Utilization of Fly Ash and Bottom Ash from Circulating Fluidized Bed Combustion (CFBC) Technologies

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Abstract. Energy production from fossil fuel combustion results in the emission of greenhouse gasses, the dominant contributor being CO2. It is well known that greenhouse gas emissions from energy production can be reduced by the use of alternative energy sources such as nuclear power and renewable energy sources. Renewable energy sources are expected to become increasingly important for our future energy demand. The effect of greenhouse gasses on global climate change has been acknowledged by many governments worldwide, and the reduction of the emissions of these gasses is becoming increasingly important. Several technologies are being developed for CO2 capture and sequestration from coal fired plants. Among those, oxy circulating fluidized bed combustion technology is one of the most promising methods to produce a stream of concentrated CO2 ready for sequestration. Use of recycled flue gas/oxygen mixtures for combustion in circulating fluidized bed combustion (CFBC) offers advantages over oxy-fuel combustion with conventional pulverized fuel (PF) firing technology.

Keywords: Recycling, Utilization, Fly Ash, Bottom Ash, circulating fluidized bed combustion (CFBC).

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1. Introduction

The National Energy Technology Laboratories proposed the new advanced coal power technologies presented in Figure 1[1]. This study is carried out in the context of the growing use of low rank coal alongside the development of environmentally friendly coal-fired power generation technologies in Korea. It provides an overview of the current situation of power generation in Korea. As Korean researchers are working to develop fluidized bed boilers as a next generation technology with high efficiency, this study compares the characteristics of the fluidized bed boiler and the pulverized bed boiler in order to offer a better understanding of the developments in this field. Finally, the behavioral characteristics and concentrations of heavy metals within the waste products of coal-fired power plants are discussed.

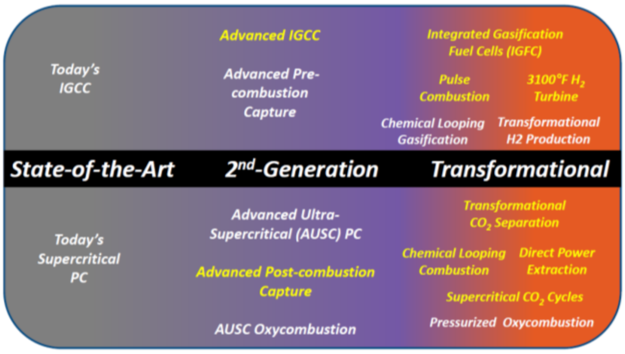
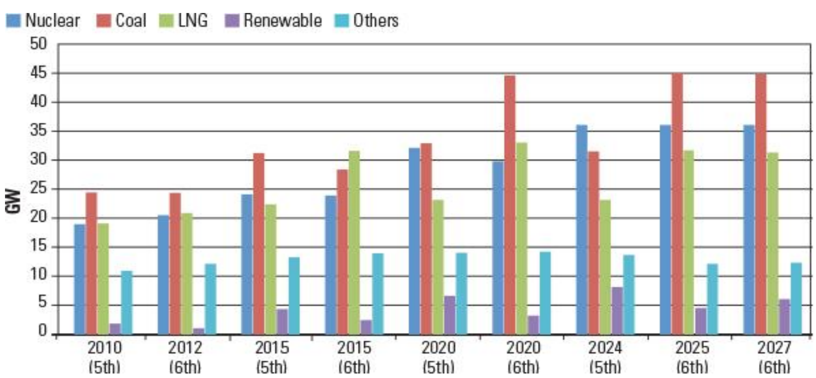


Fig. 1. DOE(NETL) Advanced Coal Power Technologies

South Korea's future energy goals are outlined in biannual power development plans based on which generation companies apply for government approvals for power plant construction. The latest installment of the so-called "Basic Plan of Long-Term Electricity Supply and Demand (BPE)" is the 6th BPE, issued this year, which covers a planning period from 2013 to 2027[2]. Figure 2 shows the South Korea's future energy sources. Coal power has to date played a particularly marked role, its share in the country's electricity mix rising dramatically from 17% in 1990 to 40% in 2010. Gas-fired generation, too, soared during that period, from 9% to 19%. Though the country's "green growth" future strategy favours nuclear power most of all, coal will continue to play a major role, presumably to boost energy security.



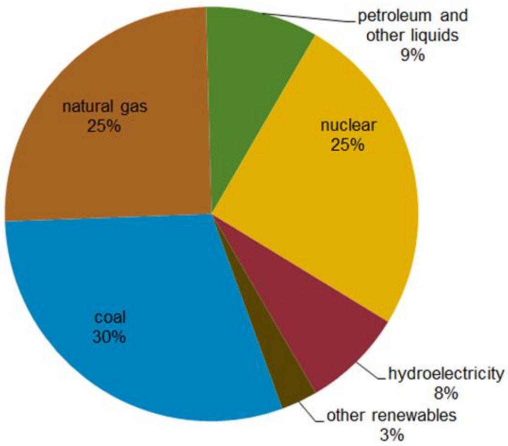


Fig. 2. South Korea's future energy plan(2010-2024).

South Korea's energy consumption is still growing and Korea dependent on imports [3](Figure 3). Rising coal consumption in South Korea and a negligible production level have caused the country to rely heavily on imports over the past several years. South Korea held only 139 million short tons (MMst) of recoverable coal reserves in 2010, according to the World Energy Council estimates. The electric power sector accounts for 62% of the country's coal consumption, while the industrial sector accounts for most of the remaining amount, according to KEEI.

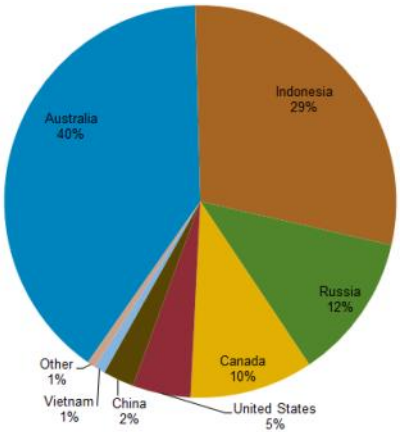


Fig. 3. South Korea's coal imports from overseas-2014.

2. Problem of Coal Power Plants By –products Generation

By products generation from coal power plants shows vigorous environmental impacts. Waste created by a typical coal plant includes more than 500,000 tons of ash (Table 1). Nationally, at least 42% of coal combustion by products is generated and it's run over to the waste ponds and landfills. In the United States alone about 130 million tons of coal combustion waste products are produced every year, which is about the same as all the residential solid waste generated in the US per year. Most coal power waste winds up in landfills, surface impoundments or in mines whereas smaller amounts are used for e.g. cement or concrete production.

Rates of coal power waste recycling are high in some European countries, including the Netherlands, Denmark and Belgium, but worryingly low among the three largest consumers of coal, China, the US and India (33 percent, 38 percent and less than 5 percent respectively). Typically, solid waste is stored in landfills, while liquid waste is stored in impoundments. Ideally these disposal sites should be designed to prevent the toxic wastes from entering the environment.

In Korea, based on the demand and policy, it has been plan to expansion new thermal power plants. In developed countries, ash recycling technologies are available to minimize the landfill problems.

Table 1. Overview of Ash production from Coal Power Plants

Year	Coal		Ash
	Total imports	Consumption	
2004	7,210	4,551	515
2006	7,088	5,020	568
2008	9,047	6,279	710
2010	10,610	7,667	867
2012	11,465	7,913	895

3. Results and Discussion

3.1. Major and Minor Component of Coal and Coal Ash

Coal contains about 120 types of different elements, of which 33 are common, and 8 types make up the majority. Results of the XRF content analysis to identify the basic components of coal are compiled in the below Table 2 and solid waste composition mentioned in Table 3.

Table 2. Major and minor chemical composition of samples by XRF (unit: wt.%).

Region	Current Available Data			Projections for 2025			
	Total urban population (millions)	Urban Waste Generation		Projected population		Projected Urban Waste	
		Per capita (kg/capita/day)	Total (tons/day)	Total population (millions)	Urban Population (millions)	Per capita (kg/capita/day)	Total (tons/day)
AFR	260	0.65	169,119	1,152	518	0.85	441,840
EAP	777	0.95	738,958	2,124	1,229	1.5	1,865,379
ECA	227	1.1	254,389	339	239	1.5	354,810
LCR	399	1.1	437,545	681	466	1.6	728,392
MENA	162	1.1	173,545	379	257	1.43	369,320
OECD	729	2.2	1,566,286	1,031	842	2.1	1,742,417
SAR	426	0.45	192,410	1,938	734	0.77	567,545
Total	2,980	1.2	3,532,252	7,644	4,285	1.4	6,069,703

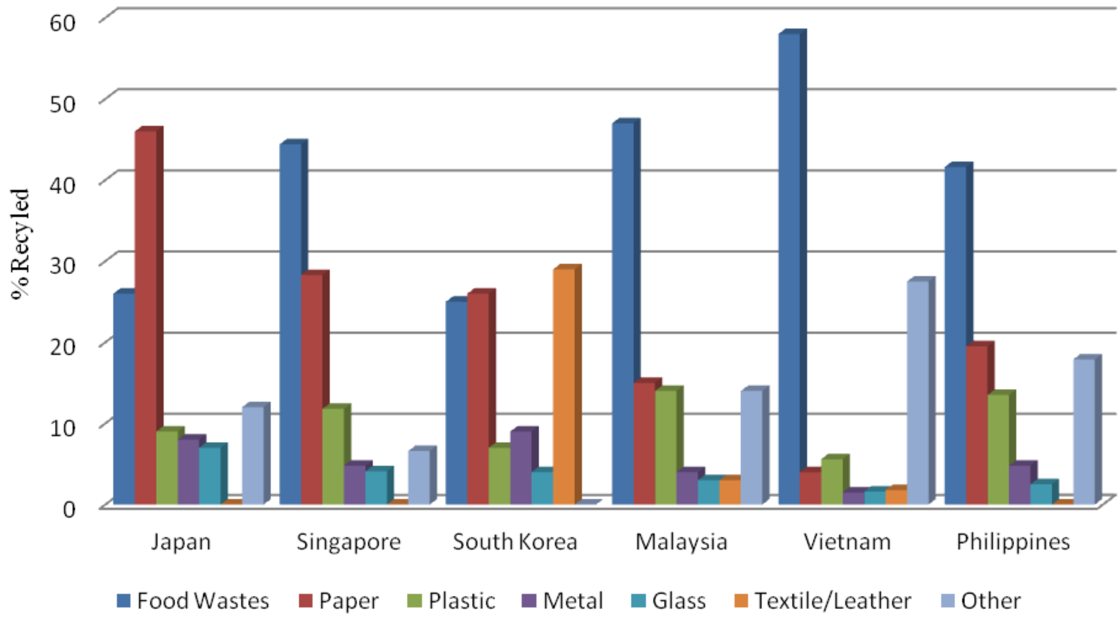


Fig.4. Solid Waste Composition from Asia

Table 3. Overview of MSW Management in Asia

Region	Collection	Treatment	Disposal
Japan	Source Separation, Fixed time collection	Incineration/WTE A few composting plant for MSW	Sanitary landfill
South Korea	Source Separation	Incineration/WTE composting plant	Sanitary landfill
China	Some cities conducted source separation. Not sufficient in rural area	Increasing number of incineration/WTE plant in large cities, some composting	Shift to sanitary landfill
Thailand, Malaysia	Some cities conducted source separation.	Limited number of incineration plants	Shift to sanitary landfill
Philippine, Indinesia, Vietnam	Insufficient collection. Some cities conducted source separation.	No incineration plants	Shift to sanitary landfill

3.1.1 Feasibility Studies in Philippine

Under the “Development Cooperation Framework for Islands” GTC-K Korea Waste management planning for sharing the technology in Bantayan, Philippines. The key technologies from Korea institute of Geosceinces and Mineral Resources are collaborates with local governments of Bantayan, Philippines in case of development of new technology for control the green gas emissions and recycling technologies of municipal solid waste(Fig.5). GTC-K provides master planning for Bantayan island waste management and waste- to-energy over carbon free island concepts. Policy and Master Planning for Bantayan is needed for long-term development of the reason.

Fig.5. GTC-K(including KIGAM R& D institute) collaboration with Bantayan local government, Philippines

3.2 Key Technologies from KIGAM: Accelerated Carbonation Technology for Alkaline Waste

Accelerated Carbonation of Municipal Solid Waste

The new technology of accelerated carbonation is widely used in many industries as an alternative method to natural carbonation which proceeds very slowly in Nature.

Natural carbonation

Natural carbonation occurs by the reaction between atmospheric CO_2 and alkaline materials, which is called "weathering". It is well known that the "weathering" depends on the initial chemical composition, the characteristic of minerals in alkaline materials and the amount of CO_2 uptake. Natural carbonation generally progresses very slowly over a long term.

Accelerated carbonation

In accelerated carbonation, CO2 in a high purity is artificially injected into solid wastes to make the reaction much faster than that by atmospheric CO2, and the reaction can be finalized within a few minutes or hours. This technology is applied to the treatment of solid wastes in which toxic metals are stabilized by carbonated materials, so that the treated solid wastes can be reutilized in other fields.

The accelerated carbonation of solid wastes containing alkaline minerals such as Ca and Mg before their landfill treatment is effective for decreasing the mobility of heavy metals by adjusting pH to below 9.5 at which their solubility is lowest. In general, an acidic condition may have the risk of causing releases of heavy metals for a long period, accompanying the decrease in buffering capacity by the decrease in alkalinity, whereas the carbonation at an acidic range can increase the buffering capacity.

Carbonation of heavy metals

In the worldwide trend towards encouraging carbonation treatment of MSWI bottom ash as described above, our research group has also performed carbonation studies using MSWI bottom ash and CO_2 in order to increase the recycling percentage of the ash and reduce the concentration of atmospheric CO_2 in Korea.

Wastewater Treatment by Accelerated Carbonation

The formation of solid carbonates between aqueous solutions containing divalent cations and CO_2 is a complicated and important process in Nature and industrial areas. Compared to the aforementioned studies on the carbonation of MSWI bottom ash, however, aqueous carbonation using wastewater is still poorly known and rarely reported in the literature. In this section, we review two representative studies which have reported on the carbonation of cations or anions in wastewater using CO_2. There are several researchers reported the accelerated carbonation of municipal solid waste and alkaline solid waste materials [4-7].

In Korea, Institute of Geoscience and Mineral Resources (KIGAM), Daejeon, established a successful pilot plant for multi-processing of MSWI ash as shown below in the Figure. The capacity of this pilot plant is 200 kg/hour (Fig.6). This pilot plant was the first one in the waste recycling field in Korea and even throughout the Asian countries, and includes multi-processes of particle separation; heavy metal stabilization, chloride removal, and green aggregate/concrete manufacture (Fig.7).

Fig.6.200 kg/hour MSWI bottom ash multi-process

Fig.7. 20 tons/hour Removal process model of heavy metals chlorides from MSWI bottom ash

This technology can be also considered as an accelerated carbonation in terms of making the reaction shorter using high purity CO_2. One of advantages of this technology compared to other CO2 storage technologies is that CO_2 is stably stored in final products such as CaCO3 and MgCO3.

Currently, accelerated carbonation processes have been focused on assessing and maximizing the storage of CO_2 by optimizing the operating conditions including pressure, temperature, liquid-to-solid (L/S) ratio, gas humidity, gas flow rate, liquid flow rate, particle size, and solid pre-treatment in numerous experimental investigations. The processes via which the carbonation of the minerals or alkaline solid wastes takes place in a single route step are referred to as direct carbonation. Usually, these processes can be divided into two types: gas-solid (dry) carbonation and aqueous (wet) carbonation; these processes are generally operated at an L/S ratio of less than 0.2 and more than 5, respectively.

3.3 CO_2 Solidification of Hazardous Elements from Inorganic Waste(power plants ash)

The accelerated carbonation of hazardous elements from wastes such as MSWI bottom ash, fly ash and power plants waste is a controlled accelerated version of the naturally occurring process. In addition, in many cases, binding of toxic metals may occur as the carbonated product rapidly solidifies. The novel method of the simultaneous calcium hydroxide carbonation with compressed carbon dioxide in order to stabilize the solid material.

4. Conclusions

The main purpose of our study was to investigate the possibilities and feasibility studies of utilization of fly ash and bottom ash from CFBC technologies. The Key technology of MSW is accelerated carbonation. The accelerated carbonation of alkaline solid waste has been proved to be an effective way to capture CO_2. The aqueous carbonation of calcium hydroxide with compressed CO2 could be an economic method to remove various heavy metals oxyanions as well as to allow the mineral sequestration of CO_2; particularly, when the $Ca(OH)_2$ source came from alkaline solid waste such as power plants ashes, waste concrete and cements, alkaline paper mill waste, etc. CO_2 capture, utilization, and storage (CCUS) is a promising technology wherein CO_2 is captured and stored in solid form for further utilization instead of being released into the atmosphere in high concentrations. Under this concept, a new convergence technology called accelerated carbonation process has been widely researched and developed.

Acknowledgements

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