CONTRIBUTION OF WTE PLANTS IN EU'S TARGETS FOR RENEWABLES. A REVIEW UNTIL 2014.

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Abstract

- Purpose (stating the main purposes and research question): The paper aims to present, count and evaluate the contribution to electricity in EU from the Waste-to-Energy facilities in the targets set out by the European Commission.
- Methods: The method used was literature and data bases review and analysis to collect, calculate and present the analytics.
- Results: The results present the importance of Waste-to-Energy facilities in covering part of the electricity needs of EU except the provision of a complete solution on the non-recyclable waste treatment.
- Conclusions: The findings of this paper support the significant role that the Waste-to Energy sector presents, in terms of energy security and contribution for achieving the goals for renewable energy production in the European Union.

Keywords

Waste-to-Energy, Energy Security, Electricity Generation, EU Power Sector, Renewable Electricity, Sustainability

Introduction

Europe is a large continent with many countries which almost all face the same lack of energy resources. Thus, the dependence on imported fossil fuels is among the problems that European Union (EU) is trying to mitigate. At the same time the municipal solid waste generation is constantly increasing as the European society is growing wealthier. Each year in the EU, 3 billion tons of wastes are produced - 90 million tons of them are hazardous. Every day about 6Mg of solid wastes are produced, according to Eurostat statistics. The produced municipal wastes present a non negligible Lower Calorific Value that should be considered as a power source. The new approach of EU to resource efficiency and the extensive experience in waste to energy facilities make this a strong possibility [1] – [3].

Waste is a resource. Generating energy from waste instead of landfilling avoids methane gas which equals 25 times CO2 in mass, and at the same time leads to the reduction of fossil fuels import, leading to less economic dependency. In combination with the energy efficiency thresholds set in Waste Framework Directive, this could prevent up to a further 45 million tons of CO2equ per year. This corresponds to the annual emissions of over 20 million cars. However, 37% of Municipal Solid Waste across the EU 27 is still landfilled. Burying the waste is a huge loss of precious materials and energy at

the same time and a lost opportunity to create more jobs, economic growth and reduce the impacts of waste on human health [2] – [9].

The biggest economies of EU and the most advanced nations are recovering energy from wastes in large combustion power plants and producing electricity and heat for several years. They have installed these plants inside their cities where the consumers of the produced energy are located. The global leaders in waste to energy plants are also located in these countries providing additional advances in local economies [3], [5], [10], [11].

Especially in the EU, more than 400 Waste to Energy (WtE) plants are in operation and at least ten are in design or under construction. Some European countries are using this significant energy resource which in many other countries is not used, as the wastes go directly to landfills resulting in waste of valuable resources. In this paper, an effort has been attempted to present the current status of the WtE plants in EU and their contribution to the Power Sector.

Power Sector of EU

Production of primary energy in the EU-28 was 771 million tons of oil equivalent (toe) in 2014. This continued the generally downward trend observed in recent years; with 2010 the main exception as production was increased after a relatively strong fall in 2009 that coincided with the financial and economic crisis. Considering a longer period, the production of primary energy in the EU-28 was 17.3% lower in 2014 than it had been in 2004. In 2014, primary energy production in the EU-28 was produced by a number of different energy sources, the most important of which, in terms of the size of its contribution, was nuclear energy accounting 29.4 % of the total. In France, Belgium and Slovakia the nuclear energy accounted for more than half of the national production of primary energy. Renewable energy sources accounted in more than one fourth, and solid fuels accounted in almost one fifth, of the EU-28's total production of primary energy, while the share for natural gas was lower reaching 15.2 %. The remainder of the total was crude oil with a share of 9.1 % of the total according to Eurostat. Fig. 1 presents this share of resources for power energy production in EU [12] – [13].

The growth of primary production from renewable energy sources exceeded all the other energy types. Growth in primary production from renewable energy sources was relatively stable from 2004 to 2014, with a slight dip in 2011. Over this 10-year period the production of renewable energy sources increased in total by 73.1 %. By contrast, the production levels for the other primary sources of energy generally fell over this period, the largest reductions being recorded for crude oil (-52.0 %), natural gas (-42.9 %) and solid fuels (-25.5 %), with a more modest fall of 13.1 % for nuclear energy [12] – [13].

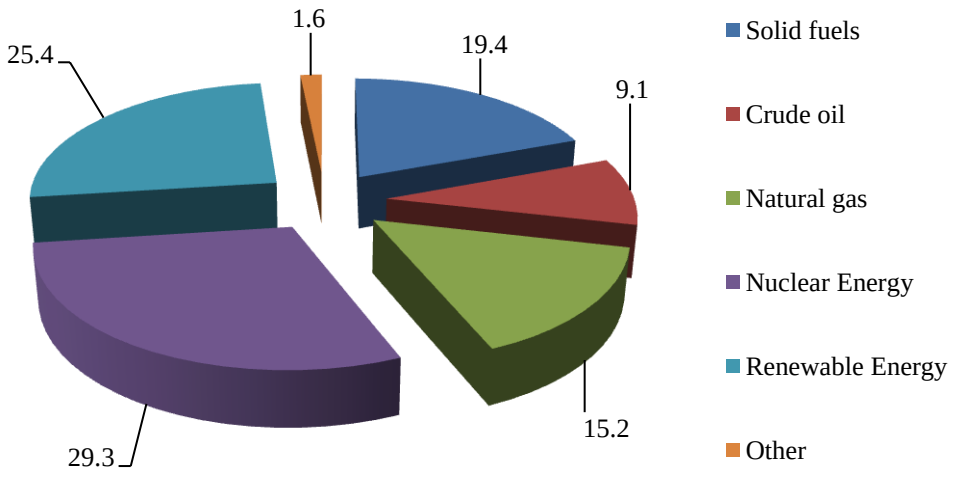

Fig. 1. Primary energy production in EU -28 for the year 2014, according to Eurostat (% of total, based on tonnes of oil equivalent) [12]

Waste Production and WtE in EU

More and more municipal solid wastes have been created as European society has grown wealthier. Each year, in the European Union, 3 billion tonnes of waste are thrown away as already stated before. Every day, around 6000Mg of solid wastes are produced in the EU according to Eurostat statistics. Managing of all this material, without harming the environment, becomes a major issue for every member state of the EU [1]-[3], [5], [10], [14]-[17].

The amount of waste generated in Europe increased by 10% for 2000 until 2010, according to the Organization for Economic Cooperation and Development (OECD). Most of what it is throw away, is either burnt in incinerators, or dumped into landfill sites (67%). Landfilling not only takes up more and more valuable land space but also causes air, water and soil pollution, discharging carbon dioxide (CO2) and methane (CH4) into the atmosphere and chemicals and pesticides into the earth and groundwater [1], [3], [5].

Europe currently treats 50 million tons of wastes at waste-to-energy plants each year, generating an amount of energy that can supply electricity for 27 million people or heat for 13 million people. Forthcoming changes to EU legislation will have a profound impact on how much further the technology will help to achieve environmental protection goals [1] – [5].

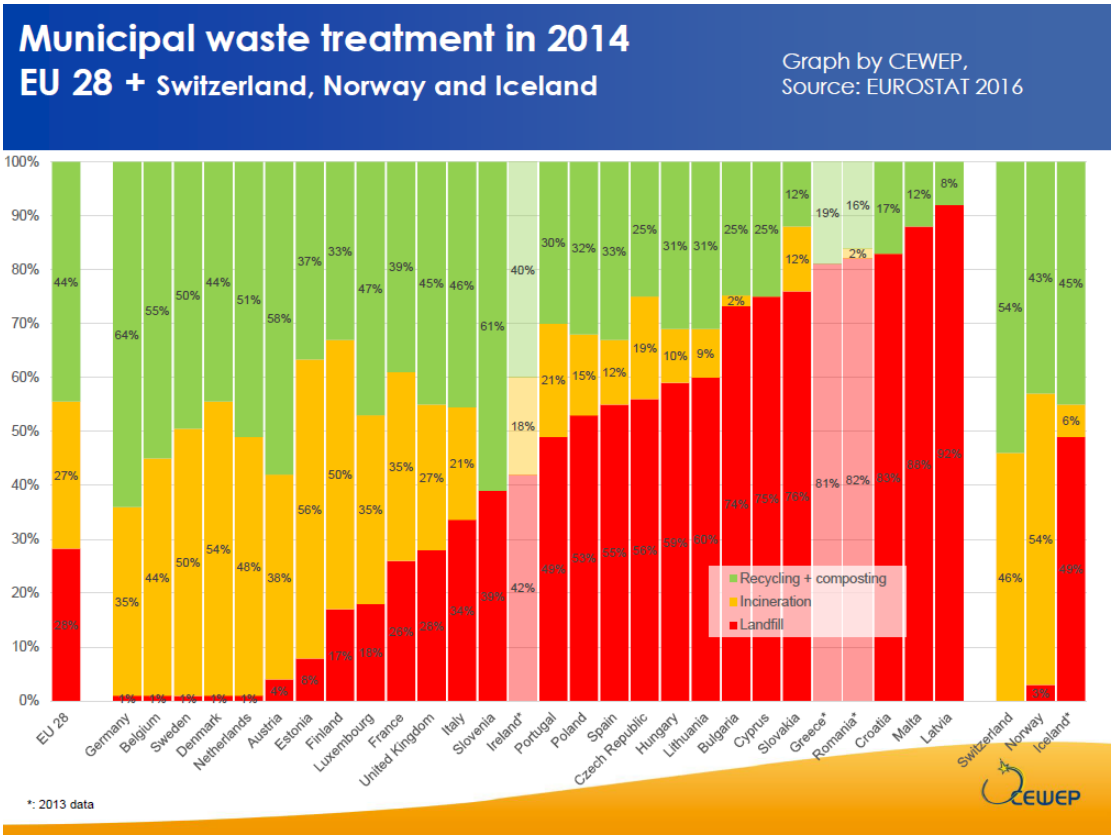

Fig. 2. Municipal waste management in 2014 in EU-28 based on Eurostat data [10]

Despite EU policy to divert biodegradable waste from landfill, landfilling remains the dominant method used in Europe – approximately 50% of the 243 million tonnes of municipal solid waste (MSW) generated in the 28 Member States of the EU (EU-28) each year is still landfilled. Fig. 2 presents the MSW treatment methods in EU-28 as it is published by the Confederation of European Waste to Energy Plants (CEWEP) [10] based on the data announced by Eurostat. One of the reasons for this continuing dominance could be public reluctance to accept waste-to-energy (WTE) plants as a safe treatment option. Approximately 58 million tons of waste is currently thermally treated each year

in about 480 WTE plants in Europe. Fig. 3 presents the distribution of WTE plants and the amount of wastes thermally treated in EU-28 in 2014 as this was officially announced by CEWEP [1], [2], [10].

Several new WTE plants in EU are also under construction or under design with more famous the new WTE plant in Copenhagen which its roof will be artificial ski runs with artificial snow, and the new one in Paris in the side of river Seine, 3km from Eifel Tower, the most visited place of Paris. These two plants are expected to become famous as the Spittelau WTE in Vienna [5], [14].

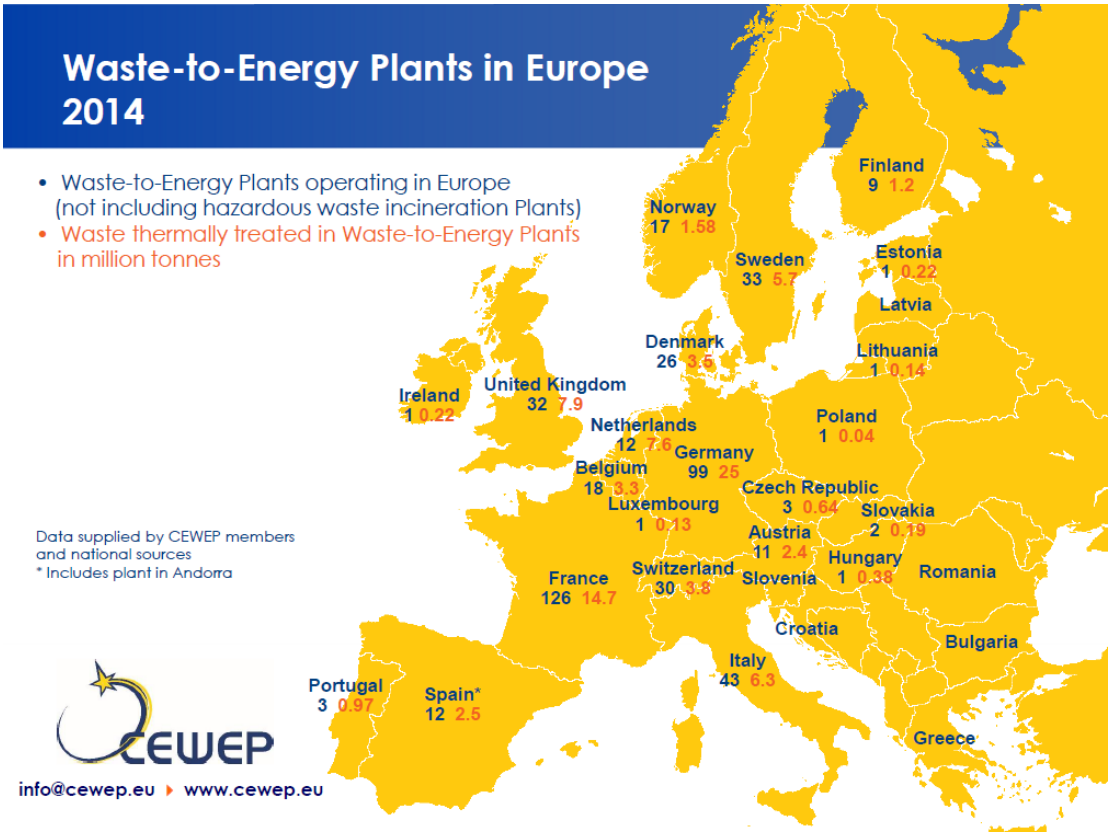

Fig. 3. WTE plants in EU and the annual amount of wastes treated in 2014, as these data were published by CEWEP [10]

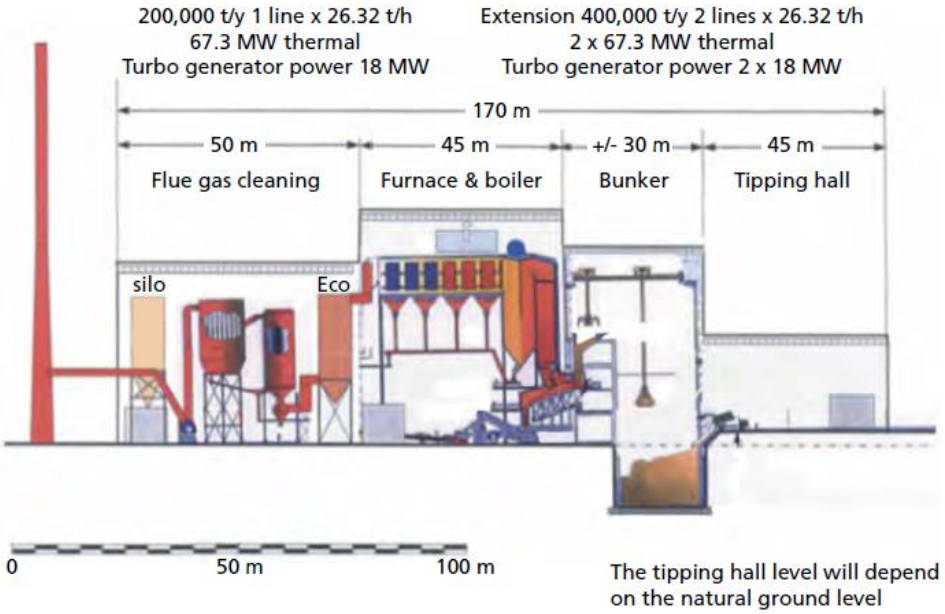

Fig. 4. Layout elevation view of grate combustion WTE [10]

In Fig. 4, an elevation layout of a grate combustion plant is presented [5]. This type of plants is the most common in EU with the majority of the existing facilities operating with this kind of technology. So this layout can be considered as a representative one. Even though this technology is very well established and it is proven as advantageous for Municipal Solid Wastes (MSW) management, only few EU countries prefer this method that also provides non negligible amounts of energy in the form of electricity and heat, covering the needs of the local communities [5], [11], [10], [14].

Looking at the past, WTE plants were considered only for waste management, thus, their contribution in energy was almost inexistent. European legislation has been a driving force in developing energy recovery from household refuse. The gradual implementation of several directives by EU, covering waste management, renewable energies and energy efficiency, was the driving force for the nowadays development. The Directive on the promotion of electricity from renewable energy (2001/77/EC) broke ground by acknowledging that the biodegradable fraction of household waste was an integral part of renewable energy sources as a component of biomass. It defined it as "the biodegradable fraction of products, wastes and residues from agricultural (including plant and animal substances), forestry and related industries, as well as the biodegradable fraction of industrial and municipal waste". Since then, household wastes have been assigned its own place in the European Union renewable energies targets, especially those of the new renewable energies directive (2009/28/EC). It is quite important to mention that this fuel is considered partly renewable source of energy depending on their composition, while each EU country determines its own percentage. For example, in Denmark the produced energy is considered to be 80% Renewable, while the average is considered to be 50% [2], [5], [16], [18], [19].

In addition, the framework directive on waste (2008/98/EC), applicable to the Member States since 12 December 2010, forces operators to improve the energy performance of their incineration plants. This directive specifies that the incineration of municipal waste cannot be considered as an energy recovery operation unless certain performance criteria (called the "R1 Formula") are met. Plants constructed since 31 December 2008, must offer at least 65% energy-efficiency, while those constructed prior to that date, must offer at least 60% [5], [16], [18], [19].

Other directives have encouraged a waste-to-energy plant construction, such as the directives on waste incineration (2000/76/EC) and industrial emissions (2010/75/EU) that have led to the reduction of pollutant emissions, and the landfill directive (1999/31/EC) that binds Member States to phase out dumping biodegradable municipal waste in landfills to 35% of their 1995 level by 2016 [5], [14] - [16], [18] - [20].

The European Cogeneration Directive (2004/8/EC) that aims to increase energy efficiency by developing high-performance cogeneration also acknowledges Waste-to-Energy plants as harnessing technology that can increase energy efficiency. The legislation has just been strengthened by the Energy Efficiency Directive (also known as the EED Directive) that the Council of Europe approved on 4 October 2012. It encourages Member States to build incineration plants which will assess potential supplies to district heating and cooling networks (article 14 and appendix VIII) [18] – [20].

As it has been already stated previously, every European Union country sets the amount of energy to be recovered by its incineration plants that it considers to be renewable, based on the biomass content of the incinerated waste, but many of them use a 50% ratio. If only the renewable part is considered, primary energy production from incineration of municipal waste is put at 8.7 Mtoe in 2013 in the European Union, namely 500ktoe more than in 2011, according to EurObserv'ER Barometer [18].

Recovery in the form of electricity, estimated at 18.741 TWh in 2013 compared to 18.739 TWh in 2010, is still the preferred energy form, mainly in the Southern EU countries, and is rising constantly. Obviously, heat sales from these plants are significantly high in those countries where district heating networks are more widespread (Germany, Sweden, Denmark and the Netherlands). This recovery channel has tended to increase slowly over the past three years, at 2.36 Mtoe in 2013, even though the

only heat producing WTE plants presents higher energy efficiency than the Combined Heat and Power CHP or Electricity only facilities [3], [12] , [18].

Table I presents the amounts of renewable electricity produced in Electricity only WTE plants and CHP WTE plants in EU. The amounts of energy seem to be small, but this is only the renewable part thus, if the percentage is considered for RES electricity the numbers are not that small. As it can be seen from this table, which is based on the data presented in [18] and Eurostat data on RES electricity production in EU for 2013, the contribution of WTE plants in RES electricity is quite high: almost 25% in Malta, 23.5% in Luxembourg, almost 21% in the Netherlands, over 6% in Belgium, near 6% in Denmark and Hungary and over 4% in UK. If the total RES electricity in EU is considered, then this amount reaches up to 2.26%. Based on these figures, it is more than obvious that the contribution of WTE facilities in RES electricity in EU is notable even though only few countries have such facilities. If the rest countries adopt this method then this percentage will definitely increased significantly [8], [12], [13].

TABLE I
Gross Electricity Production from Renewable Municipal Waste in the European Union in 2013 [18]

Countries	**Electricity only plants (GWh)**	**CPH plants (GWh)**	**Total (GWh)**	**% of the total RES Electricity**
France	1243.7	914.3	2158.0	2.23%
Spain	0.0	595.0	595.0	0.57%
Portugal	0.0	286.0	286.0	1.13%
UK	1169.4	817.9	1987.3	4.02%
Belgium	484.4	150.6	635.0	6.08%
Netherlands	0.0	2133.0	2133.0	20.97%
Luxembourg	0.0	36.0	36.0	23.52%
Slovakia	0.0	29.0	29.0	0.48%
Ireland	0.0	70.0	70.0	1.29%
Italy	1230.0	977.0	2207.0	2.43%
Austria	160.0	47.0	207.0	0.45%
Germany	3268.0	1987.0	5255.0	3.25%
Czech Republic	0.0	84.0	84.0	0.76%
Lithuania	0.0	19.0	19.0	3.05%
Slovenia	0.0	7.4	7.4	0.14%
Hungary	0.0	115.0	115.0	5.75%
Denmark	0.0	858.0	858.0	5.73%
Malta	0.0	9.0	9.0	24.99%
Finland	66.5	283.5	350.0	1.59%
Sweden	0.0	1700.0	1700.0	1.80%
European Union	7622.1	11118.6	18740.7	2.26%

Table II presents the amounts of total gross electricity produced in Electricity only WTE plants and CHP WTE plants in EU. These amounts were estimated considering the following facts:

- The average renewable electricity production is 50% according to the previously mentioned, except for Denmark where the amount of RES electricity was considered 80%
- The amounts of renewable electricity production by the WTE plants are given in Table I.

In this case the percentage of the WTE plants contribution seems even smaller. But it cannot be neglected. If the total electricity production in EU is considered, then this amount reaches up to 1.13% for the electricity. Based on these figures, it is more than obvious that the contribution of WTE facilities in electricity in EU is not negligible and only few countries have such facilities. If the rest countries adopt this method then this percentage will definitely increase. The first obvious result will be the reduction of EU on imported fuels and reduction of related expenditures for the economy. The benefits are also environmental as even less wastes will be sent in landfills, and the environmental impact will be reduced further as these facilities replace also fossil fuels leading to less GHG emissions.

TABLE II
Gross electricity production from municipal waste in the European Union in 2013, fossil and renewable contents are included.

Countries	**Electricity only plants (GWh)**	**CPH plants (GWh)**	**Total (GWh)**	**% of the total Electricity Production**
France	2487.4	1828.6	4316.0	0.76%
Spain	0.0	1190.0	1190.0	0.42%
Portugal	0.0	572.0	572.0	1.11%
UK	2338.8	1635.8	3974.6	1.11%
Belgium	968.8	301.2	301.2	1.52%
Netherlands	0.0	4266.0	4266.0	4.19%
Luxembourg	0.0	72.0	72.0	2.49%
Slovakia	0.0	58.0	58.0	0.20%
Ireland	0.0	140.0	140.0	0.54%
Italy	2460.0	1954.0	4414.0	1.52%
Austria	320.0	94.0	414.0	0.61%
Germany	6536.0	3974.0	10510.0	1.65%
Czech Republic	0.0	168.0	168.0	0.19%
Lithuania	0.0	38.0	38.0	0.80%
Slovenia	0.0	14.8	14.8	0.09%
Hungary	0.0	230.0	230.0	0.76%
Denmark	0.0	1072.5	1072.5	3.09%
Malta	0.0	18.0	18.0	0.80%
Finland	133.0	567.0	700.0	0.98%
Sweden	0.0	3400.0	3400.0	2.22%
European Union	15244.0	21593.9	35869.1	1.13%

Conclusions

Waste to Energy plants are a reality in the EU. The countries with the higher recycling rates are the ones that present also the higher waste incineration potential producing energy from that type of resource and minimize landfilling. Even though the contribution is small in many countries, the average is over 1% while there are countries like Netherlands and Denmark in which this contribution can reach or even become higher than 3%. These results can are showing that the contribution of WTE plants in EU energy security is notable and in a country by country consideration it will be found that these facilities are providing up to 25% of the total renewable electricity in Malta, 23.5% in Luxemburg or 21% in the Netherlands, while the contribution in RES electricity cannot be neglected.

References

[1] European Environmental Agency (EEA). Europe's Environment, The Fourth Assessment. Copenhagen. http://www.eea.europa.eu/ (2007). Accessed 5 May 2017

[2] European Environmental Energy. Being wise with waste: the EU's approach to waste management, Publications Office of the European Union, Luxembourg. http://ec.europa.eu/environment/waste/pdf/WASTE%20BROCHURE.pdf. (2010). Accessed 25 April 2017

[3] Confederation of European Waste-to-Energy Plants (CEWEP). Recycling and Waste-to-Energy in combination for sustainable waste management. http://www.cewep.eu/m_1038 . (2014). Accessed 2 May 2017

[4] Consonni, S. and Vigano, F.: Material and energy recovery in integrated waste management systems: The potential for energy recovery, Waste Management, 31, 2074-2084, (2011).

[5] Themelis, N.J., Diaz Barriga, M.E., Estevez P. and Velasco. M.G. Guidebook for the Application of Waste-To-Energy Technologies in Latin America and the Caribbean. (2013). http://www.seas.columbia.edu/earth/wtert/pressreleases/Guidebook_WTE_v5_July25_2013.pdf

[6] DEFRA Report. Energy from waste, A guide to the debate. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/284612/pb14130-energy-waste-201402.pdf, (2014). Accessed 20 April 2017

[7] DEFRA Report. Incineration of Municipal Solid Waste. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/221036/pb13889-incineration-municipal-waste.pdf. (2014). Accessed 20 April 2017

[8] Themelis, N.J.: Waste–to–Energy, Introduction. In Meyers, R.A., (Ed.): Encyclopedia of Sustainability Science and Technology, pp. 11828 – 11838. Springer, (2012).

[9] Reimann, D.O.: Waste–to–Energy: Energy Resource in Solid Wastes. In Meyers, R.A., (Ed.): Encyclopedia of Sustainability Science and Technology, pp. 11838 – 11851. Springer, (2012).

[10] Confederation of European Waste-to-Energy Plants (CEWEP). The renewable energy contribution of "Waste to Energy across Europe. http://www.cewep.eu/storage/med/media/wastepol/250_ExtRES_Report_JM.pdf. (2008). Accessed 27 April 2017

[11] Psomopoulos, C.S., Bourka, A., Themelis, N.J.: Waste to energy: A review of the status and benefits in U.S.A., Waste Management, 29, 1718 -1724, (2009).

[12] Eurostat. Energy production and imports. http://ec.europa.eu/eurostat/statistics-explained/index.php/Energy_production_and_imports (2016). Accessed 20 April 2017

[13] Eurostat (2014, May). Renewable energy statistics. [Online]. Available: http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Renewable_energy_statistics

[14] Psomopoulos, C.S.: Residue Derived Fuels as an Alternative Fuel for the Hellenic Power Generation Sector and their Potential for Emissions Reduction, AIMS Energy, 2, 321-341 (2014).

[15] Schiessler, N., Thorpe, E,. Jones, W., Philips, L.: LIFE and waste recycling - Innovative waste management options in Europe, Office for Official Publications of the EC, Luxembourg. http://ec.europa.eu/environment/life/publications/lifepublications/lifefocus/documents/recycling.pdf (2007). Accessed 28 April 2017

[16] Psomopoulos, C.S., Stavroulakis, C., Stavropoulos, V., Themelis, N.J.: Greenhouse gases emission reduction potential in Greece by implementing WTE facilities in strategically selected urban areas, Fres. Env. Bul., 22, 2042 – 2047, (2013).

[17] European Commission. Integrated Pollution Prevention and Control, Reference Document on Best Available Techniques for the Waste Incineration. http://ec.europa.eu/environment/ippc/brefs/wi_bref_0806.pdf. (2006). Accessed 27 April 2017

[18] EurObserv'ER. Renewable municipal waste barometer. https://www.eurobserv-er.org/pdf/renewable-municipal-waste-barometer-2014-en/ (2014). Accessed 28 April 2017

[19] Van Berlo (Marcel), M.A.J.: Waste–to–Energy Facilities as Power Plants, In Meyers, R.A., (Ed.): Encyclopedia of Sustainability Science and Technology, pp. 11758 – 11767. Springer, (2012).

[20] Bilitewski, B., Wünsch, C.: Greenhouse Gas Emission Reduction by Waste–to–Energy, In Meyers, R.A., (Ed.): Encyclopedia of Sustainability Science and Technology, pp. 4754 – 4774. Springer, (2012).