# GREENHOUSE GAS REDUCTION THROUGH USE OF WASTE AS AN ALTERNATIVE FUEL

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## ABSTRACT

The problem caused by the usage of storage and incineration methods for disposal of waste is one of the most important environmental problems today. The usage of waste as alternative fuels or raw materials in the cement industry reduces the consumption of nonrenewable energy resources and prevents the rapid depletion of natural resources. The co-processing of waste with raw materials in the cement industry is an opportunity to reduce carbon dioxide emissions. In the cement industry, a cement clinker kiln with a long retention time and an oxidation atmosphere at high temperature provides combustion of waste completely. On the other hand, the usage of alternative energy resources has a positive impact on reducing the dependency on fossil fuels and in reducing $CO_2$ emissions. The co-processing of waste reduces carbon dioxide emissions resulting from the use of fossil fuels during the production of cement and prevents carbon dioxide emissions caused by incineration plants. Non-renewable energy resources in the world can be evaluated economically. Waste disposal can be carried out and carbon dioxide emissions caused by waste incinerators can be prevented by using waste instead of fossil fuels in the cement industry. The aim of this paper is thus to show the effect of using waste as an alternative fuel to reduce greenhouse gas emissions.

**Keywords:** Cement Industry, Waste, Carbon Dioxide Emissions, Energy Recovery

## INTRODUCTION

The storage and incineration of waste are two of the most important environmental problems. The use of waste as an alternative fuel in the cement industry reduces the rapid consumption of natural resources. The cement industry is one of the most important sources of greenhouse gases. About 5-7% of $CO_2$ emissions in the world the cement industry E.Benhelal et al.(2013). The co-processing of waste with raw materials in the cement industry is an opportunity for reducing carbon dioxide emissions. It is estimated that the cement industry is accountable for about 5% of the global anthropogenic $CO_2$ emissions M.Naranjo et al. (2011). The cement industry has identified measures to reduce its carbon footprint through energy efficiency, reduction of the clinker factor, and the use of alternative fuels including carbon-neutral fuels. Portland Cement Association (2008).

In the cement industry, the length of retention time, the oxidizing atmosphere and high temperature environment of the cement clinker kiln provides combustion and degradation of the waste completely. The decrease in fuel expense and a reduction in the potential amount of $CO_2$, have been the driving force in prefering alternative fuels M. B. Larsen (1983). On the other hand, the use of alternative fuels has a positive impact on the reduction of the fossil fuel emissions as well as a reduction in the dependence on fossil fuels. In both the incineration and storage of waste

greenhouse gases will be produced. Co-processing is a more environmently friendly approach than the incineration and storage of waste. $CO_2$ emissions are reduced without requiring any additional investment and effort. The use of alternative fuels attemps to fulfill environmental responsibility of cement industry in producing sustainable cement A. Scheuer (2002).
A greenhouse gas inventory report published by the Turkish Statistical Institute, in 2012, the total greenhouse gas emissions have been calculated to be 439.9 million tons of $CO_2$. In 2012, the amount of greenhouse gas produced by energy sector, industrial processes, waste and agricultural activities are 308.6 Mton (70.2%), 62.8 Mton (14.3%), 36.2 Mton (8.2%) and 32.3 Mton (7.3%) respectively. When Turkey's greenhouse gas emissions between 1990 and 2012 were examined, it was discovered that they had risen from 188.5 Mton to 439.9 Mton. Greenhouse gas emissions from the industrial sector increased from 15.5 Mton to 62.8 Mton. Greenhouse gas emissions from waste increased from 9.7 Mton of $CO_2$ to 36.2 Mton of $CO_2$. The cement industry produced 30.328 Mton of $CO_2$ in 2012 which accounted for 48.29% of all greenhouse gas emissions from industry. The most important sources of greenhouse gases are from waste landfills (94.8%) and waste water treatment plants (5.2%) TUİK (2012).

**How to Produce Cement Clinker?**

With the increasing use of fossil fuels, the process of industrialization and the rise of greenhouse gases have placed climate change on the agenda of the cement industry. Greenhouse gases from human activities are caused by the use of fossil fuels as an energy source and by from chemical processes. The direct sources of $CO_2$ emissions in the cement industry are calcination of the carbonate in the raw material and the carbon content of the fuel used for combustion. Two types of fuel used in rotary kilns: primary fuels are namely conventional fuels such as coal, fuel oil, and natural gas and secondary fuels are namely alternative fuels such as waste and solar, wind. Fuel oil, coal, natural gas, petroleum coke, anthracite or their mixtures are used in various ratios, in the cement rotary kiln. The cement sector has an important place in the sectoral breakdown of industrial $CO_2$ emissions. The $CO_2$ emissions originating from the cement industry contributes to about 5% of the world's anthropogenic $CO_2$ emissions G.Stefanovic´ et al. (2010); D.K.Fidaros et al. (2007); H.Mikulčić (2013). Therefore, the cement sector is now trying to reduce its $CO_2$ emissions. One method of reducing $CO_2$ emissions is the use of alternative fuels.

The increase in investments will fuel demand for cement in the construction sector. Sustainable production is a fundamental principle of the cement industry. The substitution rate of waste varies with its moisture, carbon content and calorific value. The industrialized countries have had great success in replacing fossil fuels with alternative fuels in cement manufacturing for over 25 years. In the majority of European countries, the percentage of using alternative fuels for manufacturing cement is more than 35% I.Z. Bribian (2011). The cement production consumes approximately 120 kg of coal per ton of cement. About 25 million tons of coal are required to service the demand of cement in the Europe an Union by Cembrueau members annually M. Chinyama (1998). On the average 185 kg of coal were used for each ton of clinker in Turkey (the heat value of the coal was 5,000 kcal/ kg ) Ş.Gülen et al. (2003). When 4.3 billion tons of cement were produced in the World in 2014 and 69.7 million tons of cement were produced in Turkey, the importance of coal consumption in the cement industry is clear Ministry of Economy (2016). For example, the cement sector in Thailand generated about 20,633 kton of $CO_2$ emissions in 2005. The period 2010-2025 has been chosen as the scenario period to determine the potential and costs of $CO_2$ abatement in different technologies. Fourty-one $CO_2$ abatement technologies and measures for the cement industry were analyzed. The cost-effective annual $CO_2$ abatement potential for the Thai cement industry during the 15 years scenario period (2010-2025) is equal to 3,095 ktonnes $CO_2$/year. This is about 15% of the Thai cement industry's total $CO_2$ emissions in 2005. The total technical annual $CO_2$ abatement potential is 3143 ktonnes $CO_2$/year, which is about 15.2% of the Thai cement industry's total $CO_2$ emissions in 2005 A. Hasanbeigi et al. (2010).

The reduction of greenhouse gases and the improvement of energy efficiency are the determining factors of competitiveness in the cement industry. The use of waste for energy recovery in the fight against climate change aims to reduct fossil fuel consumption. The reason for amount of greenhouse gases generated by cement industry is the combustion of the raw material with fossil fuels at high temperatures. Natural raw materials such as clay, limestone and marl are extracted from the quarry area. The raw material brought from the quarry is reduced by the crusher, to gravel 25x25 millimeters. The crushed raw materials are stocked according to type. The crushed raw materials are all converted to farine in mills raw materials of cement are carefully measured. Molecular components of farine are silica and lime. Lime enters the mixture mostly from rocks containing calcium carbonate like limestone or marl. Clay is the main source of the silica. These are followed by alumina and iron oxide and lesser amounts of other agents such as magnesium and alkali oxides. Raw meal (farine) is fed to a calciner preheater consisting of

cyclones. The oxides in raw materials become free firstly by heating them to 800-1000 °C and they then form new compounds between themselves. The semimanufactured product is called clinker. The sintering of clinker is completed by combusting the preheated raw meal at 1500 ºC in a rotary kiln. After the kiln process, the clinker temperature is lowered to 100 ºC at a cooling unit using blown air. Cooled clinker is stocked in closed storage silos. The cement clinker is next taken to a mill and mixed with raw materials such as gypsum, limestone and tras for producing cement. Cement, ground in the mill, is stocked in the cement silos. In the clinker sintering process, high process temperatures are required to convert the raw material mixture to cement clinker. The rotary kiln temperatures must be kept between 1400-1500 °C at the sintering area, and the flame heat at 2000 °C. The clinker must be sintered in oxidizing conditions. The coal used in the kiln as fuel was crushed in coal mills for increasing the reaction surface area. The coal is pulvarized in the burner pipe to the kiln; the raw meal is fed into the other side of kiln. In cement production, fuel isn't burned in another oven or incinerator for its energy. The reactions and combustion are performed in the same enviroment.

Energy costs are increasing worldwide.This has led to an interest in the recovery of waste as an alternative fuel saving energy in cement production U.Kaantee, et al. (2004). Cement clinker production is an energy intensive process which consumes 3.3 GJ energy per ton. The electricity consumption is approximately 90-120 kWh / ton in the cement industry. The use of liquid and solid waste instead of coal reduces $CO_2$ emissions and fuel costs M. Chinyama (1998). The cement industry uses 2-5% of the total energy used in all industries. The main techniques for reducing $CO_2$ emissions and saving energy involve the reduction of fossil fuel usage replacing them with alternative fuels M. B. Ali, et al. (2011). Using waste instead of fossil fuels in the cement reduces the carbon dioxide emissions arising from any possible incinerator and waste storage areas. Reducing the carbon footprint by the use of alternative fuels in the cement industry is one of the targets of this sector M. Naranjo, et al.(2011)

European cement producers have intended to substitate alternative fuels for non-renewable ones while at the same time meeting the market demand. Therefore, the use of waste as an alternative fuel is now placed on the agenda of the cement sector. Using the non-renewable fuel with waste is important to eliminate any damage to the environment, as well as for reducing the use of non-renewable energy.The fuel saving by use of alternative fuel (biomass) is 0.60 Gj/ton cement and the direct $CO_2$ reduction is 59.60 kg$CO_2$/t ckinker A.Hasanbeigi et al. (2010).

In the 1980s, the sector began to use waste oil and used tires at eighties years. Sector has continued in the 1990s with solid wastes added like hazardous waste, paint sludge, waste oil, waste tires, solvents, wood, plastic, and various domestic and industrial wastes, including textiles, contaminated wastes, sewage sludge, drilling mud and other materials. The range of alternative fuels is extremely wide. The traditional kiln fuels are gas, oil and coal. Materials like waste oils, plastics, auto shredded residues, waste tires and sewage sludge are often proposed as possible alternative fuels for the cement industry. In additionaly, all kinds of slaughterhouse residue are offered as fuel nowadays U. Kääntee, et al. (2004). Norcem, Norway's sole cement manufacturer has had experience with alternative fuel combustion since 1987, when combustion of liquid hazardous waste was started. Since then, different types of solid alternative fuels, such as solid hazardous waste and refuse derived fuel have come into regular use L.Tokheim, et al. (2001). While deciding the selection of the suitable material for the cement clinker production, one has to consider that it should not interrupt the manufacturing process. Moreover, the potential environmental effects and the quality of final product should be considered.

**The Importance of Co-prosessing**

Using waste for energy recovery activities is licensed by the Ministry of The Environment and Urbanism in Turkey. Energy recovery in cement plants plays an important role in the disposal of waste used as an alternative fuel in Turkey, as in the rest of the world. Co-prosessing means using of waste as a source of energy along with fossil fuels such as coal, petroleum and natural gas. The alternative fuels derived from waste are subjected to certain processes before use such as precautionary drying, sorting, crushing, blending, homogenization feeding to kiln and dosing. European legislation in the substitution process changes from country to country considering market conditions. The boundaries of using waste as additional fuel in the cement sector in Turkey were delineated with the inclusion of the Communiqué published in 2005. The regeneration legislation has required an increase in waste use. The regulations about waste incineration were published in 2010. The purpose of the regulation is preventing the adverse affects on the environment, especially the surface water, groundwater, air, and soil and to reduce any risks that may affect human health. The regulation about co-processing and incineration describes the aim of using waste as an alternative or additional fuel for energy production and the thermal disposal of waste. The regulation also describes the co-

processing plant as a facility located with all units such as waste reception unit, temporary storage, pre-treatment unit, waste feeding and air supply systems and flue gas treatment units. The same regulation identifies the temporary storage of leftovers of burning waste and waste water treatment, including measuring devices and monitoring systems used to controlling the combustion process. The legislation in Turkey allows for a 40% use of waste in cement plants' thermal power generation. The clinker kilns are preferred to incinerators because of the high temperature, oxidizing and alkalin atmosphere for waste disposal. The combustion chamber of the kiln has a long retention time (more than 8 seconds) and is available for completing the combustion of waste. In order to obtain a license for a cement plant; gas from the combustion of waste must be burnt for at least 2 seconds at 850 °C in a controlled and homogeneous combustion zone. The retention time should be 2 seconds and the minimum temperature should be 1100 °C in the case of co-incineration of hazardous wastes contained in an amount greater than 1% of halogenated organic substances. Total dust, carbon monoxide, hydrogen fluoride, hydrogen chloride and oxygen, as well as pressure and temperature must be measured continuously. The daily average of gas emissions must not exceed the limit values set out in Table. 1 and 2.

Daily average values for total dust, HCl, HF, NOx, $SO_2$ and TOC (for continuous measurements), as average values over the sampling period of a minimum of 30 minutes and a maximum of 8 hours for heavy metals and as average values over the sampling period of a minimum of 6 hours and a maximum of 8 hours for dioxins and furans. All values are standardised at 10 % oxygen. Half-hourly average values shall only be needed in view of calculating the daily average values.

Table 1. Total emission limit values ($mg/Nm^3$ except for dioxins and furans) for the following –polluting substances

| Pollutant | C $mg/m^3$ |
|---|---|
| Total dust | 30 |
| HCI | 10 |
| HF | 1 |
| For existing plants $NO_x$<br><br>For new plants $NO_x$ | 800<br><br>500 |
| Cd + Tl | 0,05 |
| Hg | 0,05 |
| Sb + As + Pb + Cr + Co + Cu + Mn + Ni + V | 0,5 |
| Dioxins and furans ($ng/Nm^3$) | 0,1 |

Table 2. Total emission limit values ($mg/Nm^3$) for $SO_2$ and TOC

| Pollutant | C |
|---|---|
| $SO_2$ | 50 |
| TOC | 10 |

***Emission limit values for CO values are given in Industrial Air Pollution Control Regulations limits.***

The cement factories were established by operating using primary fuels in high temperature kilns such as waste incinerators. There are some distinct advantages of cement industry kilns over incinerators. All materials are processed in the same kiln together so the problem of ash does not occur; ash has become one of the raw materials that makes up cement. Another major advantage of burning waste materials in the cement kilns is that no residues are produced. The ash is completely incorporated in the clinker J.S. Damtoft, et al. (2008). Ash absorption, high combustion temperatures, long retention time and oxidizing atmosphere in the kiln and provide alternative fuel safety for the environment. Tires, oils, solvents, biomass, wastes such as animal waste are being used today instead of fossil fuels J.Karagiannis, et al.(2008). Raw materials and fuel are processed in the same kiln together. A separate boiler or tank is not needed for obtaining energy in the cement industry. Because all gas emissions are burnt at 1500 ° C, flue gas treatment such as scrubber is not required. Therefore, a waste water treatment plant is not necessary because of the scrubber. The co-processing in the same kiln produces emissions in one step instead of emissions coming from incineration and cement manufacturing processes separately. The use of waste in the cement industry will prevent gas produced by the burning of waste in an incinerator. The fuels used at high temperature during the production of cement will produce $CO_2$ emissions. Burning hazardous waste in an incinerator will produce $CO_2$ emissions, too. If the both processes are done in the cement plant instead of in separate kilns $CO_2$ emissions can be reduced significantly. Sustainable reduction of $CO_2$ emissions in the cement production has an important place. The use of alternative fuels is important for $CO_2$ reduction. O. Ekincioglu et al. (2013).There is a potential for reducing $CO_2$ emissions from the burning of fossil fuels by using alternative fuels Cembureau (2009). In recent conservation of natural resources and the reduction of $CO_2$ emissions have increased by the using alternative fuels as energy sources M. Schneider, et al. (2011). Cement plants' combustion capacity can be used instead of establishing new incinerators therefore avoiding any investment costs.

The ash resulting from the combustion of waste bonds into clinker and residual waste is not produced. Dangerous ash produced by incinerators should be stored in waste landfill. In co-processing it isn't necessary to use any first ignition fuel to create heat. Due to the production of cement, high temperature already exists in the system. Fuel used for the first ignition in the incinerator won't be used in the cement kilns. It is an advantage for reducing the emissions produced from the ignition. Energy recovery is located above of the disposal in the tridational waste pyramid. Thus, incinerators should be used in the absence of cement plants. The use of alternative fuels to reduce energy consumption and environmental costs has become important in recent years. High-temperatured alkaline environment and long-term process in the kiln provides a suitable environment for the use of hazardous waste as an alternative fuel. This issue was written up as a guide in Austria A. Rahman, et al. (2015). The alkaline environment, high temperature and long retention time allow a wide range of waste and hazardous material to be burned for the rotary kiln. The decisive factors promoting the use of cement kilns for the utilization of waste are: the high incineration temperature, the large area of the kiln, the significant length of the kiln and the alkaline environment inside the kiln E. Mokrzycki, et al. (2003). Due to the negative effects of fossil fuels (coal and petcoke most commonly used) on the environment the fuel derived from liquid and solid hazardous waste is being used in Norway, and the use of waste as a fuel is continuing to increase L.Tokheim et al. (2001). The use of waste as an alternative fuel in cement factories all over the world to reduce energy costs is an environmentally friendly way. An opportunity of using waste as an alternative fuel reduces fossil fuel demand and prevents the high installation costs of incinerators. Amount of the CO2 reduction has been presented along with the payback period for different energy savings measures as well N. Madlool et al. (2011). Therefore, by using of alternative fuels instead of coal to reduce the $CO_2$ emissions will give great results in a shorter time. Alternative fuels will reduce environmental pollution.

**Changes in Turkish Legislation on GreenHouse Gas Emissions**

"Regulation on Monitoring and Reporting of Greenhouse Gas Emissions" was published on April 25, 2012 by The Official Gazette numbered 28274 and entered into force by The Environment and Urban Planning Ministry. The regulation was revised in the Official Gazette Numbered 29003, on May 17, 2014 dated by amendments in some rules. Plants are responsible for the regular yearly monitoring of subjects to the reporting and verification process. The plants will prepare and submit the plan for monitoring and reporting. Verified emission reports containing emission measurements in the period between January1, 2015 and December 31, 2015 should be presented to the Ministry by April 30, 2016.

## MATERIAL METHODS

Greenhouse gases from cement production are due to raw material calcinations and fuel combustion. There are two accepted methods for determining the greenhouse gas emissions produced by the combustion of fuel. These methods are based on the calculation and measurement. The calculation based method determines emissions by using activity data obtained from the source streams by measuring systems and the laboratory analysis or default additional parameters. The measurement method based on measuring device that must be installed in all emission sources.
The measurement-based method determines emission sources from measuring $CO_2$ concentrations and measuring the flow of the transferred gas including in cases where the monitoring of $CO_2$ gas is transferred between facilities and greenhouse gas concentrations in the gas flow are continuously measured. Multiple fuels are combusted in cement kilns simultaneously. It is not possible to determine which greenhouse gas in the combustion reaction was produced from which. Therefore, in this study the amount of greenhouse gases will be calculated by using a method based on calculations. The formula, received from an official regulatory body is used in the calculation as follows.

***"Estimated Annual Emissions Quantity =***
***Data * Net Calorific Value* Emission Factor * Oxidation Factor."***

The emission factors are the fixed ones which have been demonstrated as a result of scientific work and identified by the Intergovernmental Panel on Climate Change, used in the methodology.

***Activity data is the amount of burned coal.***
Net calorific value (NCV) excludes the heat energy for the evaporation of water in fuel or material and the net energy that will be released from the burning with oxygen under standard conditions. 11.9 TJ / Gg (IPCC 2006 Guidelines) taken for lignite is the net calorific value.
The emission factor states the average emission rate of greenhouse gases source categories and presumes that the combustion and other chemical reactions are completed in an activity data.
Oxidation factor means that the resulting combustion of carbon is oxidized to carbon monoxide which is taken (as molar equivalent of carbon monoxide to carbon dioxide is taken) and refers to the ratio of total carbon content of fuel. It was obtained as 1 from the regulatory body.

***The amount of coal energy equivalent to the amount of waste energy will be used as the activity data.***
To determine the amount of coal as the activity data, the amount of total energy obtained from waste will be divided by the calorific value of coal. The amount of waste and calorific value of waste were compiled by the Cement Manufacturers Association of Turkey. The data for 2015 was collected from all cement plants in Turkey.

## RESULTS

The worldwide production increased at tremendous rate after World War II in line with population growth. The increasing demand for energy is essential in the production process. The natural resources are rapidly been depleted with the unsustainable use of coal, natural gas, and oil in meeting energy demands. Another problem is the toxic waste, stemming from industrialization. Adours, proliferation of pests, the spread of germs, diseases, acid rain, the contamination of groundwater by leachate, the damage to crops can all be counted is environmental problems caused by these wastes. Because of these environmental problems, soil, water and air quality is reduced; the economics of specific regions and the natural world it self are all being affected adversely.

One of the major problems caused by waste is the producing greenhouse gas emissions. The carbon dioxide concentration in the atmosphere is increasing day by day. The carbon dioxide is a gas which has the largest share of the greenhouse gases. Important sources of greenhouse gases in Turkey are landfills after the energy sector and industrial sectors. The cement industry is one of the leading consumers of energy. In addition, the cement industry is one of the leading producers greenhouse gases.

Carbon dioxide gas is produced by burning fossil fuels such as oil, coal and gas. The carbon dioxide concentration in the atmosphere is increasing day by day. This has accelerated the process of global warming and the greenhouse effect. It is evident that there is a very strong link between global warming and energy use. The climate change is a versatile, complex and global problem threatening the lives of future generations, which has important environmental consequences. This problem adversely affects all countries of the world both developed and underdeveloped. Different greenhouse gas emission scenarios based on climate models indicate that significant climate changes will be expected in the near future. The best way of prevent climate change and to minimize the negative impact of these changes is to reduce the anthropogenic greenhouse gas emissions. Although environmental pollution has increase rapidly as a result of industrialization, a great deal of research is being done to protect the environment. Waste should be used instead of coal to reduce the amount of greenhouse gas emissions during the cement production. Use of waste as fuel in the cement kilns is defined as recycling not disposing. The environmental problems will be reduced by using waste and natural resources will thus be protected by using waste as an alternative fuel instead of a primary fuel. In addition, the greenhouse gases produced by burning lignite coal will be prevented.

The production of cement in Turkey started with a plant founded in Istanbul- Darica in 1911 which produced 20,000 tons per year. Today, the total capacity of cement production has reached 126,141.205 tons in fifty-three integrated plants.
Alternative fuels derived from industrial and household waste are used in thirty-five integrated cement plant in Turkey licensed by The Ministry of Environment and Urban Planning. Data has been complied for 2015 and is given in the table below.

Table 3. Types and amount of waste co-processed in cement plants and resultant energy obtained in 2015.

| Type of waste | Amount (Gg) | Avarage Calorific Value (Tj/Gg) | Total Calorific Value Değer (Tj) |
|---|---|---|---|
| Waste resulting from agriculture, food preparation and processing waste | 4,269 | 10,47 | 44,69643 |
| Waste resulting from wood processing and paper, cardboard, production | 2,687 | 11,48 | 30,84676 |
| Waste resulting from textile industry | 16,140 | 11,09 | 178,9926 |
| Waste resulting from petroleum refining | 4,691 | 10,44 | 48,97404 |
| Waste resulting from inorganic chemical process | 0,145 | 27,00 | 3,915 |
| Waste resulting from organic chemical process | 6,366 | 6,9 | 43,9254 |
| Waste resulting from paints, varnishes, adhesives | 1,267 | 9,9 | 12,5433 |
| Waste resulting from surface processing and molding of metal and plastic | 1,475 | 11,02 | 16,2545 |
| Oil waste and liquid fuel waste | 29,100 | 27,55 | 801,705 |
| Waste packaging, absorbents, wiping cloths, filter materials and protective clothing | 32,911 | 14,56 | 479,18416 |
| Scrap tires | 62,463 | 25,26 | 1.577,81538 |
| The fabrication of plastic | 0,131 | 11,3 | 1,4803 |
| Waste resulting from transport tanks, storage tanks and barrel | 0,106 | 21,28 | 2,25568 |

| | | | |
|---|---|---|---|
| cleaning | | | |
| Waste resultingfrom construction and demolition | 0,342 | 12,46 | 4,26132 |
| Waste resulting from waste management plants and wastewater treatment plants | 385,397 | 13,21 | 5.091,09437 |
| Municipal Waste | 40,047 | 14,52 | 581,48244 |
| Total | 587,533.54 | | 8,919.42668 |

The total energy obtained from 587,533.54 tons of waste co-processed in 2015 is 8,919.42668 TJ as can be seen in the table above.

Lignite Coal =8,919. 42668 [TJ] / 11.9 [TJ/Gg]=749.53165 Gg x $10^3$ ton/Gg = 749,531.65 ton

To obtain the same amount of energy obtained from waste, 749,531.65 tons of lignite coal must be burned.

Savings in the amount of emissions = 749,528.22 [tons] x 101[tons $CO_2$/TJ] x 11.9[TJ/Gg] x 1[-] x$10^{-3}$[Gg/ton] = 900,857.97 tons $CO_2$

In 2015, 587,533.54 tons of waste was co-processed in cement kilns in Turkey and 8,919.42668 TJ of energy were obtained. This amount of energy is equivalent to the amount of energy obtained from 749,531.65 tons of lignite coal. In Turkey, 900,857.97 tons of $CO_2$ that would have been produced by burning 749,531.65 tons of lignite coal were saved from being emitted by the co-processing of waste in cement kilns in 2015.

## CONCLUSIONS

Result of combustion of waste as energy recovery; establishing incinerators using for waste which have reduced operating costs will not be needed and a reduced environmental impact resulting in fever $CO_2$ emissions because conventional fuels were not used.

The energy recovery of waste in cement kilns over incinerators has advantages such as longer retention time, increased oxidizing atmosphere and higher temperatures.

Use of waste for energy recovery is achieved by minimizing amount of waste.

The $CO_2$ arising from waste co-processing should not be included while calculating the $CO_2$ emissions from the cement industry, which for encourages waste use.

The thermal power ratio limit derived from waste for co-processing in the cement plants should be removed to increase $CO_2$ savings. If this is possible, the use ratio will be 100%.

The imported fuels are used in industry; the use of waste instead of fossil fuels will have a great impact on the reduction energy imports.

Organic compounds are decomposing completely in cement kilns. Acid gases, sulfur oxides and hydrogen chloride are fully neutralized by the active lime that is fed into kilns.

Heavy metals are bonded to the clinker with very stable chemical bonds such as metallic silicate.

The remaining ash and waste water from gas treatment do not occur. Waste does not have any negative effect on the final product/cement. Using waste as fuel in the cement plants provides an effective solution for the waste problem.

Through the use of waste as fuel in cement plants, natural resources will be protected and the cement product will have been produced sustainably.

The level of antropogenic greenhouse gases that cause global warming and climate change in the atmosphere must be stabilized for a sustainable world. Waste should be used as fuel in cement plants to reduce the greenhouse gas emissions.

The cement plants installed in all regions of Turkey do not require additional gas treatment units. Gas emissions are monitored by continuous measurement devices. Co-processing does not produce any solid or liquid waste. In this context, the cement plants will be accepted as a partner in waste management solutions. Maximum potential of cement plants in waste recycling should be utilized.

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