ANNALS of Faculty Engineering Hunedoara – International Journal of Engineering

Tome XII [2014] – Fascicule 2 [May]
ISSN: 1584-2665 [print]; ISSN: 1584-2673 [online]
a free-access multidisciplinary publication
of the Faculty of Engineering Hunedoara

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GLOBAL WARMING POTENTIAL OF THE THERMIC TREATMENT PROCESSES

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Abstract: Since the beginning of the 20th century global warming has accelerated and greenhouse gas emission has been on the rise, too. This is partly because of using out of date technologies and vehicles. During the thermic treatment processesa great amount of carbon-dioxide gets into the air, as a result of which global warming gets more intensive. This paper analyses greenhouse gas emission using theLife Cycle Assessment of the thermic treatment processes.
Keywords: Life Cycle Assessment, Global Warming Potential, Thermic Treatment Process, Waste to Energy, Combined Heat and Power

1. INTRODUCTION

Nowadays the eco-friendly treatment of continuously reproducing wastesmeans a significant problem worldwide.In Hungary, the disposal and the conventional incineration without energy generationtend to be the solution. In Western Europe, the USA and in some Asian countries the Waste to Energy (WtE) technologiesare commonly used. In Hungary there are only a few of such technologieswhile in Eastern European countries they only operate experimentally. We can efficiently generate energy out of waste with Combined Heat and Power (CHP) technologies. For this task a gas engine set ora gas turbine is the most popular method. The basis of CHP generation is that we produce useful heat and electricity in one technical cycle [1]. The definition of useful heat: the only useful heat during the Combined Heat and Power generation is a heat generated in order to satisfy the economically reasonable need of heating or cooling (2002/0185 COD).The useful heat is one of the basic points of the directive because the heat is difficult to store and transport. This is why the energygeneration has to take place near the factory requiring effective heat. Without the utilization of the generated heat Combined Heat and Power cannot be achieved. One basic aim of CHP technologies is to save carbon-dioxide and the other is the more efficient use of energy sources [2]. If we generate electricity and thermal energy in one technical cycle, we can reduce carbon-dioxide emission per kWh energy and we can also reduce the source of energy used.

2. THERMIC TREATMENT PROCESSES

The possible energetic utilization can be carried out by conventional incineration, cracking pyrolysis or gasification and plasma technology, or flow incineration (in pieces of equipment).The following sections discuss the most frequently used thermochemical technologies for Waste to Energy [3].

The most famous thermic treatment processes are [4]:

1. conventional incineration: full oxidative combustion,
2. pyrolysis: thermic degradation of organic material in the absence of oxygen,

3. gasification: partial oxidation,
4. plasma technology: partial oxidation, combination of (plasma-assisted) pyrolysis/gasification of the organic fraction and plasma vitrification of the inorganic fraction of waste feed.

These technologies can be combined. The more thermochemical approaches such as pyrolysis; gasification and plasma technologies have been applied on selected smaller scale waste streams, and have attemptedto control temperatures and pressures of the process. While the application of pyrolysis at low, mid- and high temperature is possible mainly for waste, gasification is suitable for all burnable materials. In connection with plasma technology, the elimination of hazardous waste is done by oxidation, and in this reduction method the goal is to extract raw material. Plasma technology is the least-known process. This process is very suitable for the treatment of organic waste, because at over 5.000 °C even PCBs decompose [5]. The emission levels will be sensitive to the accidental inclusion of waste. The main issue is synthesis gas cleaning. The main constituentsof synthesis gas are hydrogen, carbon monoxide, methane and carbon dioxide. Gasification plants produce large quantities of carbon dioxide and, if the synthesis gas is only used for electricity generation,and many times greater, on a power for power comparison basis, than a conventional power plant. Gas engine and turbines typically have low tolerance to impurities in the synthesis gas. With pyrolysis the emission of heavy metals is lower (due to thelack of oxygen), but one of the disadvantages is that the use of pyro oilis accompanied by significant emissions. Besides this, pyrolysis produces a large quantity of pyro coke with a high concentration of heavy metals in the cinders [6]. The new technologies differ from the traditional incineration processes in a waythat chemical energy is recovered from the waste. The derived chemical products may be used as feedstock for other processes or as secondary fuel in some cases. The waste is converted into a secondary energy source (a combustible liquid, gas or solid fuel), while it is utilised in a steam turbine, gas turbine or in agas engine in order to produce heat and/or electricity. The calorific value of the synthesis gas is below that of thenatural gas [7]. The tested technologies and the data of testsareshown in Table 1.

Table 1.The technologies and the data of the tested

Tested Technology	T [°C]	Oxidation factor	Atmosphere	Product	Engine
Pyrolysis	500 1200	$\lambda = 0$ endothermic	-	pyrolysis- gas,coke and oil	gas engine, steam turbine
Conventional incineration	1150	$\lambda = 1,5$ exothermic	natural gasadditional firing, air	flue gas (<5% burnable), slag and ash	steam turbine
Gasification	1200 1600	$\lambda = 0,55$ partialoxidation	air	synthesis gas, slag and ash	gas engine
Plasma-gasification	1200 2000	$\lambda = 0,5$ partial oxidation	air, steam	synthesis gas, vitreous slag	gas engine
Plasma technology	3000 5000	$\lambda = 0,5$ partial oxidation	steam, O_2 and CO_2blend	synthesis gas, vitreous slag	gas engine
Natural- and Biogas in cogeneration	650	$\lambda = 0,99$ exothermic	air	flue gas (<3% CH_4 content)	gas engine
Coal- fired power plant	500	$\lambda = 0,99$ exothermic	air	flue gas (<5% burnable), slag and ash	steam turbine

3. GLOBAL WARMING AND ITS EFFECTS

The central issue of environmental protection is the analysis of global warming and of its effects. The most important effect is the rise of temperature. The result of this is the melting of icecaps and the heightening of the oceans' level. Consequently, greenhouses gas (CO_2, CH_4) emission has to be reduced. The planet is warming, from the North Pole to the South Pole, and everywhere in between. Globally, the mercury is already up more than 0.8 degree Celsius, and even more in the sensitive Polar Regions. And the effects of rising temperatures are not waiting for some far-flung future. They are happening right now. Signs are appearing all over, and some of them are surprising. The heat is not only melting glaciers and sea ice; it is also shifting precipitation patterns and setting animals on the move [8]. Some impacts from increasing temperatures are already happening and other effects could happen later in this century, if warming continues:

- ✓ Ice is melting worldwide, especially at the Earth's poles. This includes mountain glaciers, ice sheets covering West Antarctica and Greenland, and Arctic sea ice.
- ✓ Sea level rise has becomefaster over the last century.
- ✓ Precipitation (rain and snowfall) has increased across the globe, on average.
- ✓ Spruce bark beetles have boomed in Alaska thanks to 20 years of warm summers. The insects have chewed up 4 million acres of spruce trees.
- ✓ Sea levels are expected to rise between 18 and 59 centimetres by the end of the century, andcontinuousmelting at the poles could add between10 to 20 centimetres.

4. KYOTO PROTOCOL

The Kyoto Protocol is an international agreement linked to the United Nations Framework Convention on Climate Change (UNFCCC), which commits its Parties by setting internationally binding emission reduction targets. The Protocol was adopted on 11 December 1997 in Kyoto, Japan. It was opened on 16 March 1998 for signature. As of November 2009, 187 countries and one regional economic organization (the EC) have ratified the agreement The EU and its Member States ratified the Protocol in May 2002. Furthermore, American Presidents argue that unless China and India agree to the Kyoto Protocol, too, the Chinese and Indians will make up for any cutback by the US - and it will put the US at an economic disadvantage at the same time. The countries had signed up to the Protocol and had made a commitment to reduce their carbon dioxide emissions and five other greenhouse gases by an average of 5.2%. Many countries set their own targets. In the EU this was originally 8% but later increased to 20% by 2020, as governments began to realise that much more had to be done. In the UK and Scotland, Climate bills more recently committed to reductions of 80%. The main aim of the Kyoto Treaty was to hold greenhouse gases at a level that will stop dangerous changes to the planet's climate system. All of the industrialised nations that signed and ratified the Treaty would collectively reduce their emissions. Hungary since the ratification of directive has reduced greenhouses gas emission by 10 per cent. The energy industry and the waste management playa significant role in the reduction of greenhouse gases.

5. LIFE CYCLE ASSESSMENT FOR DEFINING GREENHOUSE GAS EMISSION

Life cycle assessment (LCA) is a process of evaluating the environmental burdens associated with a product, process, service or activity by [9]:

1. identifying and quantifying the energy and materials used and the wastes released to the environment;
2. assessing the impacts of those energy and material uses and releases to the environment; and
3. identifying and evaluating opportunities for environmental improvements.

Today these applications include government policy, strategic planning, marketing, consumer education, process improvement and product design. They arealso used as the basis of eco-labelling and consumer education programs throughout the world. According to ISO 14040:2006: "A systematic set of procedures for compiling and examining the inputs and outputs of materials and energy and the associated environmental impacts directly attributable to the functioning of a product or service system throughout its life cycle."The Life Cycle Assessment study has four main phases (Figure 1):

1. The goal and scope definition phase: the scope, including system boundary and level of detail, of an LCA depends on the subject and the intended use of the study. The depth and the breadth of LCA can differ considerably depending on the goal of a particular LCA.
2. The inventory analysis phase (LCI phase): is the second phase of LCA. It is an inventory of input/output data with regard to the system being studied. It involves the collection of the data necessary to meet the goals of the defined study.

ISSN: 1584-2665 [print]; ISSN: 1584-2673 [online]

3. The impact assessment phase (LCIA phase): is the third phase of the LCA. The purpose of LCIA is to provide additional information to help assess a product system's LCI results so as to better understand their environmental significance.
4. The interpretation phase: Life cycle interpretation is the final phase of the LCA procedure, in which the results of the LCI or an LCIA, or both, are summarized and discussed as a basis for conclusions, recommendations and decision-making in accordance with the goal and scope definition.

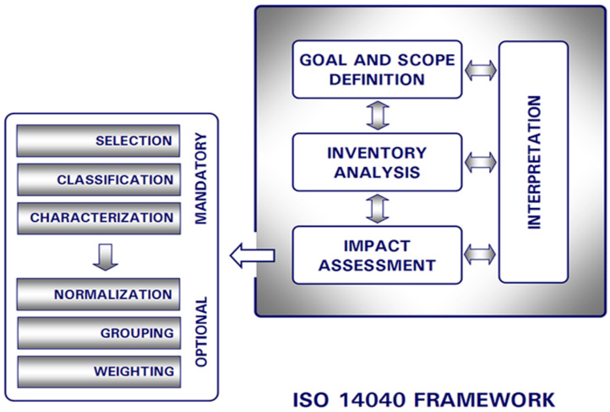

Figure 1. The phasesof the LifeCycle Assessment (www.productdesignenvironment.info)

Regarding thermic treatment of organic industrial waste I haveanalysed eleven technologies. The reference quantity was natural gas cogeneration by gas engine. I pointed out Global Warming Potential (GWP)from the environmentalcategories, because my main goal is to find carbon-dioxide saving technologies. Amongthese technologies carbon-dioxide is the most significant from all the gases causing greenhouse effect. The functional unit chosen, that is, the base for the treatment comparison, is one kWh of electricity generated. All emissions, materials and energy consumption are referred to inthis functional unit(Tables 2. and 3.) [10].

Table 2. System boundary, and the main parameters of the analysis

System boundary	Applied methods and functional unit
From the waste charging until the burning of the generated synthetic gas in a gas engine. Normal, steady operating condition.	Applied methods: CML 2001 (November, 2010.) Functional unit: 1 kWh electricity (CHP)
Operating Condition and exploitage of the power plant	
Operating Condition: Normal,steady-state condition	Exploitage: 75,34 % power exploitage per year

Table 3.Global Warming Potential definition and measure

Environmental category	Measure
Global Warming Potential (GWP)	kg CO_2- equivalent
Environmental category definition	
GWP is a relative measure of how much heat a greenhouse gas (for example: CO_2, CH_4, N_2O and FCKW) traps in the atmosphere. It compares the amount of heat trapped by a certain mass of the gas in question to the amount of heat trapped by a similar mass of carbon-dioxide. A GWP is calculated over a specific time interval, commonly 20, 100 or 500 years.	

According to the results we can say that the most significant figures were achieved by the plasma technologies (figure 2 and table 4). These figures are lower than those of the natural gas in cogeneration and the Hungarian average. The most unfavourablerateis observed by the pyrolysis (500°C). This figure is higher than the one of Hungary's coal-fired power plant in some temperature. This power plant emitted 1.22 kg CO_2 per kWhe, which they want to reduce to 0.9 kg by 2016. The higher temperature pyrolysis (1200°C) is better than the gasification, and the plasma-gasificationat some temperatures. The increase of the temperature has reduced the carbon dioxide emission per kWh electricity, because of the

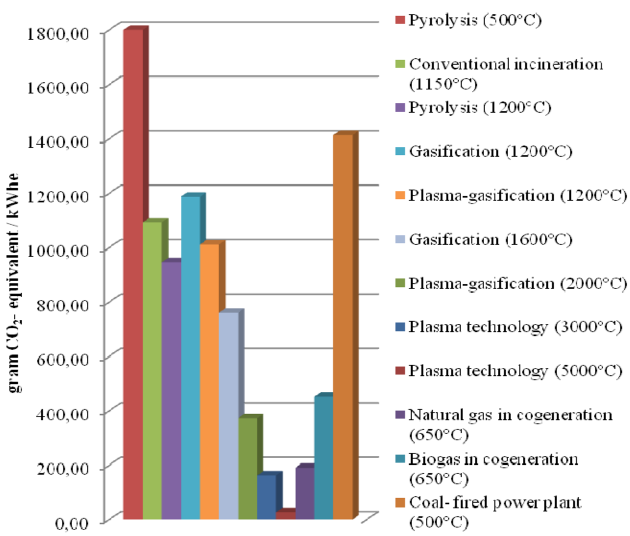

Figure 2.Carbon-dioxide equivalent per kWh electricity emission of the tested technologies

higher calorificrateof the synthesis gas. The ratesof the conventional incineration aresituated between the lower temperature gasification (1200°C) and the plasma-gasification (1200°C).

Table 4. Carbon-dioxide equivalent per kWh electricity emission of the tested technologies

Technology	gram CO_2-e/kWh$_e$	Technology	gram CO_2-e/kWh$_e$
Pyrolysis (500°C)	1828,03	Plasma-gasification (2000°C)	371,87
Conventional incineration (1150°C)	1092,26	Plasma technology (3000°C)	161,99
Pyrolysis (1200°C)	945,72	Plasma technology (5000°C)	27,49
Gasification (1200°C)	1186,85	Natural gas in co-generation (650°C)	190,56
Plasma-gasification (1200°C)	1011,28	Biogas in co-generation (650°C)	451,02
Gasification (1600°C)	759,59	Coal- firedpower plant (500 °C)	1413,75

Currently in Hungary 370 gram carbon-dioxide is created during the generation of one kWh of electricity (with LCA 443 gram CO_2-e/kWh). This amountis 553 gram (855 gram CO_2-e) in Rumania, whilein EU27the average is 430 gram CO_2/kWh of electricity (540 CO_2-e/kWh). The National Energy Strategy in Hungary would lower CO_2 emission by200 gram CO_2/kWh of electricity to 2020. The waste management and the energy industry play an important role in this endeavour.

6. CONCLUSION

The biggest advantage of plasma technology istoproduce one kWh of energy together with the lowest greenhouse gas emissions.Due totheunfavourable economic and economical sides of the plasma technology is often combined with gasification or pyrolysis. The combined technologies integrate the advantages of enabling technologies, the environmental benefits of plasma technology and the favourable economic and economical advantages of the gasification/pyrolysis.Based on the research resultsthe best solution is the plasma gasification at 2000°C temperature. My goal for the future is to further develop this technology and to find, analyse and design new technologies.

ACKNOWLEDGEMENTS

The described work was carried out as part of the TÁMOP-4.2.1.B-10/KONV-2010-0001 project in the framework of the New Hungarian Development Plan. The realization of this project is supported by the European Union, co-financed by the European Social Fund.This research was realized in the frames of TÁMOP 4.2.4. A/2-11-1-2012-0001 „National Excellence Program – Elaborating and operating an inland student and researcher personal support system convergence program" The project was subsidized by the European Union and co-financed by the European Social Fund.

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