Energy 100 (2016) 425–430

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

Relative environmental footprint of waste-based fuel burned in a power boiler in the context of end-of-waste criteria assigned to the fuel

Krzysztof Badyda [a], Piotr Krawczyk [a, *], Krzysztof Pikoń [b, 1]

[a] Institute of Heat Engineering, Warsaw University of Technology, 21/25 Nowowiejska Str., 00-665 Warszawa, Poland
[b] Department of Technologies and Installations for Waste Management, Silesian University of Technology, 18 Konarskiego Str., 44 100 Gliwice, Poland

ARTICLE INFO

Article history:
Received 12 January 2015
Received in revised form
26 January 2016
Accepted 5 February 2016
Available online 15 March 2016

Keywords:
Waste-based fuel
Chemical composition of the fuel
Conventional coal and waste-based fuel comparison
Environmental footprint analysis
CML 2001 methodology

ABSTRACT

Legal regulations on waste disposal require waste producers to limit landfilling and to find different ways of waste management, the preferred methods being recycling of material and energy potential. Currently, in Poland, the only consumers of RDF (refuse-derived fuels) are cement plants. However, the estimated potential supply of this alternative fuel far outstrips their ability to use it. One solution would be to redirect the excess fuel to power and heat production facilities. The end-of-waste criteria for a given substance or object are specified in European Unions regulations. In this study chemical compounds have been selected for their suspected impact on end-of-waste criteria and their concentrations are measured in conventional coal fuel and the proposed waste-based fuel. A question arises as to whether it is possible to create a waste-based fuel without an assigned waste status. Environmental footprint analysis was carried out using methodology based on the CML 2001 model and involved comparison of two fuels in six different categories.

1. Introduction

Regulations on waste disposal require waste producers to limit landfill and to find different ways of waste management, with recycling of material and energy potential being highly preferred factors. Estimates show that municipal waste in Poland has an energy potential of 4.5–6 Mt/r. Currently, the only consumers of RDF (refuse-derived fuels) in Poland are cement plants. However, the estimated potential supply of this alternative fuel far outstrips their ability to use it. One solution would be to redirect the excess fuel to power and heat production facilities. However, this imposes legal and economic problems.

In the Polish Waste Catalogue, alternative fuel derived from sorted municipal waste is coded 19 12 10. It is created mainly by separating the subscreen (subsieve) fraction containing mostly biodegradable material from general municipal waste. The fraction remaining on screens is sent for milling and creates a flow of refuse-derived fuel [1–4].

In Poland co-firing waste, including RDFs which have waste status, is authorized for use at power and heating plants, provided that the following requirements are fulfilled: Process conditions for thermal waste conversion – at least 2 s in a zone where the flue gas temperature exceeds 850 °C and unburned particle content in slag and bottom ash not to exceed 5%.

Emission standards for waste incineration by co-firing are dependent on the share of waste in the total fuel flow.

Owing to technical and economic constraints on the use of refuse-derived fuels, waste co-firing is practically absent from Polish power plants. This contrasts with Germany, where large power stations make extensive use of waste co-firing. For example this procedure is used at plants owned by RWE company [5] and plants previously owned by Vattenfall, like Jänschwalde.

Abbreviations: C_x, Interrelation coefficient between precursor and emission precursor of the emission of substance x [t x/ t of precursor x]; $CI_{x,i}$, Indicator characterizing substances x in impact category IC; E_x, Emission of substance x [t x/FU]; G_w, Amount of fuel used [t fuel/FU]; P_x, Precursor of the emission of substance x [t of precursor x/t fuel]; ε_x, Effectiveness of flue gas cleaning installation of substance x; AD, abiotic depletion; CC, climate change; HT, human toxicity; POF, photo-oxidants formation; AC, acidification; EU, eutrophication.

* Corresponding author.
E-mail addresses: badyda@itc.pw.edu.pl (K. Badyda), piotr.krawczyk@itc.pw.edu.pl (P. Krawczyk), krzysztof.pikon@polsl.pl (K. Pikoń).
1 Tel.: +48 32 237 12 13.

http://dx.doi.org/10.1016/j.energy.2016.02.024
0360-5442/

Power plants which are involved in Poland in the Transitional National Plan, formulated under the European Industrial Emissions Directive, are banned from using waste as a fuel, even when the waste has been formally approved for incineration. A question arises as to whether it is possible to create a waste-based fuel which would not be given the status of waste under the relevant regulations.

The European Union regulations on waste-based fuels contain the technical specification CEN/TS 15,359:2011. Its goal is determining unambiguous and transparent rules for classification and specification of SRF (solid recovered fuel) parameters. The classification of this standard is based on three parameters:

- NCV (Net Calorific Value),
- Cl (Chlorine content),
- Mercury content (Hg).

The fuels have been divided into 5 classes. However, the standard does not provide clues for meaning of a fuel being assigned to one of the classes. Thus assigning an SRF to a class causes no legal effect whatsoever. Regardless of its class, a waste-based fuel remains a waste.

The end-of-waste criteria for a given substance or object are specified in Article 14, Section 1 of the Polish Act on Waste. It states that a certain specified waste shall cease to be waste when it has undergone a recovery (including recycling) operation and complies with criteria to be developed in line with certain legal conditions, in particular: d) “The usage of the substance or object, does not negatively affect people's lives or health, or the environment”.

The environmental footprint a fuel leaves is strongly dependent on its chemical composition. Moreover, the legislator did not state the exact chemicals and concentrations required for the waste category to be dropped.

Waste management should always deal with the use of waste as substitutes for primary materials. Waste should also be utilized as a source of energy. Re-use of waste should be treated as a way of reducing environmental pollution.

Calculation of the actual level of the co-effectiveness is one of the most serious and, at the same time, one of the most difficult issues when investing in waste to energy [6].

The authors of this study selected certain substances which are suspected to have the largest impact on the criteria presented above and their concentrations are measured in conventional carbon-based fuel and the presented waste-based fuel. Based on these measurements and data retrieved from literature a comparison of the environmental footprint was made for both fuels. Furthermore an analysis was conducted comparing the combustion and exhaust gas cleaning parameters of both fuels when burned in a standard power plant boiler.

For the environmental footprint analysis a methodology in line with the CML 2001 model was used and was based on comparing the two fuels in six different categories, abiotic depletion, climate change, human toxicity, photo-oxidants formation, acidification, eutrophication.

The final emission levels were compared at the boundary of the power boiler and the environment, after flue gas treatment.

2. Characteristics of the compared fuels

The study focused on following fuels: lignite with parameters shown in Table 1 and two variants of lignite-waste fuel mixture, with 0.2% and 0.5% waste fuel content by weight. The technical parameters and elementary analysis of these fuels are shown in Table 1. The assumed waste fuel share is taken from the production capacity of a plant designated for waste fuel production and primary fuel consumption at a power plant.

Lignite with composition similar to that presented here is produced by a Polish mine and combusted in pulverised fuel boilers. The method for selecting waste fuel for further analysis is described below.

Not all fractions contained in the municipal waste may be incinerated. In commonly accepted waste processing technologies (Mechanical Biological Treatment plant), part of the waste is separated by screening in trommel screen as the subscreen (or subsieve) fraction. More waste is separated from the main flow as recyclable material fractions, e.g., paper, plastics. The rest of the waste, after processing to lower the content of non-combustible substances still further, either becomes a substrate for waste fuel production or becomes waste fuel itself. For the study presented here it was assumed that production of refuse-derived fuel may not interfere with key goals of the waste management policy and should only be complementary to those aims. Thus it was assumed that the municipal waste flow which is to be taken into account as a fuel substrate may only be made up of the waste which remains after removing the subscreen fraction and separating the material fractions as stipulated by relevant regulations and dictated by economic considerations.

The authors performed an original morphological analysis of the waste portion intended for fuel production. The results obtained were compared with the available literature.

Fig. 2 presents morphological properties for 10 samples of a waste mixture which would be a substrate for fuel production. Individual samples had different sources. In each case the sample was collected from waste following removal of the subscreen fraction (in trommel), preliminary shredding and processing in equipment used for removal of heavy fractions (e.g., stone rubble) and metals. Samples 1, 2 and 3 were collected from waste obtained by a cooperating industrial facility on three consecutive days in October. Original material included mixed municipal waste, ballast from selective waste collection system, large-sized waste items and industrial waste. The composition of sample 4 was created by averaging values for samples 1, 2 and 3. Sample 5 was obtained from sorting mixed municipal waste and ballast from a selective collection scheme. The sample was subjected to optical separation to eliminate chlorine-containing plastics (mainly PVC (polyvinyl chloride)). Fig. 1 presents a diagram of the waste processing system (Mechanical Biological Treatment plant) with an indication of sampling points.

Further sample composition was sourced from Ref. [7] (samples 6, 7, 8 and 9) and [8] (sample 10). Source [7] specified morphological properties of ballast fractions remaining after removing the subscreen fraction in trommel screen and after cabin sorting. The input to sample 6 came from waste collected selectively. Sample 7 was made of mixed municipal waste and waste from selective collection. Samples 8 and 9 were prepared from mixed municipal waste. Sample 10 was made by removing subscreen fraction <80 mm and further mechanical segregation of municipal waste.

Analysis of the morphology revealed:

- dominating role of five material fractions in analysed waste: plastics, scrap paper, textiles, composites and wood, which together constitute >90% of the total mass;
- relatively large discrepancies in content of individual components between individual samples. This applies particularly to textiles, composites and wood.

The next stage involved detailed chemical analysis of materials separated during the morphological analysis (from sample 4) in order to determine those material fractions where the content of undesirable substances is within acceptable limits. For each sample