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Estimation of the Potential for Low Cost Solid Fuels of Selected Areas in Hungary and Greece

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The biomass inventories in selected geographical areas for both countries, Hungary and Greece are determined in this paper. Particular emphasis is given to low cost opportunity fuels. This type of fuels does not require biomass cultivation processes (fertilizer and irrigation) and consequently energy exploitation shows increased environmental benefits. Those fuels are frequently used to supplement fossil energy sources, such as coal and oil. They may be even used as the main fuel for specific boilers or kilns. This study refers to the European legislation which determines the framework for rational and environmentally friendly practices for wood waste management. It also refers to the wood waste classification systems and the currently applied methods of wood waste disposal and reuse. The available biomass potential is reflected for the selected areas of Hungary and Greece, on an annual basis in order to minimise problems of periodicity and to guarantee steady supply to the potential consumers.

1. Introduction

Energy consumption is as unevenly divided across various sectors of industrialised economies as it is across geographic regions. Electricity generation provides a critical example because of the significance of electrification in world economies. The energy-consumption patterns of electricity generation and the process industries show a significant potential for using opportunity fuels. The efficient employment of renewables, including solar and its dynamic availability has become a research and development priority (Manenti and Ravaghi-Ardebili, 2013). Economic trends such as electricity-generation deregulation and increased global competition in the production of basic goods provide significant incentive for the owners of production facilities to seek the maximum use of opportunity fuels because of their favourable influence on specific plant economics. Environmental trends — including stricter regulations regarding the formation and release of pollutants such as SO_2, and NO_x — also promote the use of opportunity fuels. Greenhouse gas emissions are also regulated by the EU and many countries and are the subject of voluntary programs in other countries. These forces the combination to increase the focus upon the unconventional energy resources available to electricity generators and industrial establishments (Tillman, 2004). Among opportunity fuels, wood waste is very promising option. Waste wood comes from a wide variety of sources, in varying quantities and levels of purity. The main three areas in which waste wood is generated are: Construction and Demolition (C&D), Municipal waste (MSW) (Fodor and Klemeš, 2011) and Commercial and Industrial waste (C&I) (Nemet et al, 2011). A feature of waste wood arising, particularly from C&D and MSW, is that both the quantity and sources are unpredictable and materials are often mixed with other types of waste. This paper aims to present the categories of waste suitable for energy generation and the motivations for its utilisation. and analyses the challenges for using waste and the thermochemical technologies for its conversion to energy.

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2. Alternative fuels

Alternative fuels can be defined as those combustible energy resources that are outside of the mainstream of conventional commercial fuels, but these can be used productively in the generation of electricity and/or the production of process and space heat in industrial and commercial applications (Roberts, 2011). Burgeoning interest in the use of alternative fuels to offset purchased traditional fossil fuels has focused on the combustion, material handling, and environmental permitting challenges associated with their exploitation. A number of industries have been taking advantage of opportunity fuels. Other industries are relative newcomers to the field. Some industry analysts have indicated the potential for as much as 100 GW of electricity generation from opportunity fuels associated with distributed generation facilities (Tidona, 2011). The relative scarcity of more recent studies – including for Greece and Hungary, motivates the current work to attempt characterisation of the opportunities in the mentioned countries. Most alternative fuels can be divided into two categories: biomass fuel and industrial process waste or byproducts. Biomass fuel can take on many different forms, but all of them are derived from the carbon-based materials contained in living organisms. There are six main types of solid biomass fuel: crop residues, farm waste, food processing waste, municipal solid waste, sludge waste, and wood/wood waste. (Resource Dynamics Corporation, 2004). All of these fuels can be processed and combusted in a boiler/steam turbine configuration, some more easily than others. Most of these potential fuels are in dry form, with the exception of farm waste, sludge waste, and some types of food processing waste, which are moist fuels ideal for anaerobic digestion. Black liquor, a byproduct of the pulping process, is also a moist biomass fuel, but it is usually directly burned in boilers or gasified due to its high heat content. From the six solid waste fuels, several liquid and gaseous biomass fuels can be formed, such as ethanol, biomass gas, landfill gas, and anaerobic digester gas (Resource Dynamics Corporation, 2004). The second largest group of opportunity fuels consists of waste and byproducts from industrial processes. Iron and steel mills, petroleum refineries, textile mills, and various industrial facilities produce waste and byproduct solids and gases that can be used as fuels. There are six different opportunity fuels that can be obtained from industrial processes: (Resource Dynamics Corporation, 2004): i. Blast Furnace Gas; ii.Coal Coke; iii.Coke Oven Gas; iv.Industrial VOC's; v.Petroleum Coke; vi.Textile Waste.

3. Waste wood

Wood is one of the most valuable materials widely used for its remarkable properties, i.e. high strength, low specific weight, good insulation properties, availability, etc. The extensive use of wood and wood – based products results in high quantities of waste wood and wood residues. In Greece, it is estimated that the annual available quantities are 1,070,000 m^3/y (~640,000 t/y), which corresponds to 288,000 t oil equivalent (Skodras, 2004). Wood waste is generated from different sources and can vary considerably in composition, quality and quantity. Each of these factors can significantly affect the possibilities for utilization of wood waste. In the past, contaminated wood waste was disposed at landfills or was burned, and cleaner waste was used in the production of boards. However, new technological advances and development of alternative markets have provided more options for further utilisation of this natural resource. It is now possible to remove large amounts of pollutants from the wood waste and thus produce high-quality materials for various markets (Dercan, 2012). By cutting down forest bark, branches, leaves, discarded trees, roots, stumps, remnants of pruning, tree tops, and chips remain as wood waste. Another way of obtaining such waste are both the primary and the final wood processing when the remains include cut lumber, bark, stubs, sawdust, veneer and plywood. By processing in carpentry and furniture manufacturing stubs, sawdust and other solid waste remain. Wood as a construction material also produces a certain amount of waste, namely: corners, chips, sheeting residues, old doors and windows, floors, fences, etc. (Dercan, 2012). Landfills and other points for collection and/or classification of different types of waste are sources of wood waste. Those include municipal waste, residential, commercial, institutional and industrial products that were rejected, including durable and consumer goods, packaging, furniture, toys, wooden boards, pieces of wood and panels, waste from gardens and parks. Wood waste is generated during the production of furniture, but also at the end of the service life of the products when the office and household furniture is decommissioned. In the production of furniture timber is a significant part, and during processing a large part of it ends up as waste. Waste is often up to 60 % of sawn timber and 25 % of board materials. Final production can often produce further loss of 5 % in stubs, assembly of the product 2 % and packaging 15 %. Due to large amounts of wood waste producers must strive to limit the cost of disposal, and wherever possible, make the best use of this material. Many factories are now burning the waste, using it for heating their facilities or as a source of electricity. However, there is considerable potential for alternative use of large amounts of wood waste from this sector (Dercan, 2012).

3.1 Categorisation of Wood Waste

Wood waste is not simply clean pieces of untreated pine off cuts. A system of classification is required to differentiate between different grades of wood waste material. In Europe there is a classification system that relates to the type of wood product from which the waste originated and what (if any) treatment had been applied to the original wood product. This approach results in a three-tiered A-B-C (or variations thereof) categorisation of wood waste (Warnken, 2001): A) Wood waste is derived from untreated solid wood materials. B) Wood waste is derived from engineered panel products such as particleboard, medium density fibreboard, and plywood. C) Wood waste is derived from preservative treated timber products.

The grade of input wood waste used in recycling directly impacts on the potential end product that can be manufactured and also the gate fee associated with separated loads of wood waste for recycling (Warnken, 2001).

3.2 Motivation for utilisation waste wood

Despite the fact that, wood is the most abundant biodegradable and renewable material available, there are numerous reasons to maximise its utilisation. Economic concerns and social preoccupation with the climate change and greenhouse gas emissions as well as threats to forests due to adverse effect of climate change, could be effectively tackled by increasing the use of wood residues (Daian, 2009). When wood is used to displace high sulphur bituminous coal, sulphur emissions can be reduced by more than 80 %. Using wood waste frees up landfill space, contributes to sequestering of carbon, reduces carbon dioxide emissions from processing virgin material, and contributes to sustainable use of natural resources. Environmental issues accompany the environmental motivations of using wood waste, especially demolition wood waste. For example, in the case of waterborne wood preservatives, there is a concern about chemical leaching (if the wood is used as mulch) or concentration in the ash (if the processed wood is used as boiler fuel). These environmental issues are being researched (Spring, 2002). Since industrial economies are firstly drawn by financial motivation, economical aspects are to be considered in the study of wood waste recovery. The main factors to take into account when speaking about wood waste fuel markets are: (Rizzo, 2010): (I) Availability of the resource (price of collection and preparation). (II) Competition intensity (price of other disposal methods, price of prepare wood waste fuel). (III) Seasonal variation. (IV) Operation and investment cost for the combustion plant (including the price of energy sold)

Waste has always been seen as harmful and disturbing substances for society, the trend has been for a long time to chase them away to remote area. This behaviour, called 'Not In My Back Yard' (NIMBY) syndrome demonstrates the lack of responsibility and individualism of people in regards of this sanitary problem, pushing them to think that the greater the risk remains away from them, the more it decreases (Hunter, 1995). Eventually, one last aspect to consider regarding wood waste derived fuel and society is the question of fuel availability and energy needs. A societal issue of our contemporary world is the supply of fuel resources to lastingly answer growing energy needs. Yet, fossil fuels wells are becoming more and more expensive to find and exploit. In addition, because the major sources of oil are owed by some countries in the world, many countries in Europe are facing a situation of dependency to answer the need of energy carrier such as gasoline. In this context, emergence of renewable energy is seen as a solution to fight this unsecure and unstable situation (Rizzo, 2010).

3.3 Challenges of utilisation of waste wood

Wood waste is a light-weight material. For instance the bulk density of solid pine is approximately 450 kg/m^3. Unprocessed wood waste comprises mainly air, making it a very light-weight and bulky material. Even when processed, a range of bulk densities between 200 kg and 300 kg/m^3 of processed wood waste material are reported (Warnken, 2001). A number of challenges are associated with application of the use of waste wood. These challenges include defining the fuel sufficiently for equipment vendors and regulatory agencies. Characteristics to be established are fuel particle size, shape, and propensity to bridge, agglomerate, stick to equipment surfaces, leach, or contain hazardous components. Other important considerations are the ease and cost of transporting the fuel ; its ability to be co-fired with other traditional or waste fuels; the ability to obtain performance guarantees from boiler/furnace/steam generator vendors with the desired opportunity material; and pollutant emissions from combustion, gasification, and handling. The answers to these issues, along with the typical design issues revolving around complex multifuel steam plants with on-site electric generation, has to be obtained in the course of any feasibility analysis of waste wood (Tidona, 2011).

3.4 Waste wood thermochemical processes

There are three main thermochemical conversion processes available for converting wood waste to more useful energy forms: combustion, gasification and pyrolysis (Helsen, 2005). Combustion is the oldest technology for biomass conversion, especially for generating heat and steam from woody fuel. A waste wood combustion facility can produce steam, electricity, or both (CHP). Combustion technology is typically the lowest-cost biomass-to-energy technology to construct and operate, especially for woody fuels (Yakima County Public Works, 2003). Important chemical properties for waste wood combustion are the ultimate analysis, proximate analysis, analysis of pyrolysis products, higher heating value, heat of pyrolysis, heating value of the volatiles, and heating value of the char (Ragland et al.,1991). Ash is a waste product of waste wood combustion. Ash represents a disposal cost for the waste wood facility. Sometimes ash can be land-applied or mixed into compost, but most often it is landfilled. The four common combustion boiler designs are: Pile Burners—Pile burners are the oldest and simplest boiler design, but have low efficiencies and poor combustion control. The advantage of pile burners is a simple and low-cost design and fuel flexibility. They are not recommended for modern commercial-scale biomass-to-energy projects. Stoker-Fired Furnaces—Stoker furnaces are a proven and tested technology for wood waste combustion. Suspension-fired Furnaces—Suspension-fired furnaces inject finely pulverized fuel in a high-speed air stream for combustion. This technology is common for coal-fired boilers and achieves high efficiency, but processing wood waste biomass into the finely pulverized powder is difficult and costly. Suspension firing of biomass is normally only feasible in special situations where sawdust or other ultra-dry wood waste is co-fired or used as a retrofit fuel in a coal-fired boiler. Fluidized Bed Furnace—Fluidized bed furnaces are the newest furnace technology, although the technology has been widely used for several decades. Fluidized bed combustors can be classified as bubbling fluidized bed (BFB) or circulating fluidized bed (CFB), depending on the air velocity. One advantage of fluidized bed furnaces in wood waste combustion is the ability to handle a wide range of fuels and moisture content. Fluidized bed furnaces achieve the highest thermal conversion efficiencies of any boiler technology because of more complete combustion of the fuel. In spite of the apparent advantages of fluidized bed furnaces, stoker furnaces dominate the biomass combustion industry (Yakima County Public Works, 2003). Biomass gasification technologies have historically been based upon partial oxidation or partial combustion principles, resulting in the production of a hot, dirty, low calorific value gas that must be directly ducted into boilers or dryers. In addition to limiting applications and often compounding environmental problems, these technologies are an inefficient source of usable energy. Wood waste gasification is the latest generation of biomass energy conversion processes, and is being used to improve the efficiency, and to reduce the investment costs of biomass electricity generation through the use gas turbine technology (Demirbas, 2004). Gasification is the thermo-chemical reduction of a fuel without direct combustion. Gasifiers operate at high temperatures and pressures in an oxygen-depleted environment to convert a feedstock to a combustible gas. The immediate product of gasification is synthetic gas, or “syngas”. Syngas consists of carbon monoxide and hydrogen, with smaller amounts of carbon dioxide and methane. Syngas will contain other compounds, such as sulfur and nitrogen, depending on the chemical makeup of the fuel. Syngas can be burned to create heat, steam, or electricity. It can be converted to methane and fed into a natural gas distribution system. Syngas can also be converted to methanol, ethanol, and other chemicals or liquid fuels. Methanol produced through gasification can be further refined into biodiesel with addition of vegetable oils or animal fats. Slag is produced as a waste product of the gasification project. This is similar to the bottom ash produced by combustion, but gasification slag is denser and has a more “glassy” consistency compared with combustion ash. The two most prevalent technologies for commercial-scale gasification are fluidized bed reactors and plasma arc reactors. Fluidized bed reactors operate on the same principles as fluidized bed combustors, but are controlled so that the fuel only gasifies and is not allowed to combust. Plasma arc reactors have been used to incinerate MSW and hazardous or medical wastes. Both technologies provide very high energy conversion rates. The choice of fluidized bed vs. plasma arc technology would depend on the fuel and application (Yakima County Public Works, 2003). Pyrolysis is the basic thermochemical process for converting biomass (wood waste) to a more useful fuel. Biomass is heated in the absence of oxygen, or partially combusted in a limited oxygen supply, to produce a hydrocarbon rich gas mixture, an oil-like liquid and a carbon rich solid residue (BISYPLAN, 2012). In pyrolysis process, biomass converts into liquid (bio oil or bio-crude), charcoal and non-condensable gasses, acetic acid, acetone, and methanol by heating the biomass to about 750 K in the absence of air. The process can be adjusted to favour charcoal, pyrolytic oil, gas, or methanol production with a 95.5 % fuel-to-feed efficiency. Pyrolysis can be used for the production of bio-oil. Some problems in the conversion process and use of the oil need to be overcome; these include poor thermal stability and corrosivity of the oil. Upgrading by lowering the oxygen content and removing alkalis by means of hydrogenation and catalytic cracking of the oil may be required for certain applications (Demirbas, 2004). Pyrolysis of wood has been studied as a zonal process and is a thermal decomposition of the fuel. The reaction mechanisms of biomass pyrolysis are complex but can be defined in five stages for wood (Demirbas, 2000): (i) Moisture and some volatile loss. (ii) Breakdown of hemicellulose; emission of CO and CO_2.(iii) Exothermic reaction causing the woody biomass temperature to rise from 525 to 625 K emission of methane, hydrogen and ethane. (iv) External energy is now required to continue the process.(v) Complete decomposition occurs.

4. Waste availability potential in Greece and Hungary

An indication of the combustible renewables and waste in Hungary for the year 2010 was reported as 1840.59 tOE (t of oil equivalent) (Trading and Economics, 2012), according to a World Bank report published in 2012. The composition of the reported combustible renewables and waste comprises solid biomass, liquid biomass, biogas, industrial waste, and municipal waste. A Hungarian PhD thesis (Németh, 2009) has evaluated different sources of wood waste. It has estimated the potential for wood waste from packing in Hungary of the order of 100,000 t/y. A comprehensive earlier source (Strange, 2002) has listed a comparative waste amounts and approximate compositions for a number of European countries – including Greece and Hungary. The Figures for both countries are summarised and interpreted in Table 1. The used LHV is assumed on the basis of a weighted evaluation. The heating value of MSW depends on its moisture content. Its magnitude varies and is about half of that for coal. Frey et al. (2003) quoted of 8.3 MJ/kg at 29 % moisture content in Central Europe. Ruth (1998) cited about 10.4 MJ/kg at 25 % moisture in the US. The LHV for plastic waste is taken from (Fodor and Klemeš, 2011).

Table 1: Estimation of the combustible energy potential for Greece and Hungary for the year 1996

		Greece	Hungary
Total waste	t/y	3,606,000	5,000,000
Paper and cardboard fraction	(-)	0.18	0.19
Plastics fraction	(-)	0.10	0.05
Total combustible fraction	(-)	0.28	0.24
Paper LHV	MJ/t	8300	8300
Plastics LHV	MJ/t	43000	43000
Paper amount	t/y	649,080	950,000
Plastics amount	t/y	360,600	250,000
Paper energy potential	MJ/y	5,387,364,000	7,885,000,000
Paper energy potential	MWh/y	1,496,490	2,190,278
Plastics energy potential	MJ/y	15,505,800,000	10,750,000,000
Plastics energy potential	MWh/y	4,307,167	2,986,111
Total energy potential	MWh/y	5,803,657	5,176,389

5. Recommendation for further research

In order to suggest a more comprehensive and complete solution of the future trend of wood waste derived fuel, both in Greece and Hungary, an assessment of the environmental impacts of wood waste combustion in different conditions through sensitivity analysis within the LCA approach could give a more thorough idea of the pollution treatment method to adapt to each wood derived fuels (Daian, 2009). Additionally, an identification and assessment of the economical evolution and impacts should be carried out. Finally, other studies such as studies on social aspects and on wood waste treatment method or on energy production could be completed for the further utilization of waste wood.

6. Conclusions

This paper provides comprehensive data to assess the utilisation of opportunity and especially wood waste fuels. The twofold nature of waste wood was taken into account by considering wood as renewable material and regenerative fuel in the definition of the functional unit. In this document are summarised the available information dealing with the challenges that are related to the lack of knowledge of new technologies for exploiting wood waste, pollution of the environment with primary waste, emissions of harmful gases into the atmosphere and low awareness of the need to use waste wood. Resolving these issues would open some new paths from which would benefit: markets, stakeholders and wider public.

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