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Energy Autonomy in Small Islands in the Frame of Their Sustainable Development Exploring Biomass Energy Potential in Samothrace (Greece)

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Abstract: One of the major problems faced by small islands in the Aegean Sea, is meeting their energy needs and the increased costs these needs generate because of their distance from the mainland and the increasing price of oil. To the above, the dramatic reduction of fossil fuels and climate change should be added, which obligate Member States of the European Union to comply with Directive 2009/28 / EC, which aims at a contribution of RES of 20% (Greece 18%) in the total EU energy consumption. It is therefore desirable to explore the energy autonomy capabilities offered in each case. This paper explores the possibility of utilizing biomass and in addition the use of livestock and poultry waste for biogas production.

Keywords: Utilization of Biomass, Biogas, Small Islands

1. Introduction

Sustainable development has become a primary objective of strategic planning at a global, national, regional and local level. Sustainability, inspired by the rational management of forests since the late 19th century, is today leading the effort to achieve balance between economic growth and environmental protection. But, environmental and economic problems influence each other and are linked by social factors such as unemployment, poverty, social exclusion and ultimately social welfare.

Cornerstone of sustainable development is the rational management of natural resources, in a manner that, according to Brutland report, the ability of future generations to meet their needs is not undermined (Our Common Future, 1987). Therefore, the need for the conservation of the renewability of renewable resources and the conservation / non-exhaustion of the non-renewable ones becomes clear.

In Chapter 17 of Agenda 21, adopted at the Rio Conference, it is written that “islands are spatial units, of particular interest from both an environment and a development point of view; they are very fragile and vulnerable and in the context of sustainable development, energy is the cornerstone of their planning strategies”. In the final document of the First European Conference on Sustainable Island Development, it is stated that: "Non-renewable energy sources must be considered as provisional solutions, unsuitable as a long-term solution to the energy problem in islands". [1]

Biomass, the wind, solar power, water power and geothermal potential are the renewable energy sources that can provide sustainable energy services, which rely on the use of domestic resources. [2].

In this study, the potential of biomass utilization for energy purposes is being examined, on a Greek island. Last decades, mainly the oil importing countries make efforts for the sustainable exploitation of biomass (wood residues, crop residues, fruit residues etc.) in order to substitute the use of oil [3]. Also, the Action Plan for the biomass produced by the European Commission, promotes the increase of the energy production from wood, waste and agricultural crops [4].

Bioenergy is considered (for many regions of the European Union) as a considerable factor of sustainable development due to the established forest plantations and the agricultural energy crops [4].

2. Biomass

Biomass comes from products or waste from various human activities and is divided into four categories according to Easterly and Burnham [5]:

a) energy crops, b) wood chips, c) agricultural residues, d) solid municipal waste.

a) Energy crops are cultivated species, traditional or new, which produce biomass for energy use, i.e. heat and electricity production, production of liquid biofuels etc. For the successful development of an energy crop in a region, certain conditions must be met, according to Venturi and Venturi [6], such as: appropriateness of soil and climatic conditions, ease of insertion of an energy crop in existing crop, continuous and uniform performance in terms of quality and the quantity, competitive income in comparison to traditional crops, positive energy balance resulting from production and consumption, cultivation techniques in harmony with sustainable development, resistance to major biotic and abiotic adversities, availability of biomass sources, such as seeds, appropriate roots for the region, necessary machinery particularly for harvesting operations, specific for the given crop, which can be used in other crops, with small changes.

Energy crops that have been investigated over the last fifteen years in Greece by the Centre for Renewable Energy Sources for the production of solid biofuels are: Reed, Cardoon, Switchgrass and Miscanthus (Perennial), Kenaf, Fibrus Sorghum (Annual), Eucalyptus and Black locust (Forest plantations) (see Table 1).

Table 1. *Energy produced by dry biomass, output in product and energy. Source: Centre for Renewable Energy Sources [7].*

type	product	heat energy (μj/kg)	average yield in dry biomass (t/ha/year)	yield in energy (gj/ ha/year)
Perennial crops	Reed	18,0	1,0 – 2,0	18,0 – 36,0
	Cardoon	18,0	1,0 – 1,5	18,0 – 27,0
	Switchgrass	16,0	1,0 – 2,0	18,0 – 36,0
	Miscanthus	18,0	1,0 – 1,5	18,0 – 27,0
Annual crops	Kenaf	18,6	0,8 – 1,8	14,9 – 33,4
	Cellulosic Sorghum	16,0	2,0 – 3,5	36,0 - 63,0
Forest crops	Eucalyptus	19,4	1,8 – 3,0	31,8 – 58,0
	Black locust	17,8	0,8 – 1,3	14,3 – 23,2

A wide range of energy crops has been tested in Europe as biomass crops in the last two decades in small or large scale trials in order to test the adaptability, performance and quality characteristics under different soil and climatic conditions. Energy crops were grouped according to their end use, in oil seed crops for biodiesel production, sugar and starch crops for the production of bio-ethanol and cellulosic plants, and woody crops for heat and electricity production. Some of these cultivations can produce more than one product, such as cardoon or hemp, which can be used for producing oil and solid biomass, and grains, which can be used for the production of bioethanol and solid biomass.

The choice of the crop in each region depends on its suitability in various climatic constraints (rainfall, maximum and minimum temperature of air and soil), access to irrigation water, if necessary, and soil conditions (quality of arable land). An important parameter to consider is the acceptance of the farmers, especially in the case of perennial crops, which have a lifespan of at least 15 years.

According to Alexopoulou and Skretschmer [8], a series of fifteen promising energy crops were distinguished according to the final products or the produced energy in crops for biodiesel production, fiber crops, crops for bioethanol and ligno-cellulosic crops.

In the northern parts of the Mediterranean, mainly in the mountains, poplar crops, miscanthus, reed, corn, sunflower, sorghum, flax, sugar beet, soybean, rapeseed and kenaf crops are favored, while in the southern parts of the Mediterranean, and not so mountainous, it is more common to cultivate reed, cardoon, eucalyptus, sorghum and flax.

b) Wood chips mainly originate from industries and forests. Large quantities of wood residues come from the wood industry and / or its products, such as paper mills, sawmills and furniture manufacturing plants. While wood industries use their waste to produce energy, there is a significant amount of residue left over. In forests, there is also available biomass usable for energy purposes. Logging residues such as barks, branches, leaves and needles of coniferous trees remain on the forest ground as well as trees that have been removed during the creation of firebreaks

c) Agricultural residues can be categorized into plant and animal origin. Agricultural residues of plant origin are essentially residues remaining in the field after harvest, such as leaves, stems, fruits, twigs and food wastes, and they can be used locally or in regional biomass power plants. Residues of animal origin include waste from poultry farms, dairy farms, pig farms and slaughterhouses, as well as animal faeces,

d) Municipal waste represent a significant source of biofuels. Municipal waste include solid municipal waste and sewage. Municipal solid wastes include domestic, craft, and commercial waste, waste water as well as sanitation wastes etc. The values of density and moisture contained in the various types of waste vary depending on the country, the time of year and the region, and are critical features regarding their burning.

Biomass Energy

Biomass can be used to meet energy needs (heat, electricity) either by direct combustion, or through the production of solid, liquid and gaseous biofuels using thermochemical or biochemical methods. Since the utilization of biomass usually experiences problems regarding its large dispersal, high volume, and collection - transport - storage difficulties, it must be exploited as close as possible to the place of production. Thus, it can have many applications, according to the Center for Renewable Energy Sources [7]:

1. Cogeneration of electricity - heat to cover the needs in agricultural and other industries. I.e., through the combined production of heat and electricity, from the same source, most of the energy is recovered and profitably used. Thus, considerable energy saving is achieved, the degree of energy conversion of the fuel is increased and pollutant emissions get reduced. Indeed, conventional power plants have an efficiency of 15-40%, while that efficiency reaches up to 75-85% in co-generation systems.

2. Teleheating of residential areas, meaning safeguard of hot water for both space heating and for its direct use in a set of buildings, a settlement, a village or a city, originating from a central heat plant. The generated heat is transported by a pipeline network from the station to the heated buildings. Teleheating is growing strongly in many countries, as it presents significant advantages such as a higher degree of efficiency, reduction of pollution of the environment and the possibility of using non-conventional fuels, thus resulting in additional economic and environmental benefits.

3. Heating greenhouses. The utilization of biomass in heat production units to heat greenhouses constitutes an interesting and economical perspective for their owners. Already, in about 10% of the total area of heated greenhouses in the country, various types of biomass are utilized.

4. Biofuel production. Under Directive 2003/30 / EC, "Biofuels are liquid or gaseous fuel for transport, produced from biomass". Through anaerobic digestion of biomass, biogas is produced, which consists mainly of methane and carbon dioxide and can be used to generate heat and / or electricity. Biogas production is typically encountered on pig and poultry farms, dairy farms, as well as municipal waste landfill sites. Generally, 20 to 50% of municipal solid waste originates from urban fruit and vegetable residues [9]. Cow and pig manure, produced in villages around the cities, are included in the municipal solid waste, which is a raw biomass material. The organic matter of this biomass is converted into biogas through anaerobic digestion. Also, through the fermentation of biomass bioethanol is produced, which can be used as fuel in the transport sector. Through the process of the fast pyrolysis, bio-oil, a high energy density liquid biofuel, can be quickly produced, which can be used as an oil substitute in heating applications and in internal combustion engines for power generation.

5. Energy crops. The lingo-cellulosic type of biomass, derived mainly from forest energy crops, is exploited for the production of solid biofuel in the form of pellets or briquettes, producing heat and / or electricity, through their direct burning. Apart from solid biofuels, derived primarily from wood chips, there are plants that contain sugar (eg sugar beet) or starch crops (eg maize), which are primarily suitable for the producing of bioethanol, and sunflower and rapeseed for biodiesel production. Biodiesel presents no technical barriers and could be used as an additive to conventional diesel. More specifically, it can be blended with diesel fuel at a rate of volume up to 5% according to the EN 590: 2004 standard. Recently, research programs have been focusing on different engines (truck engines, etc.) on which the use of blends of biodiesel / diesel, ranging from 2% to 98% with the use of certain additives, has been tested [10].

First-generation biofuels (biodiesel, bioethanol, biogas), seem to occupy and create some concerns to the scientists. Their main disadvantage is the confrontation "food or biofuels?" that has begun, as well as the increase in food prices, allegedly due to the increased production of these biofuels [11]. These biofuels have been the subject of many lifecycle analyzes focusing on energy and the balance of greenhouse gases. Although reduction in the production of greenhouse gases has been achieved, greenhouse gas emissions from land use change are not considered. Recent studies show that the benefits of reducing greenhouse gas emissions locally can be offset by increased emissions elsewhere due to the intensification and deforestation [12].

Second-generation biofuels are not produced from products that can be used as food, but from lingo-cellulosic biomass, i.e. from wood biomass. These are advanced biofuels, since they are produced from plants that exist in abundance in nature, are not edible, and their production is in a pilot phase. [11]. According to Lakaniemi et al. [13], algae are the next generation of biofuels. They are photosynthetic microorganisms, which convert sunlight, water and carbon dioxide into lipids. They have high growth rates and tolerance to adverse environmental conditions. They survive and grow in low water and seawater quality. The last characteristic makes them useful in wastewater treatment plants. Their development requires smaller amounts of water than conventional agricultural crops, thus, saving water and not requiring the addition of pesticides or herbicides. Algae do not bring about changes in land use, since they can be grown in brackish water in non-arable land and thus not endanger food production, livestock and other products deriving from land crops. According to Piccolo [14], countries with a coastline on the Mediterranean between 45° and 30° north, are suitable for growing microalgae and particularly countries in the Northern Mediterranean, where temperatures throughout the year do not fall much below 15 ° C. In these areas, the growth of algae in a system of open or closed ponds is favored. According to the above, but also

Singh and Gu [15], a number of countries of the Mediterranean basin, like Israel, have great potential for microalgae cultivation.

3. Research Area

Samothrace is an island in the northeastern Aegean. Its surface is 178 km2, while the highest peak has an altitude of 1.611 m. It is the highest Greek island with the exception of the two large islands of Crete and Euboea. Its permanent population, according to the 2011 census, is 2,859 inhabitants, while the economy of Samothrace is based mainly on the tertiary sector (tourism) and the primary sector (44,73% of the working population). The main physical characteristic of the island is the steepness of the slopes of the mountain Saos. The image presented by the landscapes of the north-northeast and south-southwest of Samothrace is very different, as if they were two different islands. In the first case, the green slopes of Mt Saos, with oak forests mainly (Quercus frainetto, Q. pubescens and Q. dalechampuii), fruit crops, dense scrubland and the extremely impressive waterfalls of the streams that flow into the sea dominate. The dominant species of the riparian vegetation is oriental plane (Platanus orientalis). In the second, the landscape is hilly with sparse scrubland, farmland and olive groves, typical image of a North Aegean Sea island. The key environmental problems faced by the island are erosion due to overgrazing (more than 50 thousand sheep), given the strong slopes and torrential phenomena, a risk that exists throughout the Mediterranean [16], as well as inadequate waste management which leads either to pollution of streams, aquifers and seas from uncontrolled dropping, or excessive costs due to transport them off the island.

3.1. History of use: Energy Production in Samothrace

Before 2000, energy in Samothrace was produced in an engine room operating with oil. In 2000 Samothrace was connected to two underwater cables, 10MW of power each, with the mainland. The daily power in the winter months is approximately 2MW, while in the summer months, when maximum demand is observed, it reaches 4MW. Water heating takes place, in several cases, with the use of solar water heaters, while heating of premises, mainly, with the use of oil and, less often, of wood. In 1984, oil tanks were manufactured outside of the main town of the island (Chora). They are private and serve the island's needs for oil. The pipeline that comes from the sea passes close by houses, which increases the need for maintenance, to avoid the risk of leakage. In 1992, they built four small, 55KWh power, wind turbines on the north coast of the island, however, the Public Power Corporation dismantled them. The initial design for their replacement by turbines of more power (900 KW) through reintegration into REPOWERIN program did not materialize, whereas, during the decade from 2000 to 2010, many new applications were filed regarding the creation of new wind parks, which were not materialized.

The island, being close to the mainland, is interconnected to the continental electric network, importing all required electricity via underwater cable. Also, large amounts of fossil fuels are imported to the island via maritime transport to meet, mainly, demands in transport and heating. In this way, it becomes apparent that the island relies entirely on imported energy.

According to the Sustainable Islands Network "Daphne" [17], the distribution of primary energy demand per energy carrier for Samothrace is formed as shown in the diagram below.

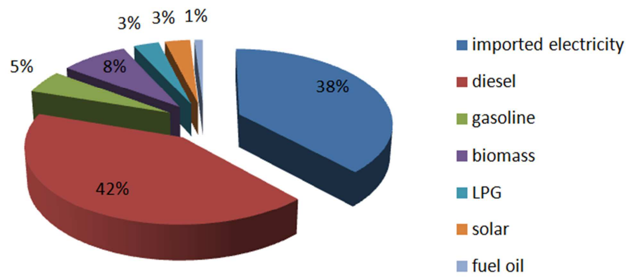

Figure 1. *Distribution of primary energy demand per energy carrier in Samothrace, Source: [17].*

According to the Network of Sustainable Islands "Daphne" [17], the final energy demand in the residential sector in the base year 2005 for Samothrace is apportioned according the following table:

Table 2. *Final residential sector energy demand in the base year 2005 [MWh], Source: [17].*

	Electricity	Diesel	LPG	Solar	Biomass	Total	Allocation of final energy demand in the domestic sector (%)
Residential sector	4.921	9.312	1.035	758	2.419	18.444	
Hot water	899	733	0	758	228	2.618	14.2
Heating and cooling	1.365	8.579	725	0	1.933	12.602	68.3
Lighting	738	0	0	0	0	738	4.0
Cooking	516	0	310	0	258	1.083	5.9
Refrigerators and freezers	724	0	0	0	0	724	3.9
Washers and dryers	44	0	0	0	0	44	0.2
Washing dishes	62	0	0	0	0	62	0.4
Televisions	57	0	0	0	0	57	0.3
Other electrical devices	516	0	0	0	0	516	2.8

The most common energy carriers in the domestic sector are electricity and oil, with the latter mainly covering space heating needs of homes. LPG is mainly used for heating and cooking, as well as biomass which mainly concerns the consumption of firewood which in most cases are burned in open fire-places. Finally, solar energy is used exclusively for the production of domestic hot water through solar water heaters. The heating and cooling sectors are the most energy consuming sectors followed by hot water production.

Since the heating and cooling sector accounts for 68.3% of the final energy demand in the residential sector in Samothrace and mainly comes from diesel, a solution is necessary in order to reduce the consumption of diesel fuel and therefore emissions associated therewith.

In the primary sector, which reflects the agricultural and fishing activities of the island, the most used energy carriers are electricity, oil and biomass, covering for the most energy needs for irrigation, heating and cooling, lighting and the use of various equipment features. In the secondary sector, the subsectors of manufacturing and construction are the most energy consuming, and to cover the final energy demand electricity oil and fuel oil are used, while, in the tertiary sector, the most used energy carriers are electricity and oil. LPG and biomass (in the form of coal) are used mainly in restaurants for cooking, while solar energy is used only to meet the demand for hot water by hotels. Finally, in the transport sector, final energy demand is divided as follows: 59% gasoline and 41% diesel. The distribution of the final energy demand into individual subsectors is as follows: 62% private use transports, 35% road freight transport and removal services, 1% passenger road transports (means of public transport, taxi, tourism, etc.) and 2% for other public and private services [17].

Energy problems currently faced by all Greek islands are focusing on the following, according to the Energy Office Aegean [18]

- They have great energy dependence on oil and a high cost of conventional power generation
- They present a serious commercial power supply problem and an incapable of base charge due to the lack of large industrial units
- They present high rates of growth in energy demand per year and large seasonal fluctuations in charge demand, mainly due to increased residential development and growth of tourism

3.2. Biomass Potential in Samothrace

The largest part of the island is occupied by rangelands. Maquis vegetation, transitional shruby vegetation, broadleaf forests and conifer forests then follow.

According to information received from the Greek Statistical Authority [19], the main crops of the island (year 2008) are as follows:

Table 3. *Area of tree crops, arable crops and vines in Samothraki [19].*

Crop Type	Surface in Ha
Tree Crops	
Olive trees for edible olives	400
Olive trees for olive oil extraction	500
Pear trees, apple trees, peach trees, cherry trees, fig trees, almond trees, walnut trees	20
Total tree crops	920
Arable Crops	
large crop plants and other crops	1645.8
Horticultural land, greenhouses, commercial flower gardens, seedbeds	37.2
Fallow lands for 1-5 years	16.0
Land, maintained in good agricultural and ENV. condition	163.4
Total arable crops	1862.4
Total Crops	
Total arable crops	1862.4 (66.64% of total crops)
Tree crops	920.0 (32.92% of total crops)
Vines, Raisinvines	12.2 (0.4% of total crops)
Total crops	2794.6

From the above table, it is concluded that 98% of tree crops are olive trees, covering an area of 9,000 Ha. Also, 88% of arable land is covered by field crops (large crop plants), such as wheat, barley, maize, fodder peas, vetch hay, perennial clover etc. These plants are used as animal feed, which are of great demand in Samothrace. The percentage distribution of crops is shown in the following figures.

Regarding available forest biomass that can be used to generate heat energy, the Greek Statistical Authority [19] gathered data on the annual production of firewood, collected in agricultural lands from 2000 to 2008. To calculate the power of the thermal energy power plant, its average value will be used for the years 2000-2008.

Table 4. *Annual production in tones, of firewood collected in farmlands in Samothrace, from 2000 to 2008.*

YEAR	2000	2001	2002	2003	2004	2005	2006	2007	2008
Annual production of firewood in tones	700	500	450	500	450	500	480	400	350

It should be noted that the Department of Crop and Animal Production of the Directorate of Rural Economy and Veterinary Medicine of the District of Evros was not able to provide data on the residues of plant origin, partly because the quantities of plant origin residues are within very extended limits, because a large portion of grain land is grazed without being harvested in the known manner of harvesting (combine harvester) due to the large number of animals present on the island and the high demand in animal feed, on the other hand very strong winds are blowing on the island, thus, luring straw stays that have remained in the field after harvesting. Approximately, according the above mentioned Department, the residues of intensive cereal crop are about 1400-1800 kgr / Ha) with a humidity of a class of 5%. The total area of cereal crops was in 2008, 526.4 Hectares, thus the residues are ranging from 736.960 to 947.520 kgr with humidity of a class of 5%.

Additionally, the Forest Authority of Alexandroupoli was unable to provide data on the forest biomass of Samothrace, because there are no forest plantations, no forests management and there were no new firebreak zones opened after 2000.

Finally, the Greek Statistical Authority [19], gathered data on the number of animals in livestock and poultry farms in the region.

Table 5. *Number of livestock animals in Samothrace.*

Animal group	Animal NO.s
pigs	1143
Sheep / goats	51900
poultry	8500
horses	92
TOTAL	61635

3.3. Utilization of Firewood from Farmland to Produce Thermal Energy

3.3.1. Methodology

To calculate the heat content of firewood harvested from agricultural land, the average annual production of firewood from 2000 to date should initially be calculated [20]. The heat content of firewood in kWh can be calculated by the formula:

$$Eth = Mn * C_p$$

where

Mn = the average annual production of firewood from 2000 to date

Cp = the calorific value of firewood, taken equal to: 3,833 kWh / kg, according to Katsoulakos and Kaliampakos [21].

The strength of the combustion plant of firewood harvested from the farmlands will also be calculated. This unit will aim to produce thermal energy for district heating of the Chora (town) of Samothrace and other neighboring regions, under certain conditions. To calculate the power of a combustion plant for the production of thermal energy, the available amount of firewood per hour (DP) in tones or kilograms should be calculated as follows:

DP = Mn / (328 days per year * 24 hours a day)

Admission: The unit will operate 328 days a year. We consider that 10% of the year, i.e. 37 days, the plant will remain closed for maintenance purposes [20], and will also operate 24 hours a day.

According to Poulis [20], for the operation of a 1MW combustion plant 240 kg of wood per hour would be required. Therefore, the power of the unit in MW which can be constructed to exploit the available hourly production of firewood can be calculated using the formula:

$$P = DP / 240$$

3.3.2. Results

From the data available [19], the average annual production of firewood, for the years 2000 – 2008, was estimated at 481.11 tones. Thus, the heat content of firewood is estimated at 480.000 * 3,833 = 1.839.840 KWh = 1.839,84 MWh. The available quantity of firewood per hour is 61 kg. Therefore, the unit that can be constructed to exploit the 480 tons per year lies in the class of 0.25 MW.

This unit, although of small capacity, is not intended to fully cover the energy requirements for heating of the whole island, but only those of the Chora and Kamariotissa, which is situated just 5 kilometers from the country. Moreover, between these two cities resides 60% of the entire population of the island. Note that the combustion unit can work complementary throughout the year in combination with the use of fossil fuels, offering savings in their use.

3.4. Utilization of Grain Residues for Heat Production

3.4.1. Methodology

The amounts of residues of plant origin, according to an official answer received by ELSTAT, fluctuate around 140-180 kgr with a humidity of 5%. Thus, 736960-947520 pounds with a humidity of 5%. For safer results the lower price will be used. According to Papazoglou and Kyritsis [22], the calorific value of grains is 17,891 MJ / ton of dry weight. The concept of an availability factor is introduced to the calculations of the available energy from cereal residues, which is the percentage of the potential of biomass that is energetically exploitable. According to Tzinevrakis et al. [23], its value depends on various factors such as ease of collection of biomass (whether there is a great dispersion, gathering in inaccessible places) and its alternative uses (eg for food). The value obtained is 0.35 with a variation of 20%. Given the dispersion of waste due to strong winds and their use as animal feed, we will take the minimum value, ie 0.28. Therefore:

Thermal Energy = Quantity of grain residues * dry weight percentage * availability factor *

Calorific grain strength

3.4.2. Results

The total energy that can be produced from burning cereal residues is 736.960 tones * 95% * 0.28 * 17891MJ / ton of dry weight = 3,507.197MJ = 974,221KWh = 974.221MWh. This energy is relatively small to be used on an industrial scale, but could cover the energy needs of small family livestock and poultry farms or even the thermal needs of the greenhouse of Samothrace.

3.5. Utilization of Livestock and Poultry Waste for Biogas Production

3.5.1. Methodology

The production of biogas depends on the organic solid content of the raw material, but a good approximation is the content of the livestock waste in dry solids [24]..

The estimated amount of biogas in m3 that can be produced from the available livestock waste is given by the following equation:

$$BP = POP * DS * BY * AF,$$

where

POP is the number of animals per group

DS is the annual quantity in tons of dry solid per animal of each group

BY the biogas yield per animal of each group in m3 / dry tn.

AF is the availability factor (0 <AF <1) of each group of animals

The total amount of biogas estimated (LBP) for all groups of animals in m3 is the sum of the estimated amount of biogas in all groups.

The density of the estimated biogas in an area in m3 / Km2 can be calculated by the formula:

$$DBP = LBP / A$$

where A is the surface area in Km2

The estimated available energy in TJ originating from the estimated biogas is given by the fomula:

$$E = 21.6 * 10\text{-}6 * LBP$$

where 21.6 MJ / m3 is approximately the calorific value of biogas

The availability factor, according to Batzias et al. [24], was estimated depending on the conditions of production for each group of animals. Due to alternative uses of animal waste, biomass availability for biogas production may differ significantly between groups of animals.

3.5.2. Results

Data supplied by the Greek Statistical Authority for 2008 regarding the number of animals (domestic or otherwise) that exist in Samothrace, and according to the above methodology, lead to the table below:

Table 6. *Total animal waste, dry solids per animal group, availability factor, biogas yield per animal group, density of estimated biogas, and bioenergy in Samothrace.*

ANIMAL GROUP	Total manure in tons per animal per year	POP (no. animals per group)	DS (tn/ head)	AF	BY (m3/drytn)	BP (m3)	DBP (m3/Km2)	E (TJ)
Pigs	1,89	1143	0,216	0,8	649	128184,2		2,76878
Sheep/ Goats	0,64	51900	0,222	0,35	120	483915,6		10,45258
Poultry	0,034	8500	0,01	0,7	359	21360,5		0,461387
Horses	8,82	92	2,6	0,1	160	3827,2		0,082668
TOTAL						637287,5	3580,27	13,76541

Estimated available energy from the exploitation of livestock and poultry waste amounts to 13.76 TJ and estimated quantity of biogas to 637,287.5 m^3. Thus, the available energy amounts to 3,822.22 MWh. The produced biogas can be used in a district heating plant in order to meet the heating needs of the entire Samothrace.

4. Location of Energy Utilization Plants from Biomass or Biogas

Under the Special Framework for Spatial Planning and Sustainable Development for Renewable Energy Sources and restrictions imposed through that, Natura 2000 sites in Samothrace are incompatibility zones. Thus, the installation of a biomass power plant in them, will be excluded. However, in the rest of Samothrace the necessary investigations can be made in order to find a suitable location of such a unit, provided that the other criteria set by the Special Framework are met.

An Environmental Impact Assessment (EIA) is considered necessary in order to ensure the minimum, and if possible zero effect of the power plant on the ecosystem of Samothrace. The necessity of this study lies in the fact that part of Samothrace that does not belong to the network Natura 2000 (Figure 2), occupies a very small area which is located nearby the protected territory. The area occupied by the Natura 2000 network is 37,458 Ha (21,021 Ha Dir. 79/409/EEC and 16,434 Ha Dir. 92/43 EEC).

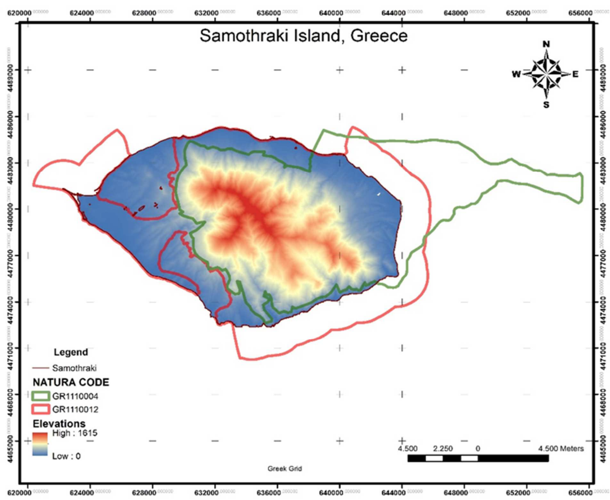

Figure 2. *Natura 2000 sites in Samothrace.*

5. Conclusions

Samothrace is an island of available bioenergy of 6,636.28 MWh, utilizing only the available firewood biomass, plant residues and livestock and poultry waste.

Calculations on the available energy content of firewood and produced biogas from livestock and poultry residues, lead to the following conclusions:

1. The total available energy from the burning of firewood and biogas is 3,822.22 + 1,839.84 = 5,662.06MWh. There are 2,859 inhabitants in Samothrace, therefore, 1.98 MWh correspond to each inhabitant. The annual final energy demand for heating from all energy consuming subsectors is 12,602 MWh, thus covering 45% of the annual final demand. This means that they can fully meet the need for heating the whole of the resident population of Samothrace for about 5 months.

2. Dividing the total available energy from the burning of firewood and biogas (5,662.06MWh) with the annual final energy demand for heating by diesel (8,579 MWh), it can be concluded that 66% of heating oil can be saved.

3. Taking into account that the lower calorific value of diesel is 10.70 KWh / l or 0.01070 MWh / l, according to the Centre for Renewable Energy, and the efficiency of a conventional oil boiler is 90%, it can be concluded that with 5,662.06 MWh, about 476,000 liters of oil can be saved, which, if burned would produce 1,266.160 kgr of CO2. (One liter of heating oil produces 2.66 kg of CO2). According to the Fuel Gas Prices Observatory of the Ministry of Development and Competitiveness, the average price for heating Diesel in October 2014 was 1.050 € / liter. So, the economic benefit of saving 476,000 liters of diesel is on average 499,800 €, ie about 700 € per household / year, a particularly important amount, given the financial crisis.

Bioenergy from grain residues is not available throughout the year, since the harvest of wheat is held in June and residues harvest is completed by July. Due to this seasonality, bioenergy can be used complementary during the summer months to meet the increased demand due to tourism. Also, the storage of grain residues for use in the time period October - March, would be more effective. During that period, the greenhouse and the mill of the island operate, whose thermal requirements could be met.

6. Suggestions

A turn towards biomass is necessary to produce cheap energy. If the use of available biomass is methodical and targeted, significant economic and environmental benefits can be yielded. Indeed Samothrace has outstanding prospects; however, these are not utilized extensively.

- The olive groves for oil production in Samothrace cover 54% of the total area of tree crops. That area of 5,000 acres is served by a mill with a capacity of 102.55 tons of oil produced annually. Unfortunately, there is no oil core plant on the island. An oil core plant could process the oil pomace of the olive mill and provide an energy-rich fuel, the olive pits, with a calorific value of 4,700 – 5,000 Kcal / Kgr. The utilization of olive pits could lead to realistic energy solutions for the island.
- The promotion of energy crops on the island will bring significant benefits not only to the farmers in the region, but generally throughout the local community. The penetration of energy crops on the domestic market can ensure adequate farm income compared to some conventional crops and enhance diversification of farmers' activities. Furthermore, the creation of a market for the production of biofuels, heat and electricity in the region, will contribute to the staying of the population in rural areas by creating new jobs and bringing additional income to the local community. And finally, the use of crops for energy reduces dependence on oil imports.
- Recycling of solid waste in conjunction with the installation of a landfill and the parallel biogas collection is proposed in the case of Samothrace, as, firstly, the quantity of waste would be reduced, and secondly, the energy potential of the island would increase. The problem of the management of solid waste on the island has not been solved as waste is transferred to the landfill of Alexandroupolis. Through proper public awareness and consensus about recycling, and a landfill establishment study on the island, in order not to affect protected ecosystems, there is an energy recovery potential from recyclable materials and produced from landfill biogas.
- The available forest biomass could increase if the authorities maintained firebreak zones in Samothrace. According to the Forestry of Alexandroupolis, there has been no opening of firebreaks since 2000. This is a troubling fact, since the maintenance of firebreaks is crucial in order to prevent the spread of fires and also, in the energy sector, forest biomass residues could be exploited for energy production. Note, also, that each year fires occur in Samothrace, which are strengthened by the strong winds that blow on the island.

The protection of the Natura 2000 network is an important criterion regarding the location of the biomass exploitation plant for energy production. Biodiversity conservation and the protection of flora and fauna should not be affected in any way by the installation of such a unit. EIAs are necessary, in order to ensure the balance of the ecosystems in the region.

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