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The use of alternative fuels in the cement industry as part of circular economy

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Abstract: The alternative waste fuels have a significant share in the fuel mix of the cement industry in Poland. The conditions inside cement kilns are favorable enough for environmentally-friendly use of waste fuels. In the article, the authors discuss the current situation concerning the use of alternative fuels in Poland, from difficult beginning in the 1990s to the present time, different kinds of fuels, and the amounts of used fuels. The use of fuels in Poland is presented against the global and EU consumption (including Central European countries and companies). The increased use of waste-derived fuels, from the level of about 1% at the end of the 1990s to the present level of about 70%, allowed for the limitation of waste storage, including avoidance of greenhouse gas emissions and consumption of conventional energy sources; those effects also contributed to the implementation of the sustainable development and circular economy conceptions. The experiences of the cement plants worldwide prove that the use of waste fuels is ecological and economical. The examples showed in the article confirm that cement plants are greatly interested in using waste fuels from waste, as they invest in the infrastructure allowing to store bigger amounts of waste and dose them more efficiently. Thus, the cement industry has become an important element of the country's energy economy and waste management system.

Introduction

Cement production technology is a highly energy consuming process (Aranda Usón et al. 2013), which results in high production costs in which the energy costs account for 30−40% (Liu et al. 2017). Therefore, numerous studies aimed at finding efficient methods to lower the energy costs of clinker production and lowering the total costs of production have been conducted. One of the most important methods to lower the costs of production is to replace fossil fuels with waste fuels (Genon and Brizio 2008).

Waste fuels are used in variable amounts in cement plants worldwide. The first use of waste (tires) as a fuel in the cement industry took place at the beginning of the 1950s in Germany (Lechtenberg 2008). Since then, waste fuels have been used in cement plants, while their development was influenced by two periods of global recession: 1980−1982 and 1990−1991, which forced the plants to reduce their production costs (Rahman et al. 2015).

The latest analysis of the use of alternative fuels in the cement industry placed special emphasis on environmental aspects: energy recovery from waste (Holt and Berge 2018), obtaining energy from renewable sources (Husillos Rodríguez et al. 2013), and avoiding CO_2 emissions (Schakel et al. 2018).

The combustion conditions in the cement kilns are sufficient enough for the alternative fuels made of waste to be used. Very high temperatures in the kilns and the high speed of the gas stream, as well as the time of the burned particle suspended in the gas stream and alkaline environment cause the usage of the alternative fuels made of waste in the cement kilns to be ecologically safe. The process of fuel burning in cement kilns is waste-free, because the ash produced during incineration is included in clinker composition.

Waste fuels used in cement plants are economically and ecologically beneficial both for the industry and society. The use of waste fuels by the cement industry enables partial solution to the problem of waste utilization (Kookos et al. 2011) and leads to fossil fuels saving (Fyffe et al. 2016). The waste is not stored in landfills and, as a result, additional emissions of pollutants can be avoided (Fyffe et al. 2016). The use of waste fuels is an important method of energy recovery from waste, from the point of view of the industry and society, in the context of a sustainable economy.

The cement industry proves that the use of waste fuels, despite the financial outlays required for installations, is economically viable. However, no precise data can be provided, as the purchase prices of raw materials cannot be disclosed due to trade secrets.

Because of the economic reasons, the combustion of waste fuels is of great importance for the society (Cao and Pawłowski 2012) since, in this way, conventional fuels can be saved. This limits significantly the negative impact on the environment.

Besides the ecological benefits, society can also enjoy some economic benefits, as the new plants for alternative fuel production provide employment for local people. The local waste management plants plan and realize production of alternative fuels of determined and stable properties.

The activities of cement plants in the field of the use of alternative fuels are in line with the idea of circular economy thanks to the use of combustible waste fractions. Thus, the cement sector contributes to reducing the use of non-renewable energy sources. By using waste as fuel, the industry reduces the negative environmental impact of mining activities, which is a very effective way to save natural resources and act in accordance with the principle of sustainable development. It also contributes to the reduction of CO_2 emissions by using biomass, and, indirectly, CH_4 emissions by using biodegradable waste fractions.

Alternative fuels combustion allows for reducing NOx emission (Cement Ożarów S.A. 2019) and may reduce the SO_2 emission (Fyffe et al. 2016). The influence of the co-combustion of alternative fuels (with appropriate properties) on the pollutant emissions is minor if the process is carried out correctly and emissions comply with regulations (Hasanbeigi et al. 2012).

The maximum possible use of fuels in cement plants is estimated to 95% (Ecofys 2016). The use of waste fuels from cement plants instead of building new incinerators enables to save 15.6 billion Euro and avoid 41 Mtons of CO_2 (Ecofys 2016).

An important factor in the increase of the amount of alternative fuels burned is the policy of cement companies that pays particular attention to environmental aspects. Taking under consideration the growing interest of cement plants in using alternative waste fuels, the amount of the obtained heat should grow up within the nearest time. The use of RDF fuels can increase up to 1.7–2 kt in the coming years (Beer et al. 2017b).

The analysis focuses on the use of alternative fuels in Poland and regional, EU, and global trends. Next, a quantitative and qualitative analysis of fuels used in cement plants in Poland, in relation to the energy recovery in power plants, is presented. In addition, CO_2 emissions from the industry in terms of avoided emissions, are discussed. The multidimensional analysis takes into account legal conditions for the use of waste fuels as a source of renewable energy and the role of cement plants in the recovery of waste with a high gross calorific value.

The purpose of this paper is to analyze the applications of alternative fuels in the cement industry in Poland, as important components of circular economy and of sustainable development in particular. The analysis was conducted in a broad scope, from ecologically safe energy recovery from refuse to the role of cement plants in the waste management economy to the use of refuse as a source of renewable energy to the influence of the use of RDF's on CO_2 emission reduction. The analysis has been presented in the context of Poland, as well as in the perspectives of multi-national corporations that operate cement plants in Poland. This is the first paper demonstrating the application of alternative fuels in such a broad thematic context.

The use of energy from waste in cement plants: current status

The Polish cement industry uses mainly less energy consuming dry method of cement production. The basic fuel used in the Polish cement industry is coal (Figure 1). This is due to the fact that Poland has significant reserves of coal (Olkuski 2013). The growing price of coal and increasing demand for cement are the reasons why cement plants are increasingly interested in alternative waste fuels.

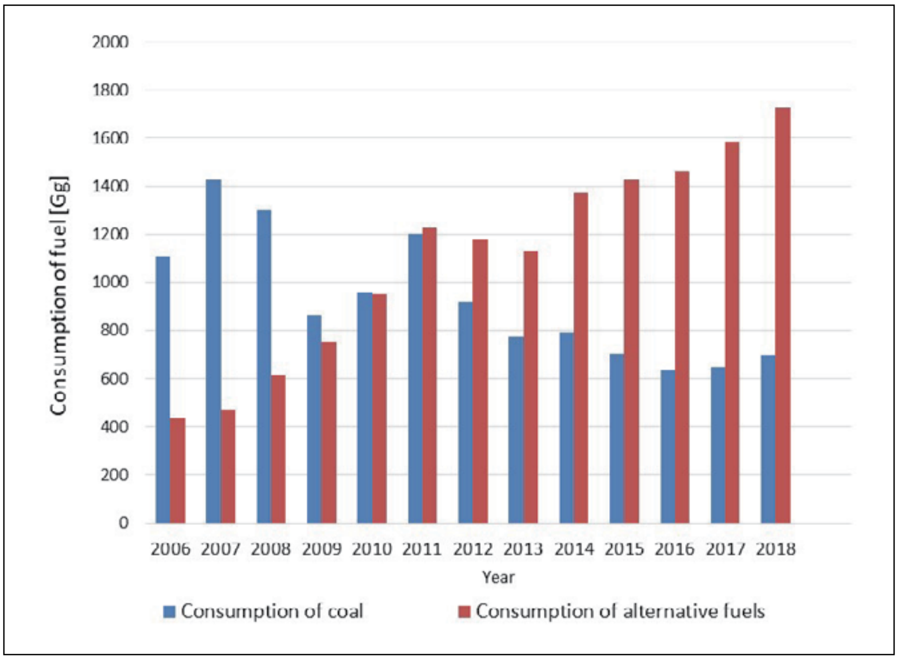

Fig. 1. The use of coal and waste-derived fuels in the cement industry in Poland, Gg, based on the data from (The Polish Cement Association 2006–2021)

The best alternative fuels for the cement industry are biomass waste fuels because CO_2 emissions from biomass combustion are traditionally assumed climate neutral, resulting in the zero emission factor for biomass. The amount of heat obtained from this kind of fuel has been rising since the year 2002 and is now bigger than the global and EU average (Table 1). The interest in waste fuels is related to the growing number of specialized plants producing stable alternative fuels. This is very important for cement plants which are not allowed to use fuels that have a negative impact on the combustion process and at the same time on the clinker production.

When comparing the amount of waste-derived fuels used in cement plants in Poland with the global and European average, an upward trend since 2005, when the average consumption was lower than in the EU and higher than the world average, can be observed. In 2008, the amount of waste fuels used in Poland increased significantly and exceeded the average consumption in the EU and the world. However, despite the dynamic increase in the use of waste fuels, higher consumption was recorded in Austria (e.g. waste tires, waste oil, paper and cardboard, solvents, plastics) (Mauschitz 2009–2018) and Germany (e.g. waste tires, waste oil, fractions of industrial and commercial waste (pulp, paper and cardboard, plastics, packaging, wastes from the textile industry, solvents), meat and bone meal and animal fat, waste wood, sewage sludge) (Verein Deutscher Zementwerke 2014–2019), the leaders in energy recovery in cement plants. These countries have a long tradition of using this types of fuel in cement plants with modern waste management systems. The comparison with the third country presented in Table 1, the Czech Republic (e.g. waste tires, biomass) (Czech Cement Association 2017–2019), which started using alternative fuels earlier and used them to a significant extent but recently reduced their use, is particularly interesting.

The quantities and types of refuse used for alternative fuel production have been significantly changing during the analysed period (Table 2). This was associated with the growing production of clinker and cement and the consequential increase of energy requirements. At the same time, the demand for cement was accompanied by the increase of conventional fuel prices and the issues relating to the storage of flammable fractions of refuse.

The factor that also affected the increase of the quantities of processed waste was the introduction of subsequent stages

Table 1. The share (%) of heat from the waste-derived fuels worldwide, in the EU countries, Poland and Central Europe based on the data from (The Polish Cement Association 2006–2021, Mauschitz 2009–2018, Verein Deutscher Zementwerke 2014–2019, Czech Cement Association 2017–2019)

Year	World	EU	Poland	Central Europe		
				Germany	Czech Republic	Austria
1990	1.5	2.0	0.0		2.0	
1997			1.34			
1998			1.39			
1999			1.15			
2000	6.0	9.0	2.07		15.0	33.47
2001			1.97			
2002			4.00			
2003			6.50			
2004			9.90			
2005	8.0	16.0	14.0	48.8	45.0	48.77
2006	9.0	18.5	19.0	50.0	39.0	48.39
2007	10.0	19.5	18.0	52.2	32.0	46.13
2008	11.0	21.0	26.0	54.4	40.0	50.92
2009	12.0	29.0	36.0	58.4	39.3	57.02
2010	12.0	31.0	39.0	61.0	38.9	62.78
2011	13.0	34.0	41.0	61.1	33.0	65.32
2012	14.0	36.0	46.0	61.0	34.1	68.41
2013	15.0	36.0	48.0	62.5	36.8	72.36
2014	15.0	39.0	52.3	63.4	35.5	75.45
2015	16.0	43.0	57.5	64.6	40.2	76.12
2016		44.0	60.0	64.8	47.1	78.28
2017		46.0	64.0	65.0	43.8	80.62
2018		48.0	65.0	67.5	70.2	81.24
2019		50.0*	70.0*	68.9	76.4	78.44

* Estimating Polish Cement Association

of emission trading programs in which the free emission assignments were reduced and replaced by free-market trading where the use of such fuels as meat-and-bone meal or sludge, that are part of biomass belonging to renewable energy source, allowed the cement industry to avoid a proportion of CO_2 emissions (Table 2).

Methods

This study takes a novel, multi-faceted approach to the issue of the use of energy from waste in the cement production process on the example of Poland; particular emphasis is placed on reducing CO_2 emissions and the use of renewable energy from biomass.

A quantitative and qualitative analysis of fuels used in cement plants in Poland in relation to the energy recovery in power plants is presented. The multidimensional analysis takes into account legal conditions for the use of waste fuels as a source of renewable energy and the role of cement plants in the recovery of waste with a high gross calorific value.

The study is constructed around four blocks of analysis:

1. The analysis of waste recovery in selected cement plants in Poland, the largest cement producers over the years, based on available data. Cement plants are grouped by international corporations, to which they belong. The obtained results are compared with the average data on the use of alternative fuels by corporations.
2. Based on the obtained data, the role of cement plants in the integrated waste management system, with particular emphasis on limiting the possibility of storing combustible municipal waste fractions with a gross calorific value higher than 6 MJ/kg, was analyzed.
3. The analysis of cement plant activities undertaken in the field of using alternative fuels from waste as a source of renewable energy was conducted.

Results

The use of alternative fuels started in the 1990s (Mokrzycki et al. 2003). The first step was an attempt to burn different types of waste. The lack of social acceptance resulted from the limited knowledge on this subject. Nowadays the majority of cement plants combust waste fuels. The share of alternative fuels and coal is highly variable. This is determined by technical, technological, and ecological limitations, but some cement plants do not publish data on the amount and type of fuels burned.

Górażdże Cement S.A.

The first attempts at co-combustion of alternative fuels from worn tires were conducted in 1992. The industrial use started in 1997. The waste includes tires, plastics, wood, rubber, textiles, non-recyclable paper, and many others (Górażdże Group 2016).

During the years 2014−2015, thanks to the co-combustion of the replaceable fuel, the emission of carbon dioxide was reduced by 218.386 kt. In the recent years, the unit indicator of CO_2 emission for a ton of clinker decreased by 7% (Górażdże Group 2016).

In the years 2014–2015, 46.9 kt of used tires and 479.7 kt of alternative fuels (shredded wood fuel, used tires, biomass, and sewage sludge) were subjected to the recovery process (Górażdże Group 2016).

In 2016, the Górażdże Cement Plant substituted 70% of conventional fuels with alternative fuels, which was significantly different from the average consumption in the HeidelbergCement Group (Figure 2) (HeidelbergCement 2004−2020).

According to estimates, the co-combustion of alternative fuels from biomass allowed for reducing carbon dioxide emissions by 402,000 tons of CO_2. Compared to the base value expressed in CO_2 equivalent, the emissions were reduced by 190,706 in 2016 and 211,387 in 2017 (HeidelbergCement 2004−2020).

Cemex

The cement plants Rudniki and Chełm belong to the Cemex Group, which is experienced in alternative fuel combustion, and use these types of fuel as well. The Chełm Cement Plant was one of the first to conduct the combustion of combustible waste fractions, and since the year 2001 it has been using the

Table 2. The use of the alternative fuels [kt] used in the cement industry in the years 2009−2018, based on the data from (The Polish Cement Association 2006–2021)

Specification	The use of the alternative fuels [kt]									
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Alternative fuel (19 12 10) – RDF	588.87	737.7	939.5	988.8	962.0	1,091.0	1,131.2	1,261.77	1,345.28	1,522.1
Tires and rubber scraps	64.63	89.5								
Tires			96.7	89.5	72.7	82.8	77.9	83.6	87.74	116.7
Rubber waste			15.6	17.5	14.5	33.7	42.0	62.77	72.61	47.1
Plastics	13.77	16.7								
Woodworking industry waste	12.32	7.2								
Coal enrichment by flotation waste	13.19	40.9	49.5	28.2	20.1	37.1	30.0		33.86	
Power plant wastes			102.2	36.0	35.5	92.7	86.1	38.5	32.8	
Sewage sludge	2.37	11.5	15.7	9.8	6.3	5.6	9.3	8.55	9.36	15.3
Others	56.7	78.5		10.7	19.5	30.0	1.2	11.67	3.25	28.1

RDF – alternative fuel (19 12 10). The mentioned cement plants burn the following types of waste: bone meal, fluid fuel, dry sewage sludge, shales, tires, and alternative fuel 19 12 10 type RDF (Figure 3, Table 3). The amount of heat obtained from alternative fuels in Cemex plants in Poland increases almost every year (Figure 3).

From 2001 on, the Chełm Cement Plant has been investing in modern infrastructure for alternative fuels, fuel storage sites, kiln gas by-pass system, biomass crushing systems, liquid fuel feeders, and meat and bone meal and dried sewage sludge systems, thus annually increasing the amount of energy recovery from waste (Table 3) (Cemex 2016). In 2020, the Chełm Cement Plant substituted over 93% of conventional fuels with alternative fuels, which was significantly different from the average consumption (25.3%) in the Cemex Group (Figure 3) (Cemex 2002–2020).

The recovery of 300,000 Mg alternative fuel production purposes in 2019 made the net CO_2 emission lower by about 190,000 Mg (Cemex 2002–2020, Cemex Polska 2010–2016, Cemex Polska 2017–2019).

The Ożarów Group

Alternative fuels used in cement plants of the CRH Group include: solid recovered fuels (SRF), used tires, solvents, used oil and biomass (meat and bone meal, sewage sludge, rice shells, etc.). In 2017 Cement Plants of the CRH group

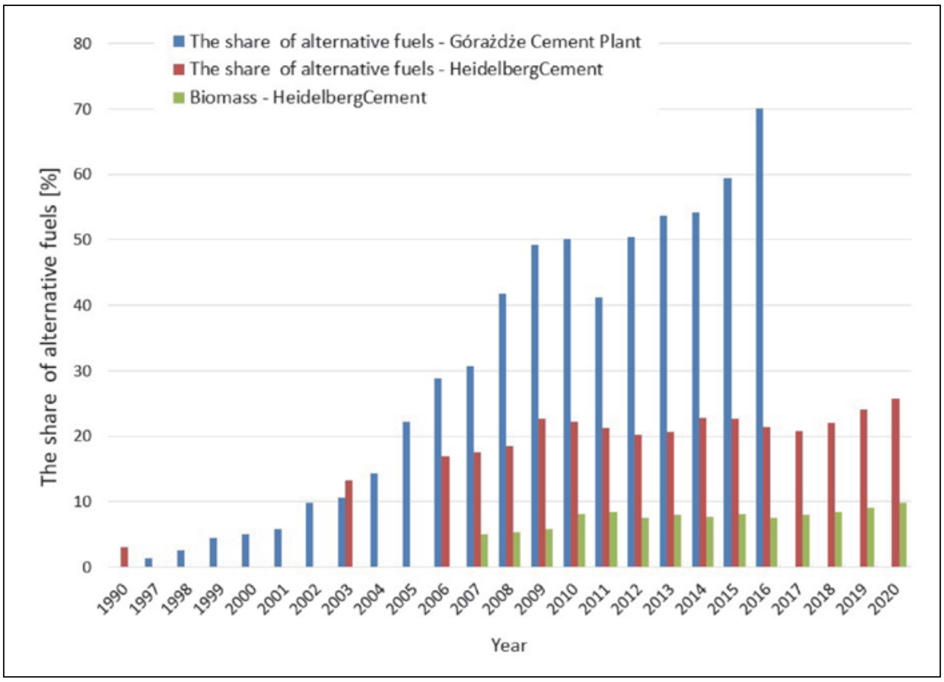

Fig. 2. The share % of waste fuels in the total amount of fuels used in Górażdże Cement Plant and HeidelbergCement, based on the data from (Bieniek et al. 2011, Górażdże Group 2016, HeidelbergCement 2004–2020)

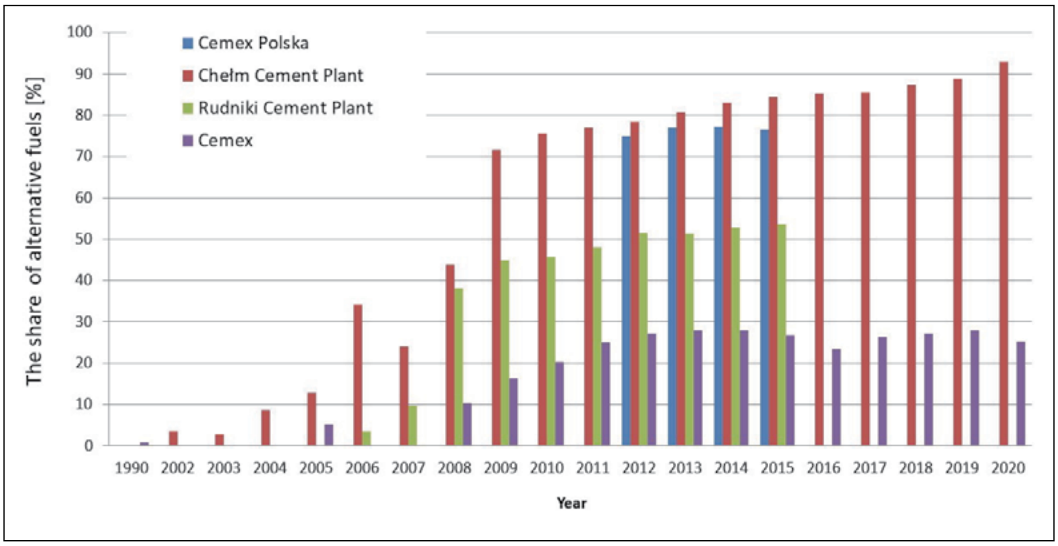

Fig. 3. The share % of waste fuels in the total amount of fuels used in individual Cement Plants of the Cemex Poland Group – based on the data from (Bąblewski 2012, Cemex Polska 2010–2016, Cemex Polska 2017–2019, Cemex 2002–2020)

used 2.0 million tons of alternative fuels (47% total energy consumption), in 2016 – 1.9 million tons, while in 2015 – 1.6 Mt – which is about 45% of the total energy consumption for their cement plants in the European Union (CRH 2018).

Currently, co-incineration of waste in the form of alternative fuel, which substitutes about 50% of conventional fuel, is carried out in the Ożarów Cement Plant. The increase in the substitution of alternative fuels was possible thanks to investments and the development of modern installations for dispensing alternative fuels (The Plan... 2016c).

LafargeHolcim

In 2016, cement plants owned by Lafarge used 362.500 kt of alternative fuels, replacing 75.8% and 71.4% of the heat obtained from conventional fuels in the Kujawy and Małogoszcz cement plants, respectively (LafargeHolcim 2017−2020). The LafargeHolcim Group produced 15 and 16.5% of heat from alternative fuels in 2016 and 2017, respectively. As a result, CO_2 emissions were reduced by 8 million tons.

In 2017, the substitution rate of alternative fuels amounted to 72.9% (or 399,410 kt) and, in 2018, to 73% (or 414,504 kt) in the Lafarge cement plants in Poland. The Lafarge corporation plans to attain at least the proportion of 84% (LafargeHolcim 2019).

The Nowiny Cement Plant (Dyckerhoff Poland)

In 2014, the share of heat from alternative fuels in the Nowiny Cement Plant reached 58.4% – a very significant achievement compared to the average for Buzzi Unicem Group (19.3%). In the year 2015 the Nowiny Cement Plant reached the level of 60.5%, while the average for the whole Group was 20.4%. In the years 2016–2017, the share of heat from alternative fuels in the Nowiny Cement Plant remained at the level of 60% with the average for the whole group at 27 and 26%, respectively. In 2020, the share of heat from secondary fuels for the whole group amounted to 29.2%, while in the Nowiny Cement Plant it was 67.5%, which was the third result after Germany (72.7%) and the Czech Republic (80.8%). The Buzzi Unicem Group estimates that the use of biomass in 2018 allowed the group to reduce CO_2 emissions by 389,957 tons (Buzzi Unicem 2014–2020).

"ODRA" S.A. Cement Mill

The use of alternative fuels in Odra Cement Plant started in 2015. In the years 2016–2019, Odra Cement Plant used 126.3 kt of alternative fuels (in 2019 – 32.158 kt). These fuels are produced only from non-hazardous waste. In the years 2015–2019, the amount of heat obtained from alternative fuels was respectively: 2015 – 22.8%, 2016 – 43.9%, 2017 – 57.2%, 2018 – 63.3%, 2019 – 61.1% ("ODRA" S.A. Cement Mill 2018, 2019).

Discussion

In the long-term perspective, the production of energy from waste in Poland is estimated to amount to 80%; in the medium-

Table 3. The alternative fuels used in Chełm and Rudniki Cement Plants,%, based on the data from (Bąblewski 2012, Cemex Polska 2010−2016, Cemex Polska 2017−2019))

Year	Chełm Cement Plant							Rudniki Cement Plant		
	Bone meal	Biomass	Liquid fuels	Dried sewage sludge	Carbonaceus shale	Tires	The alternative fuel – type RDF	Dried sewage sludge	Coaly sludge	Tires
2002							3.50			
2003							2.60			
2004							8.60			
2005							12.70			
2006					2.86		31.34			
2005					1.48		22.60			
2008					0.93	1.87	41.06			4.15
2009		0.08		0.40	0.21	2.80	67.78		0.15	3.58
2010	0.01	0.45	0.07	0.98	0.00	4.06	66.41	0.76	0.00	1.05
2011	0.34	0.05	0.12	1.40	0.00	1.94	69.40	1.20	0.20	0.32
2012	2.50	0.10 (straw)	0.004	1.40		3.9	79.20	3.10		52.7
2013	6.40		0.10	0.40		0.8	83.70			4.15
2014	6.40		0.01	0.20		2.0	82.50		0.15	3.58
2015	7.95		0.03	0.17		3.64	72.72	0.76	0.00	1.05
2016	7.54		0.08	1.18		2.69	81.24			
2017	9.14		0.10	0.19		2.60	79.69			
2018	6.98		0.13	0.27		1.90	83.65			
2019	7.61		0.13	0.18		2.49	83.06			

-term (5–10 years) it is projected to amount to 65%, while the current level is 52% (2014) (Beer et al. 2017a, b). According to the projections, the level of use of RDF's in Poland increased from 52% in 2014 to 65% in 2018, in a short period of four years.

Considering the Polish Cement Association estimation of 2019 (70%), the proportion of the planned 80% may be achieved much sooner, especially that some of the cement plants in Poland, e.g. the Chełm Cement Plant, reached the rate of 88.7% in 2019.

In the long-term, the estimated value is the same, while in the case of the medium-term it is higher by 5% compared to the EU average. The expected 65% share of waste fuels in the combustion of cement plants will allow for reducing CO_2 emissions to 2.7 kt, while 1.5 kt of waste will be processed, and 1.1 kt of conventional fuels will be saved. In addition, this will reduce investments in new waste thermal treatment plants by 1.2 billion euro (Beer et al. 2017a, b).

The increase of the use of RDF's caused a considerable reduction of natural fossil fuel consumption in cement plants.

Despite the projected increase in the use of waste fuels, there are three main obstacles indicated by experts, including (Beer et al. 2017a, b):

- Excessive bureaucracy,
- Unavailability of high quality waste fuel,
- No social acceptance.

The significant role of the cement industry in waste management is maintained for many years due to the annually increasing quantities of waste used as alternative fuel (Figure 1, Table 1).

The introduction of a ban on storage of waste with the following codes: 19 08 05, 19 08 12, 19 08 14, 19 12 12 and waste classified as 20 group, characterized by a gross calorific value above 6 MJ/kg (Regulation of the Minister of Economy of 16 July 2015 on the acceptance of waste to landfills (Journal of Laws, 2015, item 1277)), led to the fact that the cement industry, as the only one using alternative fuels in Poland, has become an attractive consumer of combustible waste fractions from regional municipal waste processing plants. Currently, there are seven municipal waste incineration plants in Poland that are not able to meet the demand for thermal treatment of waste with the gross calorific value exceeding 6 MJ/kg.

An additional advantage for the use of alternative fuels in waste management is the fact that no by-products are generated during thermal treatment, as solid by-products of the combustion process are included in the clinker. Therefore, there is no problem with their utilization, as in the case of waste incineration plants.

The analysis of the state of waste management in provinces where cement plants are located indicate that there is no need to provide additional capacity for processing by-products of the treatment of municipal waste (Lublin provinces − Chełm Cement Plant and Świętokrzyskie provinces − Małogoszcz Cement Plant, Nowiny Cement Plant, Ożarów Cement Plant), while in the case of Opole Province (Górażdże Cement Plant) attention should be paid to the significant role of cement plants in thermal processing and the analysis of their potential in the field of rational waste management (The Plan... 2016a, b, c).

The main obstacles to waste management in Poland that were determined by experts are the limited amount of waste suitable for fuel production and poorly developed waste treatment industry.

Waste fuels used in the Polish cement plants are stable thanks to the proper standards and sufficient control system. That is why cement plants, according to their technological means, may increase the amount of heat obtained from alternative fuels. The analysis indicates a clear reduction in public expenditure on waste, low costs of waste storage, and the risk of future competition for the availability of suitably prepared waste as the main obstacles to the development of the use of waste-derived fuels.

These barriers, taking into account changes in the field of waste management that have taken place in recent years in Poland, are becoming less and less significant. Compared to the year 2012, the amount of mixed waste recycled in 2016 increased fourfold, while the amount of waste subjected to thermal treatment increased forty-two times (Change 2017), which is associated with the development of new incineration plants and the increased use of RDF fuels by cement plants.

The reduction in the amount of waste that can be stored due to their gross calorific value and the increase in landfilling regional costs the reason why municipal waste processing plants are interested in the production of fuels from waste.

The use of renewable energy sources

According to The Act of 20 February 2015 on renewable energy sources (Journal of Laws of 2015, item. 478), biomass used in cement plants includes: animal meal, wood waste, sawdust, and sewage sludge. According to this definition, biomass may also include biodegradable fraction (waste labelled with the code 19 12 10) and biodegradable waste other than municipal waste classified into 02, 03 and 19 groups. Therefore, the use of waste as an alternative fuel in cement kilns contributes to the reduction of the total CO_2 emissions.

Owing to the use of RDF's, the Górażdże Cement Plant limited CO_2 emissions by 218,386 tons (2014−2015), the Cement Plant of the Cemex Group by 219,321 Mg (2017), and the Lafarge Cement Plant by 8 million tons. The limitation of such emission is also specified by the Ożarów Group.

At the same time, the use of alternative fuels from biomass is in line with the trends observed in the Polish power industry, where biomass is the most important renewable energy source (Mokrzycki and Uliasz-Bocheńczyk 2009; Uliasz-Bocheńczyk and Mokrzycki 2015). However, as in the case of each fuel, biomass burning causes pollution and waste generation. However, in contrast to the energy sector, bituminous coal is no longer the main fuel in many cement plans.

The cement plants operating in Poland also use biomass, primarily in the form of sludge and meat-and-bone meal (e.g. the Cement Plants of Chełm and Rudniki, Ożarów), also constituting RDF-type of fuels (EWC Code: 19 12 10), applied in the whole cement industry in more than 80% of all alternative fuels.

It should also be emphasized that the use of biomass-derived fuels in Polish cement plants (17%) is higher than the EU average (14%) (Beer et al. 2017a, b).

Conclusions

The cement industry in Poland has been using successfully this kind of fuel for many years. The level of about 70% of the use of alternative fuels was reached in Poland in 2019, and, taking into consideration the regulations concerning flammable fraction refuse storage and the limited number of incineration plants, no problems are expected with the availability of such fuels. Consequently, Poland exceeded the level assumed by the CEMBUREAU: 60% of alternative fuels in 2030, and is close to reaching 90% by 2050 (CEMBUREAU 2020).

The example of cement plants in Poland shows that it is possible to reduce carbon dioxide emissions to levels comparable to countries with a long history of energy recovery from waste in a relatively short time. Thanks to the use of alternative fuels, cement plants can partially avoid CO_2, emissions, use renewable energy, and become an important part of the waste management system.

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