OPTIMAL USAGE OF BIOMASS FOR ENERGY PURPOSES TOWARD SUSTAINABLE DEVELOPMENT
A Case of Macedonia

by

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One of the main goals for sustainable development of a country is providing sustainable energy resources, which means satisfying the current needs for energy without compromising the future generations. Moreover, sustainable energy resources primarily involve greater inclusion of renewable energy sources. The biomass is the most widely used renewable energy source, mainly because of its relatively low price and its availability. However, in order for the biomass to stay a renewable energy source, it must be used rationally and with a plan, which primarily requires a detailed analysis of the current situation and resources. Therefore, the aim of this paper is to calculate the optimal utilization of biomass in energy purposes, taking into account the sustainable development of a country. As an example, in this paper Macedonia is considered. A detailed analysis of the data sources related to biomass is made and several different indicators that describe the current situation in Macedonia are presented. Furthermore, several scenarios are defined in this paper in order to calculate the optimal share of biomass in the overall energy mix in Macedonia for the next 20 years, using the MARKAL model.

Key words: *biomass, sustainability, optimal share of biomass*

Introduction

One of the main drivers of the economic development of a country is the energy. The desire for higher economic growth accompanied by increased access to new markets and the increased living standard of the population have led to global increase of the energy consumption by 36.5% in the period from 2000-2014, with average annual increases rate of 2.25% [1]. If we add that most of this energy is derived from fossil fuels that contribute to increased emissions of greenhouse gases, then the sustainability of the energy system is becoming questionable, and so is the sustainability of the countries.

To achieve sustainable development, most countries are devoting more attention to one of the postulates of sustainable development, environment. In the part of the environment that is related to greenhouse gases, the solution is seen in the renewable energy sources. Glob-

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ally the share of renewable energy sources increased by 2.2% each year since 1990, which is slightly higher than the growth rate of world total primary energy supply of 1.9% [2]. The European Union also pays great attention to energy policy in order to increase the share of renewable energy sources on the one hand and on the other hand to reduce CO_2 emissions. These EU policies contributed the share of renewable energy sources in the primary energy supply to increase from 11% in 2003 to 24% in 2013 [3].

Biomass, which is considered as a renewable energy source, is a power source with the longest tradition of use. It has great influence on the policy making of a country because it is considered as a local source, so in terms of security of supply it is very important. During its growth it absorbs as much CO_2 as it emits during burning. Recognizing the role of the biomass, many developing countries plan to use its potential for achieving sustainable development. But, the share of biomass is also at high level in the developed countries, so for example in EU the contribution of biomass in the primary production from renewable energy sources is 64%. However, if a country does not pay special attention on the biomass, it can lead to unplanned usage of it, which may further lead to loss of sustainability of this source, so instead of benefiting from it, it may emit additional CO_2. Therefore, there are many papers that analyze the biomass from different aspects and according to [4] the pace of publishing in this field increased rapidly over the period from 1998 to 2013. As the biomass is country specific, many papers analyze the potential, sustainability and availability of the biomass at a country level. For example, in [5] the availability of biomass is estimated for Sicily. The sustainable development of the Lithuanian household sector in compliance with the EU policy is analyzed in [6] and it is concluded that biomass currently plays and it will continue to play leading role in the energy production from renewable energy sources. In [7], the forest and biomass resources potential, the quantification of the biomass usage for electricity, heat and vehicles fuel purposes and the GHG mitigation for Alberta is estimated. A review of biomass energy resources, its potential and conversion in India are analyzed in [8]. In this paper, policies for providing the subsidies for biomass are also discussed. Quantification of the use of forest biomass for energy purposes and its sustainability is made in [9] for Tasmania, as a country that is rich with forest resources, but lacks detailed biomass data. Detailed analyses of the potential of the biomass in Serbia and the possibilities of its use for energy purposes is considered in several papers [10-12]. The problem with the data related to biomass in Serbia is highlighted in [13]. A detailed analysis of the Montenegro biomass sector is done in [14]. In [15-17] a review of the situation of the renewable energy sources in Macedonia, including biomass is made.

Macedonia as part of the Energy Community has a target of 21% share of renewable energy in 2020. However, according to survey conducted from the Energy Community [18,19], the percentage of share of renewable energy sources is estimated to be 28%. The difference in these percentages occurs as a result of the different data for the biomass consumption from different data sources.

This paper goes further relating the biomass and its sustainability in Macedonia. Therefore, the purpose of this paper is to:

– analyze the current situation and all the relevant data that are available for the biomass in Macedonia,
– analyze the sustainability of the biomass and estimate the maximum consumption of biomass in terms of sustainability, and
– analyze the impact of biomass on the final energy consumption in Macedonia, using the MARKAL Macedonia model.

Screening of the present situation

Usage of biomass in Europe

European Union energy and climate package is a set of legislations that ensure that EU will reach its ambitious targets for 2020. "20-20-20" represents an integrated approach to climate and energy policy that aims at fighting against climate change, increasing security of energy supply and strengthening of European competitiveness. Along this line, the goal in 2020 is to have: participation of renewable energy with 20% in the gross final energy consumption in EU; greenhouse gas emissions reduction of EU by 20% compared to 1990 levels and improve the energy efficiency in EU by 20%.

Regarding the first goal of the climate and energy package, which is 20% share of renewable energy in 2020, Europe has reached 15.1% in 2013 [3]. In terms of the objectives set to each of the member states of the European Union, there are countries that have already reached or exceeded their goals, and there are countries that are still far from achieving them. Sweden and Bulgaria have met and exceeded their targets by 3%, while Estonia, Romania, Lithuania, and Italy have achieved their goals. Countries that are still far from fulfilling their goals are France, UK, The Netherlands, and Iceland.

The share of renewable energy in the total primary production in EU has increased from 11% in 2003 to 24% in 2013. It should be noted that the total primary production in this period has decreased by 15%.

At EU level, biomass and waste have the highest share in total primary production from renewable energy sources which was 64% in 2013. They are followed by hydropower with 16.6% and wind power with 10.5% (fig. 1).

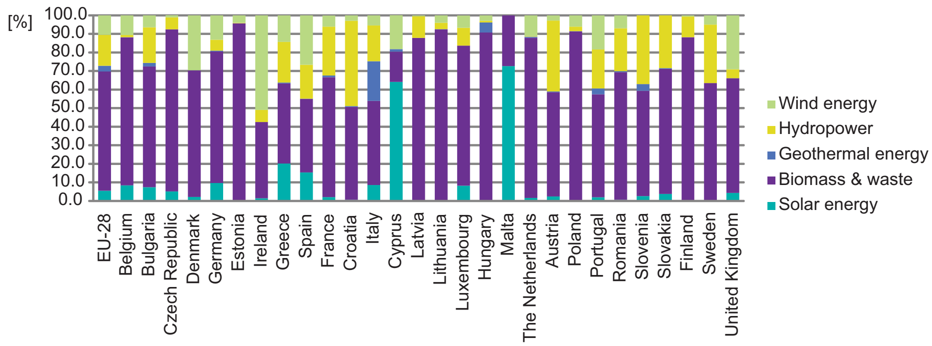

Figure 1. Share of each of the renewable energy sources in the primary production of RES, 2013 [3]

Biomass in Macedonia

The share of renewable energy sources in Macedonia in 2012 amounted to 16.8% in the gross final energy consumption, while in 2013 dropped to 15.1% because of the reduction of biomass consumption due to the relatively warm heating season [20].

The share of biomass in the energy balance of Macedonia is very important. In the total primary production of energy from renewable sources, the biomass participated with 64% in 2012, which is at a similar level as EU. The biomass accounted for 6.6% of the primary energy consumption in 2012, and 10.4% in the final energy consumption.

According to the budget survey of the State Statistical Office, 70%-75% of the households or 390,000 to 420,000 households use biomass for heating and/or cooking [21]. The biomass accounts for 34% of the final energy consumption of households.

Forests in Macedonia

In order to determine the state of the biomass in Macedonia and to ensure its sustainable development, of great importance is to first analyse the forests. Therefore, several indicators from different data sources are presented in this chapter, according to which the current state of the forests in the country is described.

According to the latest data from the State Statistical Office of Macedonia, in 2014 the total forest area in Macedonia is 983,388 ha (38.6% of the state territory), of which 90% (874,245 ha) are state owned forests, and 10% (109,143 ha) are privately owned forests (Figure 2) [22].

According to EUROSTAT [3], Macedonia has 0.55 ha/capita, which is higher than for EU-27 countries which is 0.35 ha/capita.

The forest growing stock in the Republic of Macedonia is estimated at 75 million m^3 [23], which in terms of total forest area means that there are 83 m^3/ha, which makes Macedonia a country with poor quality forests (71% of the forests is shrublands and disturbed natural forests). Regarding this indicator, Macedonia is one of the worst countries in Europe, followed only by Spain with 52.6 m^3/ha and Greece with 47.4 m^3/ha. At EU-27 level, the growing stock compared to the total forest area is 163.3 m^3/ha.

According to the State Statistical Office (SSO) the forest exploitation is continuously decreasing in Macedonia [22]. Actually, in 1984 the annual cut was about 1.1 million m^3 timber, and in 2014 it was 0.66 million m^3, of which 0.5 million m^3 is wood, 0.12 million m^3 is industrial wood, and 0.04 million m^3 is waste (fig. 3 and tab. 1). About 90% of the deforestation is from deciduous trees, and the rest from conifer trees.

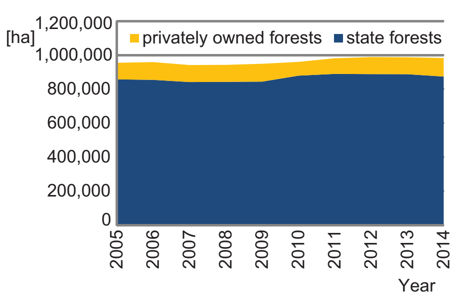

Figure 2. Forest areas by type of ownership, situation as at the end of each year

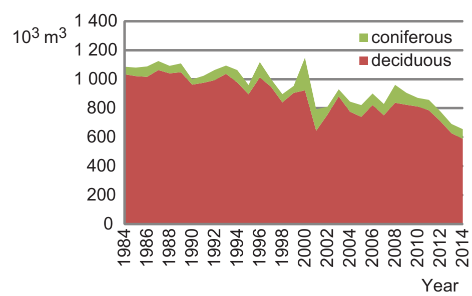

Figure 3. Forest exploitation

The high percentage of shrublands and disturbed natural forests (71%) allows them to be used as fuel because they lack the technical mass. According to this, fuel wood and scraps accounts for 82% to 86% of the total forest exploitation (tab. 1), but this information cannot be considered as reliable since much of the population is supplied with wood from illegal logging which cannot be registered. In addition to the claim is the survey done by Center for Renewable Energy Sources and Savings (CRES) for the Energy Community [18, 19], according to which the consumption of biomass for heating in households is more than three times greater than that recorded in the energy balance [24]. This problem is detected by several institutions in Macedonia and as a result, with the help of funds from the Energy Community, the State Statistical Office has conducted a survey on household consumption and currently they are processing the obtained results.

Except for heating, depending on the year, from 120 to 150 thousand m^3 timber is also used as commercial timber and the scraps have been reduced in the last two years to a level of about 40,000 m^3, while in the previous period there were 70,000 to 100,000 m^3 scraps (as shown in tab. 1).

Table 1. Timber harvested in and outside forests (in 10^3 m^3) [22]

	2010	2011	2012	2013	2014[(1)]
Total gross volume	871	857	779	691	655
State forests	662	658	621	566	532
Forests in private ownership	209	199	158	125	123
Commercial timber	123	143	127	114	121
Fuel wood	675	636	579	536	495
Scraps	73	78	73	41	39

[(1)] Data on private forests are estimated

The fires have great impact on forest destruction. In the period from 2005 to 2014 about 94,000 hectares of forest area was damaged from fires (tab. 2). The greatest area was affected in 2007 – 34,443 hectares, followed by 15,046 hectares in 2008, and 19,312 hectares in 2012.

Table 2. Damages to forests [ha] [22]

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Damage caused by insects [m^3]	4920	4663	1523	1643	12	3513	327	–	300	618
Damage caused by plant diseases [m^3]	26	852	300	62	108	200	–	–	177	649
Fire damages [ha]	3093	3594	34443	15046	1030	4725	8702	19312	2844	1150

In order to achieve forest sustainability and thus preserve forests, a continuous and planned afforestation is required. As a result, thanks to the fund for afforestation which functioned until 1990, 140,000 hectares were afforested. As forest exploitation has decreased in the last 30 years, the artificial afforestation has also a continuous decline (fig. 4). 7,000 hectares were afforested in 1984, and in 2014 it was reduced to only 1,000 hectares. In the period from 1998 to 2008 it is in the range from 2,000 to 3,000 hectares. It is important to note that with the action of the government and the NGO sector, in 2009 trees were planted on a total area of 4,000 hectares, which represents the largest afforestation in the last 25 years.

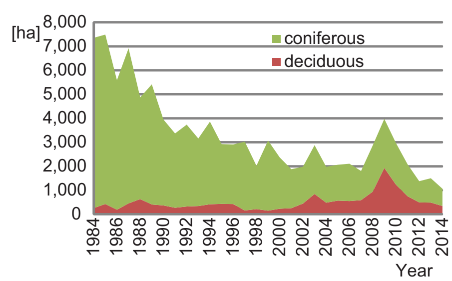

Figure 4. Artificial afforestation [22]

Another source of information about the state of the forests at a global level is the site of the Global forest watch [25, 26], where data are generated by processing and analysing satellite images. On the site, there is an interactive map that can be used to analyse the data about the forest change in the world, or in a specific area or country. Particularly, the forest gain in the period from 2001 to 2012 and the forest loss for a selected period from 2001 to 2013 may be analysed. It should be noted that the term "tree cover" is defined as all vegetation taller than 5 meters in height, and it is the biophysical presence of trees and may take the form of natural forests or plantations existing over a range of canopy densities. Also, forest "loss" indicates the removal or mortality of tree canopy cover and can be due to a variety of factors, including mechanical harvesting, fire, disease, or storm damage.

When selecting Macedonia, it can be noticed that the forest loss from 2001 to 2012 is 28,837 ha, and the forest gain in the same period is 10,437 ha. This is not in accordance with the data from the State Statistical Office of Macedonia that indicate that there is a forest gain of 31,285 ha in that period. However, according to Hansen *et al.*, [25, 26] the team that published the dataset mapping global forest cover loss and gain from 2000 to 2012, the data provided for tree cover and tree cover loss and gain in the map cannot be compared against each other, due to variation in research methodology and/or date of content. Another important note is that it cannot distinguish between forest cover types (for example, the map does not make a difference between natural primary forest and land use which are not equivalent especially regarding reforestation). So, the dataset on gains still requires further validation and research before it can be used as a reliable indication of real forest cover gains. According to this, at this point the map serves only as a general indicator, which has to be supplemented with additional data.

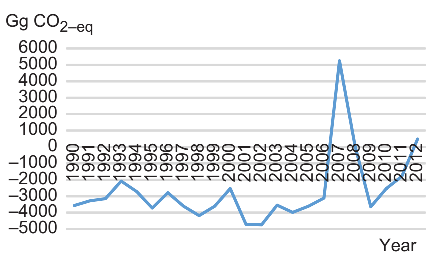

Figure 5. CO_2-eq emissions in Macedonia from land use changes (Source: Inventory of greenhouse gases, Ministry of Environment and Physical Planning, 2013)

CO_2-eq emissions from land use in Macedonia

According to the last GHG inventory made as a part of the Third National Communication [27] and recalculated in the First Biannual Update report [28] it is shown that the CO_2-eq emissions from the forestry during the whole period from 1990 to 2012 are negative except in 2007 and 2012 (fig. 5) when the emissions are positive as a result of the big amount of fires (tab. 2). This means that the forests in Macedonia are at a sustainable level. The inventory is made with the official data from the State Statistical Office.

Waste biomass

The waste biomass is comprised of: residue from forest-cutting, residue from wood processing, residue from agriculture, residue from livestock breeding, industrial residue, and solid municipal waste.

In [16, 17] an overview of the waste biomass potential of Macedonia is made, but it is concluded that there is not enough reliable data to assess the economic feasible potential, nor there is sufficient experience in the performance of specific power plants.

Macedonia is experienced in terms of use of waste biomass from forest-cutting, wood processing and agriculture, where its primary use is related to heat generation. However, this type of waste biomass is suitable also for use by cogeneration plants for heat and electricity generation.

The results shown in tab. 3 were obtained by summing up the non-utilized biomass whose use for heat and electricity cogeneration can be considered cost-effective, together with the portion of biomass used for heat generation by old boilers that can be redirected for use by cogeneration plants.

Table 3. Waste biomass from forest-cutting, wood processing and from agriculture that can be used for heat and electricity co-generation in a cost-effective manner

	Thousands tons per year
Residue from forest-cutting	20
Residue from wood processing	10
Residue from agriculture	35
Total	65

The 65 thousand tons of waste biomass from forest-cutting, wood processing and from agriculture can generate around 50-70 GWh electricity and 120-180 GWh heat at cogeneration plants depending on the demand and accessibility to heating energy consumers.

Solid municipal waste in Macedonia is disposed at large number of landfills. However, only landfill Drisla, servicing the region of Skopje, is properly managed. For the forthcoming period plans have been made to establish integrated regional management of solid municipal waste. Seven regional landfills have been planned for establishment throughout Macedonia. Total quantity of solid municipal waste in Macedonia accounts for nearly 700 thousand tons per year. From this amount, the regional landfill Drisla accounts for around 200 thousand tons, while the other regional landfills account for 50 or 100 thousand tons, each. Lower heating value of municipal waste in Macedonia is estimated at 7860 kJ/kg.

If we implement all phases of managing waste, which includes recycling, and also composting of waste, which includes food and garden waste, (which account for around 42%), then the amount of waste from which electricity can be produced is much lower, and so its feasibility is questioned.

It is estimated that paper and plastic waste contribute with 24% and 6% in the total waste quantity, respectively. If the average degree of 50% paper and plastic waste recycling is achieved, the waste quantity would be reduced to approximately 600 thousand tons and the calorific value of waste would be 6200 kJ/kg, while under a high degree of paper and plastic recycling the waste quantity will be reduced to around 500 thousand tons and the calorific value of waste would be less than 4000 kJ/kg. Depending on the option pursued the potential of solid municipal waste in Macedonia ranges from 500 to 1500 GWh annually. If it is used only for electricity generation it would imply a generation in the range of 200-500 GWh annually provided the total potential in Macedonia is put into use. If we assume that only Drisla, as the biggest landfill in Macedonia will have economic justification to produce electricity, then up to 2035, 50-90 GWh of electricity will be produced annually from municipality solid waste. The upper limit implies that Macedonia will not implement plastic and paper recycling, which – of course – is unrealistic, while the lower limit under high degree of waste and paper recycling implies technologies with high investment costs due to the low calorific value of waste.

Residue from livestock breeding contains stable-generated waste used for energy purposes, primarily biogas obtained from anaerobic fermentation. Biogas is obtained from methane and carbon-dioxide in the ratio 2:1 and from small quantities of NH_3 and H_2S. In Macedonia, the residue from stable breeding of livestock and poultry are estimated at around 5.5 million tons per year. This refers to the theoretical potential, about 3.5 is the technical potential. It can be used to obtain a total of around 90,000 m^3 biogas per year, with a total energy of around 600 GWh. However, experiences in terms of cost-effective use of biogas in the region are modest and the actual potential does not exceed 25% from the total potential. It is estimated that such potential can result in a maximum of less than 50 GWh electricity.

Present national legislation on RES
Preferential producers

For the purpose of stimulating construction of new power plants using renewable energy sources or high-efficiency cogeneration plants, Article 149 of the Energy Law prescribes that these facilities can obtain the status of preferential producer, and thereby the right to sell electricity under FiT. The FiT can be applied in a manner and under procedure stipulated in the Energy Law and the by-laws adopted pursuant to the law. The FiT for sale of electricity produced and delivered from biomass and biogas are 150 €/MWh and 180 €/MWh, respectively with duration of 15 years [29].

Five plants for electricity generation from biogas have been licensed by the Energy Regularly Commission (ERC) in the period 2013-2014 with a total installed capacity of 6.99 MW. As a result, the quota for FiT for electricity generation from biogas of 7 MW, has *de facto* been fully utilised. Two of these plants (2.99 MW) has been commissioned in 2015, the other ones are expected to be operational by the end of 2016 [30].

On the other hand, there has been very little interest in the development of biomass-powered power plants. So far, the ERC has awarded two licences for electricity generation from biomass with installed capacity of 1.4 MW [30], which means that the quota for FiT for electricity generation from biomass (10 MW) is still available.

Methodology

For the purpose of analysing the biomass in the Republic of Macedonia, in this document the MARKAL model is used [31-33]. The objective of MARKAL is to minimize the total cost of the system, adequately discounted over the planning horizon. The objective function is the sum over all regions of the discounted present value of the stream of annual costs incurred in each year of the horizon. Therefore:

$$NPV = \sum_{t=1}^{R} \sum_{t=1}^{NPER} (1+d)^{NYRS(1-t)} ANNCOST(r,t)[1+(1+d)^{-1}+(1+d)^{-2}+...+(1+d)^{1-NYRS}]$$

where *NPV* is the net present value of the total cost for all regions, *ANNCOST* (*r, t*) – the annual cost in region *r* for period *t*, discussed below, *d* – the general discount rate, *NPER* – the number of periods in the planning horizon, *NYRS* – the number of years in each period *t,* and *R* – the the number or regions.

The total annual cost *ANNCOST* (*r, t*) is the sum over all technologies *k*, all demand segments *d*, all pollutants *p*, and all input fuels *f*, of the various costs incurred, namely: annualized investments, annual operating costs (including fixed and variable technology costs, fuel delivery costs, costs of extracting and importing energy carriers), minus revenue from exported energy carriers, plus taxes on emissions, plus cost of demand losses.

Input data and assumptions

There are multiple sources of data for the consumption of fuel wood biomass in Macedonia. In this section a detailed review of all the data sources is given, in order to define the assumptions and the projections for the consumption of biomass, while observing its sustainability.

The first official data source on the consumption of biomass used for energy purposes is the energy balance of the State Statistical Office [24]. According to it, the consumption of biomass in Macedonia ranges from 580,000 to 780,000 m^3, except in 2007 and 2013 when it was about 535,000 m^3 and 561,000 m^3, which is mostly due to the relatively warm heating seasons and the habit of people to buy firewood at the last moment (fig. 6). 90-93% of the biomass is used in the household sector and therefore attention will mainly be directed towards this sector.

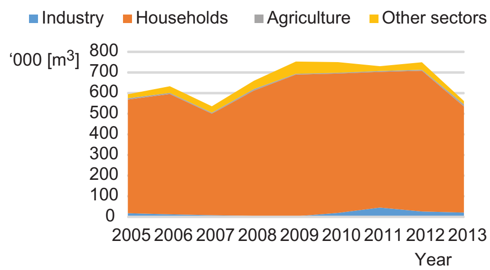

Figure 6. Biomass consumption for energy purposes for the period from 2005 to 2013 according to the SSO energy balance

The second data source is the budget survey that is also conducted by the State Statistical Office [21], but according to which the amount of biomass consumed in households does not correspond to that of the energy balance. The average consumption of firewood in the households in the period from 2009 to 2013 varies and ranges from 2.8 to 5 m^3 per household, which multiplied by the number of households in Macedonia leads to the fact that the biomass consumption in households in Macedonia is from 1.5 million m^3, up to 2.7 million m^3 (as presented in tab. 4). Compared with the data presented in the energy balance it is 2 to 4 times larger.

Table 4. Input data

		2009	2010	2011	2012	2013
Budget survey by State Statistical Office (SSO)	Estimated number of households	539,327	543,426	547,650	553,415	555,266
	Solid fuel cooker [%]		72.4	70.8	69	67.6
	Solid fuel stoves [%]		22.8	23.6	30.4	30.2
	Firewood [m^3]	5	2.9	2.8	2.7	3.6
	Total firewood consumption [m^3]	2,696,635	1,575,935	1,533,420	1,494,221	1,998,958
Energy balance from SSO	Total firewood consumption in households [m^3]	686,980	675,128	657,254	681,980	513,707

The next data source that is used to determine the consumption of biomass in Macedonia is the survey conducted by CRES for the Energy community [18, 19] and upon which the target for Macedonia's participation in renewable energy in 2020 has been changed from 21% to 28%. According to this survey, the consumption of biomass in Macedonia for the heating seasons 2009-2010 and 2010-2011 was similar, and it was approximately 2.4 million m^3, which is several times greater than the consumption in the SSO energy balance. In order to make a comparison between these three sources of data, it is needed to compare the data for 2009, 2010, and 2011, with data from CRES. The data from the SSO budget survey and the data from CRES survey are similar, and are equal to 1.94 million m^3 and 2.43 million m^3, respectively, in the period 2009-2011, while the consumption by the SSO energy balance is 0.67 million m^3 (as shown in tab. 5).

Table 5. Comparison on the average annual consumption of fuel biomass for the period 2009-2011

2009-2011 different sources	Energy balance	SSO budget survey	CRES
m^3	673,121	1,935,330	2,429,872
Ktoe	171	241*	303

* Calculated using the calorific value of biomass used in the CRES study.

If the consumption of biomass expressed in m^3 is important, in order to be able to determine the sustainability of forests, then the biomass consumption expressed in Ktoe is important in order to be able to determine the energy gain from it. In order to determine the biomass consumption in Ktoe, the calorific value of it is needed. As there are various data regarding the consumption of biomass, there are also different data for its calorific value. According to the SSO the calorific value of the biomass is about 10 GJ/m^3, while according CRES depending of the type of biomass it ranges from 3.5 GJ/m^3 to 6.17 GJ/m^3. Thus, according to the SSO energy balance, the average consumption of the fuel biomass expressed in Ktoe in the period 2009-2011 was 171 Ktoe, and according to CRES it was 303 Ktoe (tab. 5).

There are three different sources of data, and therefore the further analysis will process only the data from the SSO energy balance and CRES survey as the lowest and highest variant.

In order to determine the needs of energy in the households, the MARKAL model was used, by including the following input data:
(1) the rate of GDP growth,
(2) the number of inhabitants,
(3) the number of dwellings,
(4) the average number of people per dwelling,
(5) the number of newly built apartments,
(6) the number of apartments that will undergo renovation, and
(7) heating degree days.

Using this input data and the data for consumption of biomass in the energy balance, it is obtained that in 2012 the useful energy is 480 Ktoe, and in 2035 it is projected at 810 Ktoe (as shown in fig. 7). However, if the data from CRES for biomass are used, it is obtained that in 2012 the useful energy is 570 Ktoe, and in 2035 it is projected to be 950 Ktoe. As a result of the difference in the useful energy consumption in 2012, which is 90 Ktoe, the gap between the useful energy in both cases is steadily increasing, so in 2035 it is 135 Ktoe.

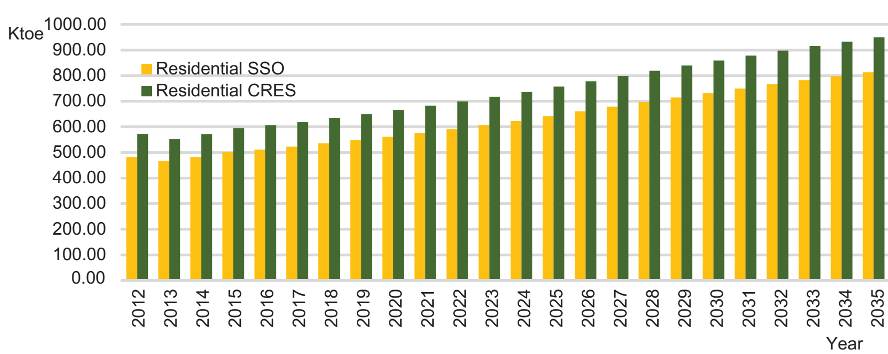

Figure 7. Useful energy in residential sector

In order to determine by how much the consumption of biomass may be increased, while remaining sustainable, it is necessary to know the annual forest growth. In this case also, there is no single data, so different sources state that the annual growth of the forests is estimated to be in the range of 1.6 to 1.85 million m^3 [16, 23, 34, 35]. According to the current practice [35], about 65-70% of this growth is allowed for cut, while the planned cut is 60-70% of the allowed cut. Finally, 80% to 90% of the planned cut is realized. To maintain the sustainability of forests and forest growth, and also to maximally use the biomass, in this paper an increase of 40% compared to the biomass that is registered in the energy balance is projected, which means that over 90% of the allowed cut will be realized.

Regarding the biomass evidenced by CRES of 2.4 million m^3, there is no room for an increase, because it is already more than the natural growth of forests. Here it is important to emphasize that during the budget survey some people reported using biomass from own production (residue from agriculture) which means that this biomass should be excluded from the forests. So, according to CRES the biomass consumption is at the upper limit of sustainability. In the period until 2035, an increase in the biomass of 10% is envisioned, which does not mean an increase in deforestation, but it means regular artificial afforestation, planting of fast growing trees, greater utilization of waste biomass and reduction of losses.

If we use the data from CRES for calculating the CO_2-eq emissions from forestry, then the results will be a little positive. But, assuming that some amount of the biomass reported from CRES is from own production (not from forests) than the CO_2-eq emissions from the forestry will be around zero. This means that the forests are still at a sustainable level, but in that case Macedonia will not have sink.

Results

One of the few energy potential that Macedonia has is the biomass, which according to the analyses in the previous chapters is insufficiently explored, and there are various data on its consumption. Therefore it was necessary to make a number of analyses to assess the implications that biomass can have on final energy consumption, and accordingly the implications on the percentage of renewable energy sources. Therefore, a number of scenarios were created, and only the most important ones are presented in this paper.

Because there are different data on the consumption of biomass, we have decided to review the implications of biomass recorded in the energy balance and biomass recorded by the survey CRES, as the smallest and largest recorded consumption. To maintain consistency with the proposed strategy for energy development until 2035, in this paper baseline scenario (BASE) using both types of data and scenario with energy efficiency and renewable energy (EE + RNW) are designed. The development of scenarios is done using the MARKAL model for energy planning.

The baseline scenario and the scenario with EE and RNW using data from the energy balance are consistent with the same scenarios presented in the Strategy for Energy Development until 2035. According to these data, it is obtained that during the whole period of planning, the biomass increases by about 39% (tab. 6), which is the maximum allowed limit in order to preserve sustainability. Final energy consumption increases by 68% compared to 2012 and the average annual growth is 2.3%, while the average annual biomass growth is 1.4% (tab. 6). In the EE + RNW scenario the same rate of biomass increase (40%) is predicted, while the final energy consumption is growing at an average annual rate of 1.7% or throughout the whole period it is increased by 48%. In this (EE + RNW) scenario, usage of more efficient technologies for heating and cooking are predicted, but the biomass as one of the cheapest energy fuels dominates and therefore in this case it increases to 40%. On the other hand, the rise in the standard of people and the usage of more efficient technologies will only increase the space that is heated. For example, if previously 40 m^2 are heated, with the increase of the standard 60 m^2 will be heated, and the consumption of biomass in both cases will remain the same because the efficiency of the technologies will improve.

Table 6. Total final energy consumption and final energy consumption of biomass using the data from SSO

	Ktoe	2012	2015	2020	2025	2030	2035	P1	P2
BASE	Biomass	189	192	227	239	251	263	1.4%	39%
	Total	1826	1891	2162	2457	2778	3066	2.3%	68%
EE+RNW	Biomass	189	192	227	239	251	263	1.5%	40%
	Total	1826	1879	2069	2271	2503	2709	1.7%	48%

In the baseline scenario using the data from CRES, an increase of the biomass by about 9% is obtained (tab. 7), which is near of the maximum allowed limit of sustainability in this case. It is interesting to note that the final energy consumption increases by 63%, which is 5% lower compared to baseline scenario with SSO data, while in absolute values, the final energy in the baseline scenario with CRES data is about 130 Ktoe more. The rise in the final energy consumption is lower because there are no other energy sources and more efficient technologies are used, and therefore this scenario is more expensive compared to the baseline scenario with SSO data. Similar results are obtained in the EE + RNW scenario where the growth of final energy consumption is 45% or an average annual growth of 1.6%, while the overall biomass grows to about 9%.

Table 7. Total final energy consumption and final energy consumption of biomass using the data from CRES

	Ktoe	2012	2015	2020	2025	2030	2035	P1	P2
BASE	Biomass	331	331	350	354	356	359	0.4%	9%
	Total	1968	2018	2293	2595	2918	3200	2.1%	63%
EE+RNW	Biomass	331	303	337	353	356	360	0.4%	9%
	Total	1968	1995	2194	2411	2648	2855	1.6%	45%

Table 8. Electricity generation from biomass and biogas

	GWh	2012	2015	2020	2025	2030	2035
BASE	Biomass	0	0	20	30	40	50
	Biogas	0	7	49	49	119	119
EE+RNW	Biomass	0	0	25	40	50	60
	Biogas	0	7	56	84	84	154

In terms of production of electricity and heat from biomass and biogas, the difference of the data sources SSO and CRES makes no difference because it is a waste biomass and biomass from agriculture which is not a subject of analysis in the mentioned data sources. As a result, there is only one baseline and one scenario with EE and RNW presented in this paper. In the baseline scenario, the electricity production from biomass is increased from 20 GWh in 2020 to 50 GWh in 2035 (tab. 8). The electricity production from biogas has increased from 7 GWh in 2015 to

119 GWh in 2035. On the other hand, in the EE + RNW scenario the production of electricity from biomass has increased from 25 GWh in 2020 to 60 GWh in 2035, while the production from biogas from 7 GWh in 2015 to 154 GWh in 2035.

Table 9. Heat generation from CHP on biomass

	GWh	2012	2015	2020	2025	2030	2035
BASE	Biomass	0	0	34.9	52.3	69.7	87.1
EE+RNW	Biomass	0	0	43.6	69.7	87.1	104.5

It is planed that the power plants that produce electricity from biomass will also produce heat, which means that these plants will be CHP. According to the baseline scenario, in 2035 it is forecasted that the biomass CHP will produce 87 GWh heat and in the EE + RNW scenario 105 GWh (tab. 9).

Conclusion and recommendations

According to the analyses made in this paper it was concluded that there are many different sources of information about the biomass. Particularly, there is no single data about the consumption on biomass, annual forest gain and loss, annual growth of forests, the calorific value of the biomass, *etc*. Therefore, a great effort was made to analyze all the data, to distinguish those that are not accurate, and to define scenarios from the rest of the data. Accordingly, a number of scenarios were created, and an assessment of the implications that the biomass can have on the final energy consumption was made. In this paper, only the most important ones are presented: baseline scenario (BASE) and scenario with energy efficiency and renewable energy sources (EE + RNW). For both of these scenarios, the minimum (SSO) and the maximum (CRES) recorded consumption of biomass was analysed. The obtained results are the following:

- In the BASE scenario with SSO data, up to 2035 the biomass increases by about 39%, which is the maximum allowed limit in order to preserve sustainability, and on the other hand, to maximally utilize the biomass. The final energy consumption increases by 68% compared to 2012. In the EE+RNW scenario the same rate of biomass increase is predicted, while the final energy consumption is increased by 48%. In this scenario, usage of more efficient technologies for heating and cooking are predicted, but the biomass as one of the cheapest energy fuels dominates and that is why it increases to 39%.
- In the baseline scenario using the data from CRES, an increase of the biomass by about 9% is obtained, which is the maximum allowed limit of sustainability in this case. The final energy consumption increases by 63%. The rise in the final energy consumption is lower compared to the BASE scenario with SSO data because there are no other energy sources and more efficient technologies are used, and therefore this scenario is more expensive. Similar results are obtained in the EE + RNW scenario where the growth of final energy consumption is 45%, while the biomass grows to about 9%.

Additionally, in this paper the electricity and heat production from biomass and biogas in the analysed period are presented for both scenarios.

In order to achieve this and to maintain sustainability of the forests, regular artificial afforestation, planting of fast growing trees and greater use of waste biomass including the solid municipal waste is recommended, so that the annual growth of forests does not become less that 1.85 million m^3. Because, Macedonia is a country with poor quality of forests compared to the other countries in EU, it is recommended also to put effort in increasing the percentage of high quality forests, compared to shrublands and disturbed natural forests.

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