

# INVESTIGATION STUDY FOR TECHNOLOGICAL APPLICATION OF ALTERNATIVE METHODS FOR THE ENERGY EXPLOITATION OF BIOMASS/AGRICULTURAL RESIDUES IN NORTHERN GREECE

by

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*Biomass energy potential is addressed to be the most promising among the renewable energy sources, due to its spread and availability worldwide. Apart from that, biomass has the unique advantage among the rest of renewable energy sources, to be able to provide solid, liquid, and gaseous fuels that can be stored, transported, and utilized, far away from the point of origin. For the northern region of Macedonia in Greece, biomass utilization is considered to be a major issue, due to the considerably intensive regional agricultural activities. Wood by-products, fruit cores, rice husk and cotton gin waste provide a promising energy source for the region. The energy potential of the available agricultural biomass produced in the region is much enough to cover the 10% of the annual oil consumption utilized for thermal applications. However, the cost of energy utilization of biomass is considerably high due to the high cost of the logistics concerning the collection, transport, and storage of biomass. The available utilization technologies developed, to handle efficiently all different species of biomass, cover a wide technological range. One of the most promising technologies involving thermal treatment of biomass and the production of a gaseous fuel (biogas) for industrial heat applications and electricity production, is the thermochemical conversion. In the present work, an investigation concerning biomass potential for energy production in the region of central Macedonia in Greece, utilizing several locally produced biomass species, is conducted. Emphasis is put on the energy utilization of agricultural by-products and residues. Agricultural sector is of great importance due to the considerably intensive agricultural activities in the region of Central Macedonia.*

Key words: *biomass, agricultural residues, thermal treatment, energy, Greece*

## Introduction

Fossil fuel depletion has resulted in the increased scientific and governmental concern towards the exploitation of renewable energy sources (RES) (including bio-

mass), the production and usage of biofuels, and the development of a global energy web to promote hydrogen. In an international level, interest towards the utilization of biofuels has been increased, due to the low cost of biomass, the relatively low sulfur content, and the biodegradability that easily achieved via thermal processes. Greece has sufficient biomass potential, adequate to cover a considerable part of the national energy needs [1]. Figure 1 indicates the main available, for energy production exploitation, agricultural residues in Greece [2]. Thousands of tones of agricultural by-products produced annually; and less than the half of them are utilized via combustion, in appropriate units imple-

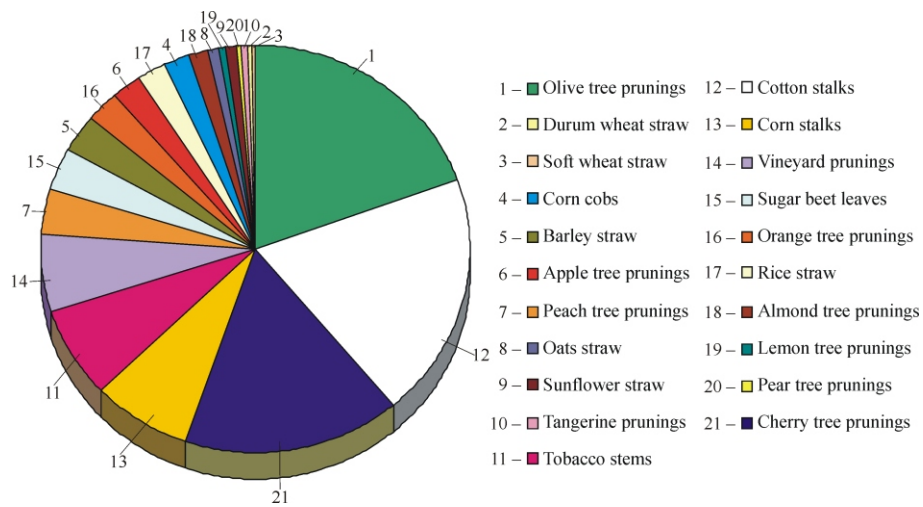


Figure 1. Availability of agricultural residues in Greece [1] (color image see on our web site)

mented in agro-industries to cover their energy needs [2]. The rest of them are dumped unutilized creating several environmental problems. Towards that direction, thermo-chemical conversion technologies of agricultural residues and by-products could contribute in producing energy, as well as bio-products with the consequent environmental, social and economical advantages. All agricultural residues can not be exploited through thermal treatment and – at a first approximation – the elemental composition could indicate the most suitable for energy production. Table 1 indicates the elemental composition of indigenous agricultural residues as potential solid fuels. The elemental analysis was performed in a CHN-LECO 800 analyser.

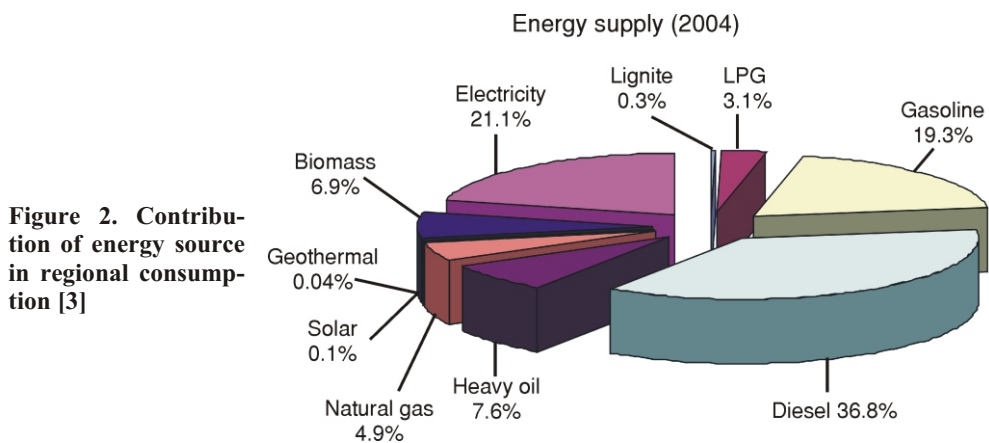
### Energy sources in Central Macedonia region

Energy sources utilized to cover the energy needs of the region of Central Macedonia is electricity, liquid fuels, natural gas, and in smaller degree liquefied petrol gas

**Table 1. Elemental composition of main agricultural residues in Greece**

Agricultural residue	Moisture [wt%]	C [wt%. dry]	H [wt%. dry]
Olive tree prunings	7.1	47.27	6.41
Cotton stalks	6	40.47	5.18
Durum wheat straw	40	44.84	6.23
Corn stalks	n. a.	43.8	6.42
Soft wheat straw	15	45.74	6.27
Vineyard prunings	40	44.98	5.87
Corn cobs	7.1	43.77	6.23
Orange tree prunings	40	43.50	5.95
Apple tree prunings	40	48.09	6.34
Rice straw	25	37.96	5.38
Peach tree prunings	40	43.67	5.38
Almond tree prunings	40	46.08	6.31
Lemond tree prunigs	40	44.01	6.15
Sunflower straw	40	42.43	5.9
Pear tree prunings	40	48.68	6.7
Cherry tree prunings	40	46.50	6.12
Tabacco stems	85	27.27	3.82
Apricot tree prunings	40	48.71	6.51

(LPG), biomass, geothermic, and lignite (for heating application). The contribution of each energy source [3] is depicted in fig. 2. Reference year of the presented data is 2006.



**Figure 2. Contribution of energy source in regional consumption [3]**

Liquid fuels' contribution is the highest (63.7%), with electricity following (21.1%). These data are consistent with the national energy consumption profile (liquid fuels 65% and electricity 23.5%) [3]. The consumption of gasoline, diesel, and crude-oil in Central Macedonia, reaches the 18, 23, and 32% of the national consumption, respectively [4]. Increased consumption of crude-oil for industrial applications has led to its augmented percentage. Diesel is mainly used in the domestic sector (39%) as well as in transportation (36.5%) [3]. The *per capita* consumption exceeds the national mean consumption for 33% due to the increased heating requirement, because of Central Macedonia's geographical position (northern Greece) [4]. Gasoline is exclusively used to meet transportation needs and the *per capita* consumption exceeds the national mean value for 15%. Concerning electricity utilization, Central Macedonia reaches the 18% of national use, while the *per capita* consumption exceeds the national average consumption for 5%. Industrial sector holds a significant part in regions' energy consumption, reaching 32% (compared to the 20% in national level). LPG is mainly used in the industrial sector (more than 50%), domestic and tertiary sector, and in a relatively small percentage in transportation sector (city cabs). Solar energy is utilized mainly in domestic applications (heating water 89%) and secondly in tertiary sector (mainly in hotel units). Wood is mainly used for space heating in domestic and tertiary sector in agricultural regions, as well as for the heating of greenhouses. For this purpose other energy sources are alternatively used like peach cores, lignite, peat, and low enthalpy geothermal energy. It should be noted that natural gas is not included in the previous analysis. It is estimated that natural gas has replaced, in a quite high degree, crude-oil and LPG in the industrial sector, and in a lower degree, diesel oil for space heating applications in domestic and tertiary sector [2, 3].

### Energy demand in each sector

Energy consumption profile by sector regarding the year 2006, is similar to the national, and to the European Union's profile, concerning transportation sector capturing the main part of 33% among the rest. Transportation sector appears to be in the first place, with gasoline being the most used fuel (58%), indicating the preference in using passenger cars as the major transportation mean. The *per capita* gasoline consumption in Thessaloniki, is much higher than the region's average consumption, while this does not happen with the per inhabitant number of cars, indicating the important role of Thessaloniki as a transportation harbor. Domestic sector holds the second largest percentage of consumption, in contradiction to the national energy profile, in which industry employs the second place. This fact reveals the necessity of increased domestic space heating, because of the rather cold climate in relation to the rest of the country. Space heating is responsible for the 75% and heating water for the 9% of the total domestic energy consumption. Industrial sector spends the 20% of the total energy consumed in the region of Central Macedonia. In tertiary sector only the 9% of the total energy is consumed, with diesel and electricity (concerning the year 1996) being the two dominant energy sources, (nowadays that natural gas is intruding with fast pace, considerable part of diesel has been replaced). 70% of tertiary sector's energy is consumed in the prefecture of

Thessaloniki. Slightly lower percentage of energy (7%) is spent in agriculture. Figure 3 presents the energy demand contribution by sector in Central Macedonia [4].

### Biomass potential

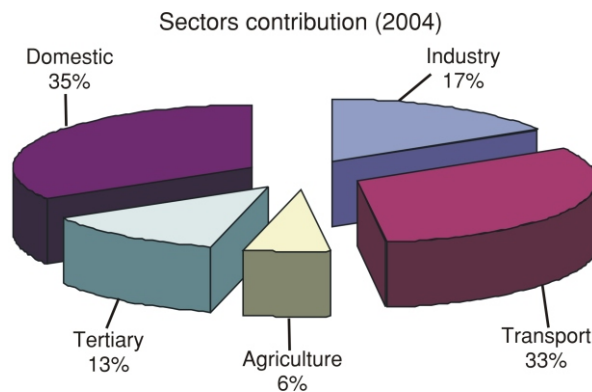
Forestry residues resulting from woodcutting and wood processing applications, residues resulting from the rarefaction of plantations and the tree lopping, comprise biomass. This material is of no commercial value and remains unutilized rotting onsite. Considerable amount of biomass residues are produced in wood processing units. Forestry residues can be utilized to generate steam for heating and/or electricity applications.

Agricultural waste like straw, rice husk, sugarcane, corn and soya residues as well as walnuts and kernels comprise an energy source with considerable potential. Significant quantities of the above-mentioned biomass species can be utilized to produce sufficient thermal power to meet the energy needs of small to medium size industrial units as well as for distant heating of buildings [1]. Bioethanol can be produced from biomass either by cultivations of amyllum based biomass species, like potatoes and corn, if hydrolyzed and convert amyllum to saccharate, or alternatively if corn cultivations undergo a biological or anaerobic process, converting contained saccharate to alcohol. The resulting bioethanol can be utilized in transportation either directly supplying modified internal combustion engines or blended with gasoline in a ratio bioethanol/gasoline equal to 20% without engine modifications [5].

A recently emerged biomass category of great potential is energy crops, including all plant species, cultivated in order to be used as a biomass source for the production of bio-fuels. Most important energy crops are sweet sorghum, fiber sorghum, rape plant, miscanthus, canes, coppice, and eucalyptus. Sweet sorghum is the most important energy crop in national level, since the produced bio-diesel quantity derived from a 1000 m<sup>2</sup> area reaches one tone [6].

### Agricultural and forest residues

Utilization of biomass is a major challenge for the region of Central Macedonia, due to regions' intensive agricultural production. The utilized biomass species are wood



**Figure 3. Energy demand contribution by sector in Central Macedonia [3, 4]**

residues, cores, rice husk, and cotton gin waste. The available energy potential deriving from agricultural biomass species is presented in tab. 2. It is obvious that the available biomass energy potential is enough to cover the 10% of the national annual oil consumption, used to meet thermal needs. However, the cost associated with the energy utilization of biomass can be high enough, due to the high cost concerning the necessary transportation and logistics. Concerning wood residues coming from both private and public forests, the annual production in the region of Central Macedonia reaches 374,000 m<sup>3</sup> [6].

**Table 2. Annual produced quantities and energy potential of biomass [6]**

Cultivation type	Total combustible matter [tons]	Calorific value [kJkg <sup>-1</sup> ]	Energy content of biomass [MJ]	Tons of oil equivalent (toe)
Cotton gin waste	32,760	14,700	481,572	11,469
Cotton shanks	281,019	17,640	4.957,175	118,028
Rice straw	64,000	12,180	779,520	18,560
Rice husk	25,600	12,180	311,808	7,424
Cornstalks	445,000	18,060	8.036,700	191,350
Peach tree lopes	152,460	18,900	2.881,494	68,607
Peach cores	29,400	14,700	432,180	10,290
Olive tree lopes	318,000	18,900	6.010,200	143,100
Total toe				568,828

### **Technological applications for the energetic exploitation of agricultural residues in northern Greece**

The exploitation of energy potential of Central Macedonia in northern Greece, through the use of innovative energy utilization processes is of great importance and is set as main target in policy decision making. The development of reliable and cost effective combustion technologies with innovative reduction of atmospheric pollutants, the development of small scale conversion units (<1 MW) using feed-stocks focus on self-running processes, the development of reliable and cost effective gasification systems for electricity generation, the cost effective production of biofuels for transport from various feedstock and energy crop resources and lately the exploration of routes to produce H<sub>2</sub>-rich clean syngas are the targets in this area set by EC and also by Greece.

Biomass energy conversion technologies cover a wide scientific and technological range [7], and the applicability of each method relies on each specific utilized biomass fuel, as well as on the desired end product [8-12]. They are divided in thermochemical processes (combustion, gasification, pyrolysis), suitable for biomass species with low moisture content and high carbon fraction, and biochemical processes (aerobic and anaerobic fermentation), which are suitable for biomass species with high moisture content.

The end product of each biomass utilization process could be thermal power for industrial applications, which is the most common way, as well as electricity production and co-generation of heat and electricity in distributed consumption systems. Thermal processing of organic waste materials can produce heat or a number of liquid or gaseous fuels. There are three main options for recovering energy from biomass by:

- (1) mass burn (combustion or direct incineration) of residues without pre-treatment,
- (2) production of more or less refined fuels out of the main waste stream via new pyrolysis or gasification techniques, and
- (3) development of new approaches involving the recovery of chemicals combined with gasification, pyrolysis, and hydrogenation and/or reforming of the gases and oils produced.

The advantage of thermo-chemical conversion technologies of agro-waste are decentralized energy conversion systems, which operate economically, even for small scale. The design of reactor depends upon type of fuel used and whether reactor is portable or stationary. The key to a successful design of gasifier/pyrolyser is to understand the properties and thermal behavior of the fuel as fed to the gasifier/pyrolyser. Operation of gasification/pyrolysis systems demand knowledgeable and skilled operator. But it is economical at many places and may lead to self-reliance in the crucial time of fuel crisis.

Biomass contains tremendous quantities of hydrogen, as do common waste products that end up in landfills. It is now possible to capture the methane produced from the decomposition of organic residue and use it to power turbines to generate electricity or to strip away the carbon to make pure hydrogen fuel. New technologies are combining the residual heat from fuel cells with turbines, resulting in some of the highest efficiencies ever measured.

A promising field that will be in the foreground of energy policies in the coming decades is the utilization of RES for the production of hydrogen. Hydrogen production can be achieved via the electrolysis of water, using electricity coming from RES. Wind power seems to be the most feasible among the rest of the RES. Hydrogen can be utilized either in conventional power production systems (direct combustion in internal combustion engines) or in innovative technology applications (utilization in fuel cells). The development of such pilot applications can result both in the exploitation of regions energy potential as well as in the cross border diffusion of technological know how.

### **Fostering the utilization of biomass**

Global energy use has grown 20-fold over the past century internationally. It is expected to increase 2% annually until 2020. This means a doubling of energy consumption by 2035. This means a tripling of energy consumption by 2055. The greatest increase is from transport, where 95% comes from petrol. Energy production/consumption has a serious negative impact to the environment [7].

National and international commitments to reduce CO<sub>2</sub>-emissions (Kyoto, Buenos Aires) will trigger the replacement of CO<sub>2</sub>-intensive technologies by renewable. The

utilization of biomass – if carried out in a sustainable way – is almost CO<sub>2</sub> neutral. Bioenergy is mainly an indigenous source and therefore reduces dependency on energy imports and increases security of supply. Bioenergy, like the other renewable sources, has an enormous potential of job creation, predominantly in agriculture and forestry and in small and medium sized enterprises. In this effort to reverse these negative trends, the EU has made a commitment to integrate environmental concerns into energy policy. The European Commission put forward a number of new initiatives to improve the integration of environmental care and to foster electricity and biofuels production from renewable sources.

The advantages of biomass (agricultural residues) utilization are the following:

- it provides an end use for low value/negative value products,
- it maintains existing market for coal,
- it increases domestic economic growth and job creation,
- increase economic activity in rural/agricultural areas, and
- it also increases business for equipment suppliers.

## Conclusions

RES utilization is a major issue in contemporary energy policies. Biomass and particularly agricultural residues have the potential to cover a significant part of Central Macedonia region's energy requirements contributing in a non energy dependant development. Only a minor part of regional agricultural energy potential is been utilized up to now and this via the application of combustion. The energy potential of Central Macedonia is sufficient to cover a significant part of energy needs which concern production procedures. The rational use and exploitation of biomass potential can lead to economically feasible solutions for regional agricultural industry. Based on present data, the perspectives regarding the successful implementation of pyrolysis and gasification of biomass residues for the production of biofuels or other material in national energy production sector are considerably promising.

## Acknowledgments

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