Management of waste from energy production – waste combustion in Poland

A Uliasz-Bocheńczyk and P Bąk
AGH University of Science and Technology, Faculty of Mining and Geoengineering, al. Mickiewicza 30, 30-059 Krakow, Poland
aub@agh.edu.pl

Abstract. Energy production processes generate mineral waste – products of the combustion of solid fuels and waste from after-treatment systems. This is classified as group 10 waste – waste from thermal processes. For many years such waste has either been recovered or disposed of in landfills (D10 process), according to waste management hierarchy. The most important areas in which combustion waste is utilized are: the production of construction materials, macro-levelling, the rehabilitation of degraded land, and backfilling. Certain types of combustion waste are currently classified as a by-product. Energy mineral waste management is implemented in accordance with the provisions of the Waste Act of 14 December 2012. In spite of the examples of proper combustion waste management given in this paper, the amount of disposed waste had increased by 2016 while at the same time recovery on a national scale had declined. In 2016 both fly ash and compounds of fly ash and calcium-based reaction waste from flue-gas desulfurization in solid form were no longer disposal and the volume that was recovered had increased. The key problem are dust-slag compounds resulting from the wet treatment of furnace waste, almost 90% of which are landfilled.

1. Introduction

Because of the raw material conditions prevailing in Poland, the basic forms of fuel powering the country’s energy industry are hard coal and lignite. In the last few years, due to the obligation to use renewable energy sources, the commercial power industry makes use of solid biomass [1].

Coal is one of the most important energy sources in the world and provides almost 30% of its non-renewable primary energy [2]. In the case of Poland, at current consumption levels there are sufficient industrial coal sources to last more than 40 years [3]. Coal will thus continue to be the country’s basic energy raw material. Hence, constant restructuring of the mining industry in many areas is justified, as is investment in new technologies for exploiting this raw material. Mining is a highly capital-intensive and specific industry, which involves some degree of mining-geological risk associated with extraction activity [4].

Besides emitting gaseous pollutants, the combustion of solid fuels also generates waste with certain properties depending on the energy raw material and type of boiler used. According to the Regulation of the Minister of Environment of 9 December 2014, such waste is classified in the waste catalogue (Journal of Laws 2014, item 1923) [5] as Group 10 waste – waste from thermal processes.

The main types of waste generated in energy production processes are: dust-slag compounds from the wet treatment of furnace waste (10 01 80), fly ash from coal (10 01 02), compounds of fly ash and
calcium-based reaction waste from flue-gas desulfurization (10 01 82), and slag, waste incineration and boiler dust (10 01 01) [6].

For many years mineral waste from the power industry has been treated using recovery processes, although some of this waste has been disposed in landfills.

However, a significant percentage of waste incineration in other countries is recovered [7,8].

In Germany and Denmark, 100% of ash and slag is recovered while in the USA, Great Britain and China it is up to 70%. In turn, Russian cogeneration plants produce approximately 1.3 billion tons of ash, but out of these only 3 million tons (10%) are recovered [8].

Eight hundred Mt of fly ash alone is produced by global coal combustion, primarily in the following countries: China, India, the USA and EU [9]. Ash recovery ranged in different countries from 3% up to 90%; in the USA – 50%, the EU – over 90%, India – 60%; China - 67% [10]. For many years fly ash from coal combustion has been used in different branches of the economy, among other things as sorbents for cleaning waste gases and as agents for removing toxic components from waste, in zeolite synthesis, as well as in the production of construction materials, road construction, and mining [11].

One form of waste that is difficult to utilize is biomass waste incineration [12]. For example, in Lithuania a significant percentage of ash from biomass combustion (25,000 – 30,000 tons) ends up in landfills [13].

The aim of the article is to present the current situation in the management of waste from energy production in Poland in light of the current market trends.

2. Waste from energy production processes– furnace waste and waste from gas treatment systems

The latest data on the amount of waste generated by the power industry together with the methods used to handle such waste are given by the Central Statistical Office [14], including fly ash (table 1), for dust-slag compounds from the wet treatment of furnace waste (table 2), and for fly ash and calcium-based reaction waste from flue-gas desulfurization in solid form (table 3).

The amount of fly ash produced over year has changed over the last 9 years, ranging from a maximum of 4.6 million tons in 2012 down to 3.3 million tons in 2016 and 2017. The amount of recovered waste and landfilled waste has also fluctuated. According to data from the Central Statistical Office [14] for 2016, the ash from the combustion of coal was not disposed in landfills (table 1), while the amount of waste deposited in landfills has declined.

| Years | Fly ash generated during the year | Waste landfilled (accumulated) to date (as of the end of the year) in million tons |
|-------|----------------------------------|-------------------------------------------------------------------------------------|
|       | grand total                      | recovered                                                                 | disposed                  |
|       | (million tons)                   | total of which temporarily stored | temporarily stored |
| 2007  | 4.5                              | 98.7                          | 0.4                       | 0.3                       | 0.9                       | 18.8                     |
| 2008  | 4.2                              | 90.0                          | 8.0                       | 0.0                       | 2.0                       | 18.7                     |
| 2009  | 3.7                              | 89.5                          | 10.0                      | 0.0                       | 0.5                       | 18.7                     |
| 2010  | 4.0                              | 89.3                          | 6.1                       | 0.2                       | 4.6                       | 18.5                     |
| 2011  | 4.5                              | 92.5                          | 4.6                       | 0.1                       | 0.3                       | 19.0                     |
| 2012  | 4.6                              | 84.4                          | 14.7                      | 0.1                       | 0.9                       | 27.2                     |
| 2013  | 4.5                              | 87.0                          | 10.6                      | 0.1                       | 2.2                       | 27.2                     |
| 2014  | 3.8                              | 0.1                           | 0.1                       | 0.0                       | 0.5                       | 26.9                     |
| 2015  | 3.3                              | 3.3                           | 6.6                       | 0.1                       | 0.8                       | 26.3                     |
| 2016  | 3.3                              | 86.7                          | 11.3                      | 0.0                       | 2.0                       | 26.0                     |
In the case of dust-slag compounds from the wet treatment of furnace waste (table 2), in 2016 the amount of recovered waste declined while the amount of waste stored in landfills has increased to 303,600 tons.

Table 2. The different methods for dealing with dust-slag compounds from the wet treatment of furnace waste [14].

| Years | Dust-slag compounds from the wet treatment of furnace waste generated during the course of a year (% of waste generated) | Waste landfilled (accumulated) to date, (as of the end of the year) in million tons |
|-------|-----------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|
|       | grand total (million tons) recovered | disposed total of which landfilled temporarily stored |                                                                                   |
| 2007  | 6.8 | 23.3 | 71.9 | 71.9 | 4.8 | 241.8 |
| 2008  | 7.4 | 28.2 | 65.1 | 65.0 | 6.7 | 243.1 |
| 2009  | 8.9 | 17.9 | 80.1 | 80.1 | 2.0 | 253.5 |
| 2010  | 9.0 | 13.6 | 78.4 | 78.4 | 8.0 | 253.7 |
| 2011  | 10.4 | 12.8 | 82.5 | 82.5 | 4.7 | 258.0 |
| 2012  | 10.6 | 11.6 | 85.1 | 85.1 | 3.3 | 266.9 |
| 2013  | 11.5 | 10.3 | 86.7 | 86.7 | 3.0 | 276.6 |
| 2014  | 12.0 | 0.0 | 10.4 | 10.4 | 0.2 | 285.9 |
| 2015  | 12.0 | 0.6 | 87.4 | 87.4 | 1.2 | 294.1 |
| 2016  | 11.4 | 8.6 | 87.5 | 86.5 | 0.9 | 303.6 |

Ninety percent of fly ash and calcium-based reaction waste from flue-gas desulfurization in solid form (table 3) is recovered, not landfilled and only temporarily stored.

Table 3. The Different methods for dealing with fly ash calcium-based reaction waste from flue-gas desulfurization in solid form [14].

| Year | Compounds of fly-ash and calcium-based reaction waste from flue-gas desulfurization in solid form(% of waste generated) | Waste landfilled (accumulated) to date, (as of the end of the year) in million tons |
|------|-----------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|
|      | grand total (million tons) recovered | disposed total of which landfilled temporarily stored |                                                                                   |
| 2007 | 3.9 | 96.2 | 3.7 | 0.1 | 0.1 | - |
| 2008 | 4.0 | 99.9 | 0.1 | 0.1 | - | - |
| 2009 | 3.4 | 99.9 | 0.1 | 0.1 | 0.0 | 0.0 |
| 2010 | 3.8 | 100.0 | - | - | 0.0 | 0.0 |
| 2011 | 4.2 | 100.0 | - | - | 0.0 | 0.0 |
| 2012 | 3.9 | 99.9 | 0.0 | 0.0 | 0.1 | 0.0 |
| 2013 | 3.8 | 100.0 | - | - | - | 0.0 |
| 2014 | 3.2 | 0.2 | - | - | - | 0.0 |
| 2015 | 3.2 | 1.2 | - | - | 0.0 | 0.0 |
| 2016 | 3.0 | 92.8 | 0.1 | - | 0.5 | 0.0 |

Despite the considerable amount of waste from energy production that is recovered, the National Waste Management Plan 2022 [6] identified a number of waste management problems. The authors of the plan [6] underline a relatively large amount of waste from energy production compared to the total
waste, the decline in the amount of waste that is recovered and an increase in the amount of waste that is disposed of, as well as the large volume of waste stored in landfills.

The combustion waste from energy generation is primarily used in the production of construction materials (including cement), the construction of roads and mining (table 4). Two problem areas are fly ash from biomass combustion 10 01 03, which is used in small amounts, as well as biomass waste incineration 10 01 82, which is only landfilled [15].

| Year | Amount captured | Utilization type |
|------|-----------------|------------------|
|      |                | Construct. materials | Cement | Road construction | Mining | Others |
| bottom ash, slag and boiler dust (excluding boiler dust mentioned in 10 01 04) (10 01 01) | 1728.7 | 182.2 | 1.4 | 595.5 | 245.5 | 212.5 |
| coal fly ash (10 01 02) | 5025.0 | 1901.1 | 968.9 | 191.8 | 698.6 | 484.6 |
| fly ash from peat and untreated wood (10 01 03) | 27.0 | - | - | - | - | 6.0 |
| calcium-based reaction waste from flue-gas desulfurization in solid form (10 01 05) | 729.9 | 175.6 | 124.6 | 10 | 47.1 | 316.5 |
| dust-slag compound from the wet treatment of furnace waste (10 01 80) | 15921.8 | 2985.8 | 202.5 | 1625.6 | 29.6 | 3221.0 |
| calcium-based reaction waste from flue-gas desulfurization in sludge form (10 01 07) | 357.6 | - | - | - | - | 218.1 |
| sand from fluidized beds (10 01 24) | 559.7 | 35.2 | 12.8 | 135.0 | 20.5 | 344.4 |
| compounds of fly ash and calcium-based reaction waste from flue-gas desulfurization in solid form (dry and semi-dry methods of desulfurization and fluid bed combustion) (10 01 82) | 4159.5 | 27.6 | 21.7 | 270.2 | 792.1 | 812.2 |
| fly ash from co-incineration other than those mentioned in 10 01 16 | 652.1 | 428.8 | 223.1 | - | - | 0.1 |

3. Examples of waste management in plants operating in the commercial power industry in Poland

Power stations and cogeneration plants in Poland burning solid fuels conduct waste management in accordance with the provisions of the Waste Act.
3.1. Dolna Odra Power Plant Complex
The incineration waste generated in the Dolna Odra Power Station is comprised of the following: dust-slag compounds generated in power boilers, fly ash captured in flue gas dedusting units, synthetic gypsum from flue gas desulfurization systems, and dust from fluidized beds generated by biomass boilers. Waste incineration is partially recovered in the following cases: construction and the restoration of degraded land. Fly ash and synthetic gypsum are by-products, the entire production of which is fully utilized [17].

3.2. Opole Power Station
The following forms of waste are generated by fuel combustion flue gas cleaning technology at the Opole Power Station: slag, fly ash from coal, and gypsum.

Gypsum produced by the flue gas desulfurization unit is a raw material used by Knauff company in the production of plasterboard and is classified as a by-product. Other by-products include fly ash that meets the requirements of the PN-EN 450-1 standard.

All the waste produced in the Opole Power Station is stored selectively in special places designated for this purpose and is then transferred to specialist firms possessing legally required waste management licenses. Waste types 10 01 01 and 10 01 02 can also partially be covered by the D5 waste disposal process in the “Groszowice” waste incineration landfill [18].

3.3. Turów Power Station
In 2017 the Turów Power Station produced a total of 1 437 541.25 Mg of waste incineration, which was then treated using the R5 recovery process and supplied as an additive in construction materials. Waste incineration produced at the Turów Power Station is used to fill in adversely transformed sites [19].

3.4. PGNiG TERMIKA (Kawęczyn Heating Plant, Pruszków Cogeneration Plant, Siekierki Cogeneration Plant, Żerań Cogeneration Plant, and Wola Heating Plant)
By-products of combustion (ash and slag) at the PGNiG TERMIKA plants are regularly transferred to recipients possessing the appropriate licenses. They are used in the following areas: road construction, in the production of construction materials and as levelling material. The ash and slag generated in large volumes during peak heating period are stored and then recovered in the summer.

3.5. PGE Górnictwo i Energetyka Konwencjonalna, Kielce Cogeneration Plant branch
The following forms of waste incineration generated at PGE Górnictwo i Energetyka Konwencjonalna Kielce Cogeneration Plant Branch are: dust-slag compounds from WP-140 boiler, dust-slag compounds from boilers WR-25 and OR-50, ash and slag from biomass combustion from OS-20 boiler [21].

In PGE Górnictwo i Energetyka Konwencjonalna, Kielce Cogeneration Plant branch waste is collected selectively, gathered in specially designated and suitably prepared sites and then subjected to either recovery or disposal processes.

Dust-slag compounds from WP-140 boiler following its hydraulic transportation via pipelines is then disposed of in the „Gruchawka” landfill.

Dust-slag compounds from boilers WR-25 and OR-50, ash and slag from biomass combustion from OS-20 boiler, 22 277.0 Mg of which was generated in 2017 has been taken from temporary waste storage by physical persons.

Ash from biomass combustion (523.4 Mg produced in 2017) is disposed of or recovered [21].

3.6. ENERGA Kogeneracja Sp. z o.o.
One hundred percent of the ash and slag resulting from the combustion of hard coal at ENERGA Kogeneracja Sp z o.o. is recovered and utilized in the production of concrete, the production of construction ceramics, the restoration of degraded areas, and levelling [22].
4. Conclusion
The problem connected with the waste generated by the power industry has compelled interested entities to conduct economic, legal, technical, ecological and social analyses on the possible ways of utilizing landfilled materials [23]. From an economic perspective, costs are of key importance. According to data [16], the environmental protection costs of power stations and cogeneration plants in Poland (2014) totaled PLN 2.170.332.000 which accounted for 8.4% of the total costs of generating electricity and heat. According to data for 2013 the corresponding costs amounted to PLN 2.152.434.000 which translates into 7.6% of overall costs.

The environmental protection costs of power plants and cogeneration plants include charges and fees for emissions of pollutants, the use of water, the discharge of waste water and the landfilling of waste. Moreover, these costs include penalties for air pollution, discharging waste-water in waters and land, as well as for other uses of the environment [16].

In accordance with the hierarchy of waste management methods [24], measures should be taken to prevent waste generation, which in the case of waste from energy production primarily involves the application of suitable combustion technologies [6].

Methods for reducing waste from energy production include improving the energy efficiency of installations, applying modern combustion technologies, replacing solid fossil fuels with biomass, as well as increasing the share of energy obtained from renewable sources in the overall energy balance [6]. It is important to stress, however, that biomass combustion produces waste that is of limited commercial use.

Solid-fuel power stations and cogeneration plants try to recover as much waste as possible and minimize landfilling. Plants also classify their waste as a by-product, which by definition is used for economic purposes.

The current economic situation in Poland will result in an increased demand for this type of waste from the building, construction, and mining industries in the future. This is due to the ongoing restructuring process of the mining industry (including the closure of mines and reclamation of post-mining areas).

The main problem is the management of waste from biomass combustion. Therefore, further studies on the management of waste are required.

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