	36	215	644	1.025
Plužine	9	0	5	14	27
Podgorica	1.339	7.391	0	198	8.929
Rožaje	0	26	0	459	485
Šavnik	0	0	0	84	84
Tivat	0	143	0	0	143
Ulcinj	3.888	14.322	0	0	18.210
Žabljak	0	0	0	251	251
TOTAL	**12.347**	**49.237**	**2.761**	**7.813**	**72.157**
Coefficients					
Residue / Product	1,00	1,10	1,10	0,80	
Moisture Content (%)	15,00	15,00	15,00	15,00	
Net calorific value (GJ/t)	14,40	15,50	14,50	14,50	
Availability (%)	0,30	0,30	0,30	0,30	

Table I.2Arboricultural residues

Districts	Apples	Pears	Plums	Vineyard	Olives	Citrus	Total
							Technical Potential (t)
Andrijevica	17,33	7,88	54,90	0,00	0,00	0,00	80,10
Bar	45,68	39,60	14,18	232,65	200,43	289,17	821,70
Berane	63,00	16,88	199,80	0,00	0,00	0,00	279,68
Bijelo Polje	302,40	24,30	246,38	0,00	0,00	0,00	573,08
Budva	1,26	0,23	0,23	3,38	316,20	10,53	331,82
Cetinje	11,34	2,25	5,63	297,90	0,00	0,00	317,12
Danilovgrad	283,50	25,20	31,50	322,88	0,00	0,81	663,89
Herceg-Novi	5,67	0,90	3,15	73,13	207,57	25,11	315,53
Kolašin	166,64	23,63	35,33	5,18	0,00	0,00	230,76
Kotor	27,09	3,15	10,13	44,55	91,80	65,61	242,33
Mojkovac	36,86	9,23	3,15	0,00	0,00	0,00	49,23
Nikšić	149,63	51,08	79,43	31,95	0,00	0,00	312,08
Plav	126,00	45,00	270,00	0,00	0,00	0,00	441,00
Pljevlja	119,70	60,75	175,50	0,00	0,00	0,00	355,95
Plužine	10,08	5,63	7,20	0,00	0,00	0,00	22,91
Podgorica	198,14	109,58	150,98	8.839,13	14,79	27,27	9.339,87
Rožaje	5,99	2,70	9,45	0,00	0,00	0,00	18,14
Šavnik	7,25	2,93	22,50	0,00	0,00	0,00	32,67
Tivat	1,89	0,68	0,90	21,60	149,43	25,92	200,42
Ulcinj	16,38	27,00	16,65	25,65	244,80	1.482,30	1.812,78
Žabljak	0,00	0,00	0,00	0,00	0,00	0,00	0,00
TOTAL	**1.595,79**	**458,55**	**1.336,95**	**9.897,98**	**1.225,02**	**1.926,72**	**16.441,01**

Districts	Apples	Pears	Plums	Vineyard	Olives	Citrus	Total
							Technical Potential (GJ)
Andrijevica	260	118	824	0	0	0	1.202
Bar	685	594	213	3.490	3.006	4.338	12.326
Berane	945	253	2.997	0	0	0	4.195
Bijelo Polje	4.536	365	3.696	0	0	0	8.596
Budva	19	3	3	51	4.743	158	4.977
Cetinje	170	34	84	4.469	0	0	4.757
Danilovgrad	4.253	378	473	4.843	0	12	9.958
Herceg-Novi	85	14	47	1.097	3.114	377	4.733
Kolašin	2.500	354	530	78	0	0	3.461
Kotor	406	47	152	668	1.377	984	3.635
Mojkovac	553	138	47	0	0	0	738
Nikšić	2.244	766	1.191	479	0	0	4.681
Plav	1.890	675	4.050	0	0	0	6.615
Pljevlja	1.796	911	2.633	0	0	0	5.339
Plužine	151	84	108	0	0	0	344
Podgorica	2.972	1.644	2.265	132.587	222	409	140.098
Rožaje	90	41	142	0	0	0	272
Šavnik	109	44	338	0	0	0	490
Tivat	28	10	14	324	2.241	389	3.006
Ulcinj	246	405	250	385	3.672	22.235	27.192
Žabljak	0	0	0	0	0	0	0
TOTAL	**23.937**	**6.878**	**20.054**	**148.470**	**18.375**	**28.901**	**246.615**
Coefficients							
Residue/ Product	0,35	0,25	0,25	0,25	1,02	0,30	
Moisture Content (%)	15,00	15,00	15,00	15,00	15,00	15,00	
Net calorific value (GJ/t)	15,00	15,00	15,00	15,00	15,00	15,00	
Availability (%)	0,90	0,90	0,90	0,90	0,50	0,90	

Table I.3 Livestock Residues

	Cattle	Pigs	Poultry	Total
Districts				**Number of Heads**
Andrijevica	2.801	250	11.788	14.839
Bar	2.144	118	25.535	27.797
Berane	8.496		25.552	34.048
Bijelo Polje	12.026	339	9.515	21.880
Budva	44		8.252	8.296
Cetinje	589		1.834	2.423
Danilovgrad	3.066	280	22.848	26.194
Herceg-Novi	676	39	3.935	4.650
Kolašin	2.215	344	4.502	7.061
Kotor	618		201	819
Mojkovac	2.110	657	6.509	9.276
Nikšić	10.990	226	32.160	43.376
Plav	4.980	624	5.261	10.865
Pljevlja	14.035	7	20.270	34.312
Plužine	2.672		4.275	6.947
Podgorica	5.826	181	19.763	25.770
Rožaje	8.172	81	7.331	15.584
Šavnik	3.135		4.951	8.086
Tivat	61	97	1.344	1.502
Ulcinj	3.172	72	20.713	23.957
Žabljak	1.366		149	1.515
Total	**89.194**	**3.315**	**236.688**	**329.197**
				Theoretical Potential (GJ)
Andrijevica	24.043	699	2.607	27.348
Bar	18.403	330	5.647	24.380
Berane	72.926	0	5.650	78.577
Bijelo Polje	103.227	948	2.104	106.278
Budva	378	0	1.825	2.202
Cetinje	5.056	0	406	5.461
Danilovgrad	26.317	783	5.052	32.153
Herceg-Novi	5.803	109	870	6.782
Kolašin	19.013	962	996	20.970
Kotor	5.305	0	44	5.349
Mojkovac	18.111	1.837	1.439	21.388
Nikšić	94.334	632	7.112	102.077
Plav	42.746	1.745	1.163	45.654
Pljevlja	120.471	20	4.482	124.973
Plužine	22.935	0	945	23.881
Podgorica	50.008	506	4.370	54.884
Rožaje	70.145	226	1.621	71.993
Šavnik	26.910	0	1.095	28.004
Tivat	524	271	297	1.092
Ulcinj	27.227	201	4.580	32.009
Žabljak	11.725	0	33	11.758
TOTAL	**765.608**	**9.268**	**52.339**	**827.214**
Coefficients (wet basis)				
waste per animal (t/yr)	1,622	0,301	0,021	
biogas yield (Nm3/t of waste)	245	430	450	
biogas LHV (GJ/Nm3)	0,0216	0,0216	0,0234	

Table I.4 Forest biomass

	Fuelwood	Forest residues	Total
Districts		**Technical Potential (m^3)**	
Andrijevica	8.696	1.913	10.609
Bar	1.653	83	1.736
Berane	6.742	3.160	9.902
Bijelo Polje	14.201	2.569	16.770
Budva	108	5	113
Cetinje	11.946	602	12.548
Danilovgrad	6.365	795	7.160
Herceg-Novi	438	22	460
Kolašin	17.487	2.639	20.126
Kotor	444	22	466
Mojkovac	2.895	616	3.511
Nikšić	26.691	2.823	29.514
Plav	1.438	2.251	3.689
Pljevlja	11.205	11.922	23.127
Plužine	14.552	2.383	16.935
Podgorica	18.013	2.161	20.174
Rožaje	4.000	3.776	7.776
Šavnik	5.931	302	6.233
Tivat	0	0	0
Ulcinj	858	43	901
Žabljak	2.518	2.607	5.125
TOTAL	**156.181**	**40.695**	**196.876**

	Fuelwood	Forest residues	Total
Districts		**Technical Potential (GJ)**	
Andrijevica	80.032	16.307	96.339
Bar	18.052	834	18.886
Berane	55.297	24.033	79.330
Bijelo Polje	133.680	22.384	156.064
Budva	1.179	54	1.234
Cetinje	130.435	6.068	136.503
Danilovgrad	68.207	7.869	76.076
Herceg-Novi	4.783	224	5.007
Kolašin	179.647	25.068	204.715
Kotor	4.849	224	5.073
Mojkovac	26.276	5.179	31.455
Nikšić	281.299	27.500	308.799
Plav	11.357	16.492	27.849
Pljevlja	88.808	87.643	176.450
Plužine	139.916	21.209	161.125
Podgorica	187.228	20.761	207.990
Rožaje	31.309	27.417	58.726
Šavnik	64.617	3.044	67.661
Tivat	0	0	0
Ulcinj	9.370	433	9.803
Žabljak	19.187	18.433	37.620
TOTAL	**1.535.530**	**331.175**	**1.866.705**
Coefficients			
moisture %	30	50	
	conifers		
basic density (kg/m3)	420		
LHV of absolute dry biomass (GJ/t)	18,9		
	non-conifers		
basic density (kg/m3)	645		
LHV of absolute dry biomass (GJ/t)	17,9		
Availability (%)	100	50	

Table I.5 Wood processing industry residues.

	Sawmill residues	Other wood industry residues	Sawmills bark	Total
				Technical Potential (t)
TOTAL	**111.732**	**13.125**	**15.643**	**140.500**
				Technical Potential (GJ)
TOTAL	**1.122.458**	**212.611**	**110.436**	**1.445.505**
Coefficients				
moisture %	40	10	50	
		conifers		
basic density (kg/m3)		420		
LHV of absolute dry biomass (GJ/t)	18,9		16,9	
		non-conifers		
basic density (kg/m3)		645		
LHV of absolute dry biomass (GJ/t)	17,9		16,1	
Availability (%)	80	75	60	

ANNEX II. METHODOLOGICAL APPROACH

Biomass feedstocks within this work cover residues deriving from agricultural and forestry activities as well as wastes and energy crops. The analysis for the residual feedstocks has been based on national statistics and respective regional assumptions for co-efficients at national level. Both input and output data have been validated through a series of consultations with national biomass experts.

II.1 Definitions

II.1.1 Agricultural biomass

Agricultural biomass includes field crop, arboricultural, livestock and agro-industrial residues. For scenario and assumptions reasons and since energy crops are not cultivated in Albania yet, with have treated energy crops as a separate category in this study and haven't included them in the *Agricultural biomass* category.

Field crops are producing two types of field residues, i.e dry and fresh or green residues

- ✓ Green field crop residues, such as sugarbeets, potatoes, etc., are left in the field in fresh, succulent condition. These residues are usually rotting in the field and in some occasions they are used for animal feeding. That type of residues because of high moisture content, usually more than 70%, can be considered as potential feedstock for biogas applications.
- ✓ Dry field crop residues are derived from field crops, such as small grain cereals (wheat, barley, oat, rye, and rice), maize, oil crops (sunflower, rapeseed, etc.), etc. These residues are incorporated into the soil, burned in the field or collected and used for various purposes (animal feed, bedding, mushroom cultivation, etc.).

Arboricultural residues are the prunings of grapes and trees such as apple trees, olive trees, pear trees, etc.

Two main sources of *livestock residues* are manures and slaughter residues – the latter is not included in this study. Energy can be derived from animal manure as long as it is collected in lagoons or large tanks and can be considered feasible only in in-stall livestock systems, excluding therefore sheep and goats from such practices since their breeding is extensive and the produced manure is spread all over the grazing land. Intensive livestock consists of cattle, pigs and poultry farming. Since animal manure is of a high water content, it can be digested anaerobically for the production of biogas, which can be burnt for heat or/and electricity production.

II.1.2 Forest based biomass

Forest based biomass includes fuelwood, forest residues and wood industry residues.

- ✓ Fuelwood is the form of wood used primarily for heat or for conversion to a form of energy.
- ✓ Forest (or logging) residues are woody biomass by-products which are created during harvest of merchantable timber. They are usually left at the logging site due to the high cost of collection and the maintenance of soil condition. Forest residues that can be used either for industrial heat or densified wood fuels (pellets and briquettes) production include tops, branches, stumps and bark.
- ✓ Wood industry residues are woody biomass by-products originating from the wood processing as well as the paper and pulp industry. In each phase of wood processing several by-products are produced such as chips and particles, sawdust, slabs, edgings and shavings. These residues can be either used in particleboards or pulp production or used for energy purposes in industrial boilers and for densified wood fuels production (pellets and briquettes). Bark is also included in industrial residues, if industrial wood is debarked at the sawmills. Black liquor, which is a by-product of the pulp industry, can also be used for energy production.

  Residues from the wood processing were further subdivided into *sawmill* and *other wood industry residues*. *Other wood industries* include plywood, veneer sheets and secondary processing industries such as furniture industry. Sawmill residues are treated separately because they have different characteristics (e.g. different moisture content) and of course they are the major fraction of wood industry residues.

II.1.3 Energy crops

Energy crops in this study are defined as crops specifically bred and cultivated for energy production either by direct conversion to heat and electricity or by production of bio-fuels (solid, gaseous or liquid).

The following Table summarizes the main energy crops under consideration in Europe.

Table II.1 Agronomic aspects of selected energy crops under study in Europe.

Species	Sowing/ establishment	Harvest	Yield (t/ha)	Remarks
Oil crops				
Rapeseed	March- May	June- July	3-5 (grain)	Both annual (spring-sown) and biennial (winter-sown) types of *Brassica napus* ssp. *oleifera* are cultivated. Winter crops can be harvested from late July, spring ones usually ripening during September;
Brassica carinata	March- May	June- July	2,5-3 (grain)	Originated from Ethiopia, it is a late growing plant, which is mainly grown in warm tropical regions. It is vulnerable to the cool regions, thus its cultivation is not recommended to those areas with heavy winters.
Sunflower	March- May	June- July	2,5- 4	Annual plant with a strong taproot, from which develop deeply-penetrating lateral roots. Modern crop cultivars may be less than 1 m tall (dwarf types) or 1,5 m (semi-dwarf) at maturity.
Sugar crops				
Sweet sorghum	March- May	Sept- Nov	16-35 (fresh stems)	C4 annual grass with a well-developed root system and robust aerial parts, which are usually supported by prop roots. Growth characteristics are very variable, depending upon the type; some varieties may exceed 4 m in height, while others may attain 50 cm.
Sugarbeet			14-20	Annual crop requires good-quality land. High productivity and also higher emission levels of agrichemicals. Deployment in the UK, Germany and other member states for bioethanol production.
Starch crops				
Wheat	March- May	June- July	2,5-9 (grain)	Wheat and barley are annual grasses 60 - 120cm tall. Varieties have been traditionally bred for starch and straw has been used for feeding and bedding purposes. Recently both crops are used as feedstocks for bioethanol production in Europe and worldwide.
Barley	March- May	June- July	2-7 (grain)	
Corn	March- May	June- July	10-15 (grain)	Corn is recently used as a bioethanol feedstock with specific varieties being bred for this purpose.
Lignocellulosic				
Fiber sorghum	March- May	Sept- Nov	16- 27	A hybrid deriving from grain and broomcorn sorghums. Annual plant, growing to 3.5-4 m tall, with high water use efficiency. It can be grown successfully on a wide range of soils except water logged and acidic.
Cardoon	Feb- March or Sept- Oct	July- Sept	10-22	Low input, high biomass yielding crop, well adapted to the semi-arid Mediterranean climatic conditions. due to its winter growth and to its robust rooting system, it offers protection against soil erosion in sloping and marginal lands.
Miscanthus	March- June	Feb- April	2-24	Perennial C4-crop that is harvested each year. So far, only limited commercial experience in Europe. Breeding potential hardly explored.
Giant reed	March- May	Feb- April	12-24	C3 perennial crop, native to the Mediterranean region. Tolerant to various soil types with high productivity under irrigation. It abundant root system provides tolerance to drought conditions, efficient water uptake and protection to soil erosion.
Switchgrass	April- May	Feb- April	10-20	Perennial C4-crop that is harvested each year. It is a cool-season grass and does best on moderately deep to deep, somewhat dry to poorly drained, sandy to clay loam soils. It does poorly on heavy soils.
Willow	March- April	Nov- Dec	8-20	Perennial crop with typical rotation of some 3–4 years. Suited for colder and wetter climates. Commercial experience gained in Sweden and to a lesser extent in the UK and some other countries.
Poplar	March- April	Nov- Dec	8-18	Perennial C3-crop, currently especially planted for pulpwood production in various countries. Current typical rotation times 3-4 for coppice systems or 8–10 years for single stem systems.

Source: adapted from Panoutsou, 2010.

II.1.4 MSW

Municipal solid waste (MSW) refers to waste collected by or on behalf of municipalities; the main part originates from households, but waste from commerce and trade, office buildings, institutions and small businesses is also included.

In order to define the biomass potential of MSW only the component which is of biological origin (mainly kitchen and garden waste, paper and cardboard) is considered, along with the proportion of other waste fractions which are of biological origin.

Availability of organic waste for energy use depends strongly on variables like economic development, consumption pattern and the fraction of biomass material in total waste production.

II.2 Biomass potentials assessment

The excel built model uses primary data for the three resource categories (residual biomass, energy crops, MSW) and calculates their theoretical and technically available energy potential.

Theoretical Potential: The total quantity of biomass that can be produced annually from a specific crop or waste / residue / by-product. Theoretical Potential is the quantity grown or disposed, constrained only by macro-factors such as land availability and growth yield.

Technical Potential: This considers important issues around "practical availability" and is invariably a proportion of Theoretical Potential. Thus, calculation of Technical Potential considers factors such as other competing demands, the need for residues to stay on the land to replenish soil nutrients, etc.

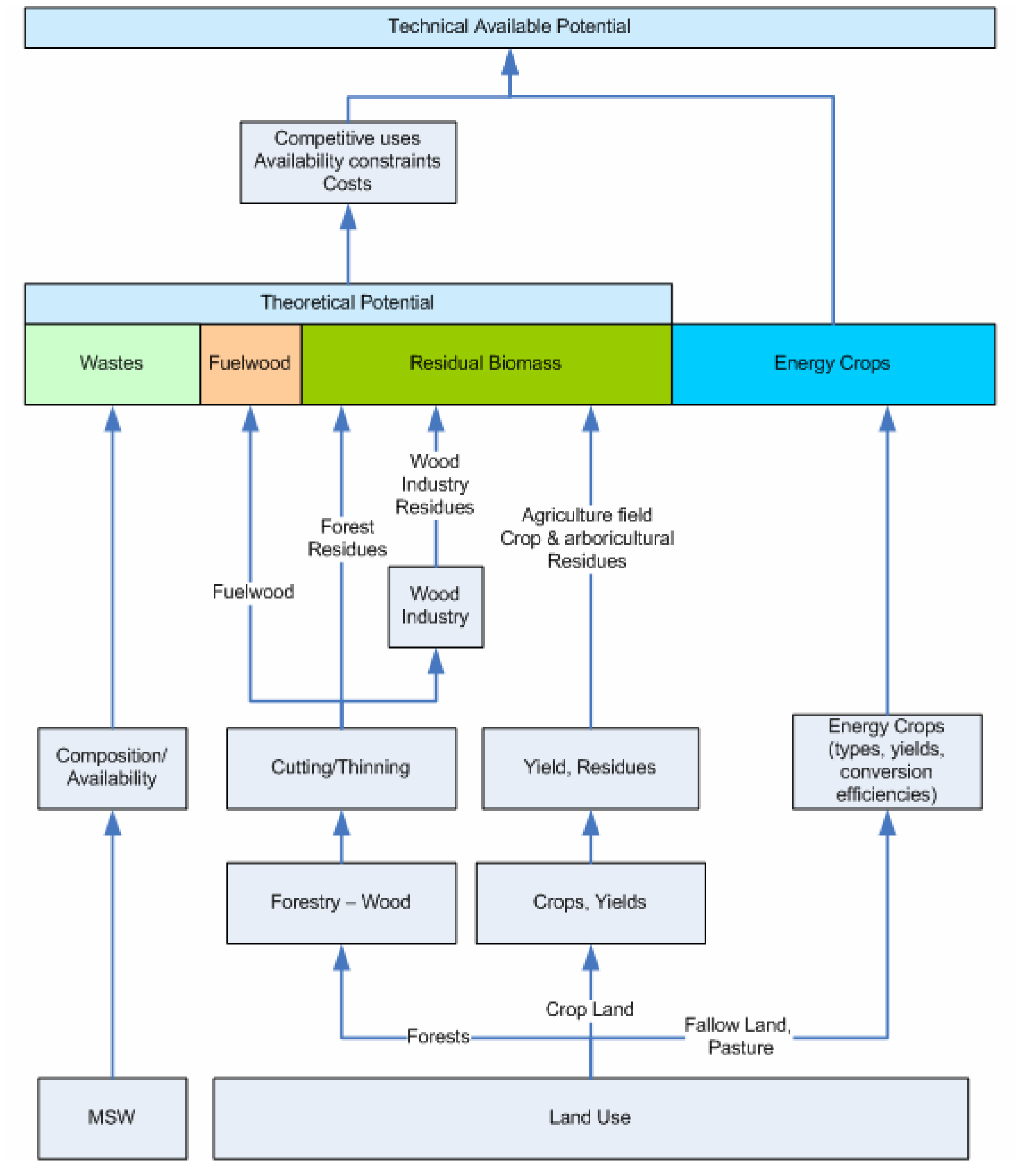

Figure II.1 Schematic representation of the methodology used to estimate the biomass potentials for the different feedstocks in Montenegro.

II.3 Theoretical Potential

II.3.1.1 Agricultural biomass

The total agricultural biomass potential from agriculture *Eresagr* consists of the sum of the different types of residues considered:

$$Eresagr = Erescrop + Eresind + Eresanim \quad (II.1)$$

Erescrop	field crop and arboricultural residues potential [GJ]
Eresind	agro-industrial residues [GJ]
Eresanim	animal residues potential [GJ]

II.3.1.1.1 Field crop & arboricultural residues

For each crop i cultivated in region j of CP k, the annual energy potential $Erescrop_{i,j,k}$ is calculated based on the following formula:

$$Erescrop_{i,j,k} = c_{i,k} P_{i,j,k} H_{i,k} \quad (II.2)$$

$c_{i,k}$ country specific ratio of residue over main product [t/t]
$P_{i,j,k}$ annual production of main product i cultivated in region j of CP k [t]
$H_{i,k}$ country specific lower heating value of residue [GJ/t]

The total energy potential for each country was obtained by adding the potential from all major crops produced in each region (subscript j):

$$Erescrop_k = \sum_j \sum_i Erescrop_{i,j,k} = \sum_j \sum_i c_{i,k} P_{i,j,k} H_{i,k} \quad (II.3)$$

In some cases the residue to product ratio was not available and instead the residue production per cultivated area factor (t/ha) was employed. Then the energy potential was calculated as follows:

$$Erescrop_{i,j,k} = r_{i,k} A_{i,j,k} H_{i,k} \quad (II.4)$$

$r_{i,k}$ country specific residue production per cultivated area [t/ha]
$A_{i,j,k}$ cultivated area of crop i in region j of CP k [ha]

Table II.3 Moisture, energy content and residue coefficients for field crop and arboricultural residues in Montenegro.

	wheat	barley	rye	maize	apples	pears	plums	citrus trees	olives	grapes
residue/product	1,00	0,80	1,10	1,10	0,35	0,25	0,25	0,30	1,02	0,25
moisture (%)	15,0	15,0	15,0	15,0	15,0	15,0	15,0	15,0	15,0	15,0
LHV (GJ/t)	14,4	14,5	14,5	15,5	15,0	15,0	15,0	15,0	15,0	15,0

Data on the annual production (or cultivated area) was obtained through available national statistics and/or FAO statistics and validated by a network of local experts. Data on residue coefficients, lower heating values and moisture contents were obtained by consulting the network of local experts and comparing different literature sources. In countries where there were no available data on the aforementioned coefficients, values from neighboring countries were employed. The Table below presents the moisture, energy content and residue coefficients for field crop and arboricultural residues in Montenegro.

II.3.1.1.2 Livestock residues

The amount of generated manure for animal species i in region j of CP k was recorded and the respective energy potential $Eresanim_{i,j,k}$ was evaluated based on the formula:

$$Eresanim_{i,j,k} = p_{i,k}C_{i,j,k}Y_{i,k}H_{i,k} \qquad (II.5)$$

$C_{i,j,k}$ number of animal species i nurtured in region j of CP k [heads]

$p_{i,k}$ country specific manure generation factor for species i [t/head/yr]

$Y_{i,k}$ country specific biogas yield [Nm^3/t manure]

$H_{i,k}$ country specific lower heating value of biogas [GJ/Nm^3]

The total potential for each country was evaluated by summing the energy potential provided by all species nurtured in each region:

$$Eresanim_k = \sum_j \sum_i Eresanim_{i,j,k} = \sum_j \sum_i p_{i,k} C_{i,j,k} Y_{i,k} H_{i,k} \qquad (II.6)$$

Data on the number of nurtured animals were obtained through available national statistics and/or FAO statistics and validated by a network of local experts.

Moreover, the manure generation factor, the biogas yield and the energy content of the produced biogas of the examined animal species depend on factors such as body size, kind of feed, physiological state (lactating, growing, etc.), and level of nutrition[1]. Values for these coefficients were given by local experts for FYROM, Serbia and Ukraine, while they were cross-checked with literature values. For countries, where no values were given by local experts or in cases where the given values deviated significantly from literature averages, such as Albania, values from neighboring countries were employed (Table II.3).

Table II.3 Parameters for energy production from livestock residues.

	waste per animal (t/yr)	biogas yield (Nm^3/t of waste)	biogas LHV (GJ/Nm^3)
Serbia, Montenegro, Croatia, BiH (dry basis)			
Cattle	1,62	245	0,0216
Pigs	0,30	430	0,0216
Poultry	0,021	450	0,0234

[1] Junfeng, 2005

II.3.1.2 Forest Based Biomass

In order to calculate the theoretical potential of wood fuels (fuelwood, forest residues and wood industry residues) one needs to know their quantity as well as their energy content. Then the potential for wood fuel i in the region j of CP k is given as follows:

$$Eforest_{i,j,k} = M_{i,j,k}H_i \qquad \text{(II.7)}$$

$M_{i,j,k}$ quantity of wood fuel i produced in region j of CP k [t]
H_i lower heating value of wood fuel i [GJ/t]

The total potential for each country was evaluated by summing the energy potential provided by all wood fuels produced in each region:

$$Eforest_k = \sum_j \sum_i Eforest_{i,j,k} = \sum_j \sum_i M_{i,j,k} H_i \qquad \text{(II.8)}$$

Lower heating value *H* is greatly influenced by the total moisture of woody biomass. The lower heating value of biomass containing a known percentage of water can be calculated from the lower heating value of the absolute dry biomass, which is approximately equal to its higher heating value. In Equation 10 *H* describes the lower heating value (in GJ/t) of the biomass at a specific total moisture, H_o the lower heating value of the fully dry biomass, and *w* the total moisture (in %). The constant “2,26” results from the evaporation energy of water.

$$H = [H_o(100 - w) - 2{,}26w]/100 \qquad \text{(II.9)}$$

Moreover, the quantity of wood fuels is usually found in m^3 (CUM) in statistics, therefore wood fuels density is needed in order to convert from volume to mass. Actual density *d* (ratio of the mass to the solid volume on green basis) is related to the basic density d_o (ratio of the mass on dry basis to the solid volume on green basis) according to the following equation:

$$d = \frac{d_o}{1 - \frac{w}{100}} \qquad \text{(II.10)}$$

Values for the basic density d_o, the lower heating value of absolute dry biomass H_o and the moisture content *w* of wood fuels examined in this study were obtained by a Serbian forest biomass expert[2], who is also involved in various FAO projects and studies in the region, and were regarded the same for all CPs (Table II.4 and II.5).

Table II.4 Basic density and lower heating value of absolute dry biomass for conifers and non-conifers.

	conifers	non-conifers
basic density (kg/m³)	420	645
lower heating value of absolute dry biomass (GJ/t)	18,9	17,9

[2] Branko Glavonjic; Belgrade State University, Faculty of Forestry.

Table II.5 Moisture content (%) of the wood fuels examined in this study.

	moisture %
Fuelwood	30
Forest residues	50
Bark	50
Sawmill residues	40
Other wood industry residues	10

For black liquor accounting as woodfuel, it was assumed that from one ton of chemical cellulosic pulp production, an amount of liquor equal to 2,27 CUM of fuelwood, in energy terms, results[3].

Regarding the quantities of forest biomass, various sources were used, depending on data availability in each country. The main data sources were national statistics, FAO statistics[4], experts' estimations and reports from FAO or European projects (e.g. Biomass Energy Europe project). Furthermore, in order to calculate material flows of woody biomass where no data were available, FAO/UNECE country specific conversion factors were employed[5].

[3]FAO, 1997. Wood Energy Today for Tomorrow, Part B: Background overview of available data on wood energy in Europe/OECD. Forestry Department.

[4]FAOSTAT, http://faostat.fao.org/

[5] United Nations 2010. *Forest product conversion factors for the UNECE region*, Geneva.

II.3.1.3 Energy crops

In order to account for food & feed growing demand and changing dietary patterns, as well as biodiversity and landscape concerns in this work the land area that can be available for energy crops is calculated as the sum of a portion of the existing fallow land and 10% of the available grassland (based on FAO & national statistics). The loss of more than 12% of the pasture area in the EU would be considered to represent a significant loss of biodiversity and natural landscape[6].

$$Aencr_i = Afl_i + Agr_i \qquad (II.11)$$

$Aencr_i$ Energy crop area [ha]

Afl_i fallow land area [ha]

Agr_i 10 % of grassland area [ha]

Since no data were available for fallow land at prefecture level in Albania, only grassland was considered for energy crops cultivation. Although this represents a conservative scenario, the team decided not to use arable land in this work as there were a number of uncertainties for future policy and related targets in the agricultural sector that could not be further analyzed within this work.

Table II.6 presents the energy crops considered in the two scenarios their yields, main energy markets and energy conversion factors:

Table II.6 Energy crops; yields and energy conversion factors.

Crop	Biofuels yield (2010) (t/ha)	End use	Biofuels energy content (GJ/ t)
Oilcrops	2,70	1st gen Biodiesel	37
Sugarbeet	44,41	1st gen Bioethanol	27
Wheat	3,66	1st gen Bioethanol	27
Maize	4,67	1st gen Bioethanol	27
Perennial grasses	10,00	2nd gen Bioethanol	27
		Heat & Electricity	16
SRC	8,00	2nd gen Bioethanol	27
		Heat & Electricity	16

Source: BFIN, 2009; De Wit et al., 2009; EU, 2009; Laohalidanond, Heil, and Wirtgen, 2006; McAloon et al.,2000; Viewls, 2005

[6] European Environmental Agency, 2007.

II.3.1.4 Municipal Solid Wastes

For each of the CPs k the amount the energy potential of the organic fraction of municipal solid waste (MSW) $Emsw_k$ was estimated as follows:

$$Emsw_k = P_k p_k Co_k Ho \qquad (II.12)$$

P_k population in CP k.

p_k per capita waste generation [t/yr]

Co_k biodegradable waste fraction in MSW [%]

Ho biodegradable waste lower heating value [GJ/t]

Population data, the per capita waste generation rate and the composition of MSW were obtained from national statistics, European Environmental Agency[7] reports or United Nations environment statistics[8]. Lower heating value of biodegradable waste components was obtained from Smith et al. 2001[9].

II.3.2 Technical Potential

II.3.2.1 Agricultural biomass

II.3.2.1.1 Field crop & arboricultural residues

Soil quality issues and antagonistic uses, such as animal feed and bedding and mushrooms cultivation, reduce the quantity of arable crop residues available for energy purposes. In addition, harvesting methods, can further limit the residues availability. Furthermore, arboricultural residues availability was found to be between 80 and 90% in most CP and refers mainly to their collectability. Some quantities, especially bigger branches from olive trees prunings, are already used for household heating purposes and therefore their availability is further limited.

The availability factors employed in this study for Montenegro were provided by the established network of local experts and cross-checked with literature values (Table II.7).

Table II.7 Arable crop and arboricultural residues availability factors in Montenegro.

Arable crop residues	cereals	maize	oilcrops	sunflower	sugarbeet
Western Balkans	0,30	0,30	0,30	0,00	0,30
Arboricultural residues	fruit trees	olives	vineyards		
Montenegro	0,80-0.90	0,50	0,90		

[7] European Environmental Agency, http://www.eea.europa.eu/themes/waste

[8] United Nations Statistics Division, http://unstats.un.org/unsd/environment_main.htm

[9] Smith, A.; Brown, K.; Ogilvie, S.; Rushton, K.; Bates, J. 2001. Waste management options and climate change. Final report to the European Commission, DG Environment.

II.3.2.1.2 Livestock residues

Technical potential of biogas takes into account accessibility of livestock wastes and technical appropriateness of their anaerobic digestion, which depend primarily on the size of the farms. Manure collection and exploitation is considered feasible only in medium and large farms. Furthermore, confinement of the animals and collectability of the residues are important factors. As for an example one should take into account cattle manure losses due to summer outdoor keeping in Ukraine. Moreover, the various technologies employed in a farm are crucial, e.g. pig farms equipped with manure water wash systems.

Due to the aforementioned reasons a detailed survey needs to be carried out in order to asses the livestock residues availability in a country. Nevertheless, a first approach was made in this study by employing country level availability factors, which were given by local experts in Croatia and were found in literature for Ukraine, Serbia and FYROM. For Albania, BiH, Montenegro and Moldova the same values as in FYROM, Croatia, Serbia and Ukraine were employed respectively. The value for Albania was estimated at 25%.

II.3.2.2 Forest Based Biomass

Ecological exigencies, equipment operability, retrieval efficiencies, the existence of steep slopes, transport distances and forest road infrastructure limit the collection of forestry residues. Forest residues availability was set to 50% for all of the studied countries, a value that was regarded realistic by local forest biomass experts. Furthermore, wood industry residues availability was set to 80%, a value which incorporates only technical barriers in their collection and utilization and not any antagonistic uses such as particleboards and pulp industry. Bark availability is estimated between 60% to 80%. A bark availability factor of 60% was employed, since we chose to remain on the conservative side.

ANNEX III. ELECTRICITY AND HEAT CONVERSION ASSUMPTIONS

The following were the key assumptions:

Electricity generation (co-firing, CHP etc.):	35% efficiency
Heat generation (CHP):	50% efficiency
Heat generation (district heat, boilers etc)	80% efficiency
Heat generation (small scale stoves, ovens etc)	50% efficiency
Plant availability	80% of 7008 hours per year

The above are all considered to be realistic but conservative factors.