A Discussion of Ways to Reduce Greenhouse Gases Emission from Chemical Processes

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Abstract:- *During the last 3 centuries, the industrial revolution generates various gases, which have great damage on our health and environment. One of the most riskiness gases groups to environment is Greenhouse gases. Greenhouse gases in general and carbon dioxide in particular, have a United Nation attention in last few years. These gases release from natural and industrial sources. Scientists and engineers have tried to reduce these gases emission from the chemical processes by different ways. Each way for mitigate Greenhouse gases emission has some disadvantages such as demands massive energy, causes further pollution, etc.*

Keywords:- *Carbon dioxide, clean energy, Greenhouse gas, Global warming, Climate change*

1. INTRODUCTION

In the modern world, energy plays a significant role as a building and development tool of civilization. Therefore ,the demand for energy in general and electricity in particular increased dramatically in the last century. Fossil fuels have mostly been used in energy generation plants [1]. The combustion of the fossil fuel in energy plants, and in the chemical industries emits different gases. One group of these gasesis called “Greenhouse gases”.

Greenhouse gases (GHGs) include carbon dioxide (CO_2), methane (CH_4), hydrofluorocarbons (HFCs), per flourinated compounds (PFCs),Nitrous oxide (N_2O) and water vapor. High amounts of the greenhouse gases are emitted from natural sources[2]. In spite of Greenhouse gases are not toxic gases, when the concentrations of these gases increase in the Earth’s atmosphere, that may lead to environmental and health issues. When concentration of Greenhouse gases increases over the standard levels in Earth’s atmosphere causes phenomenon of global warming [3].

The greenhouse gases have various properties, such as the average lifetime in the atmosphere, and the solar radiation trapping capacity. For example, methane is more 20 times effective in trapping heat than carbon dioxide. The chlorofluorocarbons and hydrochloro fluoro carbons have a low capacity of heat-trapping, but these gases are considered as stratospheric ozone depleting gases [4].

According to Mashmool et al. (2010), 40% of total greenhouse gas emissions round the world come from energy plants, and about 22% of these emissions come from the industrial sector. So, the reduction and management of Greenhouse gases emissions is necessary to control the global warming [1].

However, in additional to environmental issues of the Greenhouse gases, the emission of GHGs in general and CO_2 in particular from the chemical processes, costs a lot of money. Wagner (2014) emphasizes that the cost of CO_2which emitted from industrial and energy sector in 2013, reached to 40$ per ton.

This paper will begin by states the non-natural sources of greenhouse gases emission. Then it will explain in the details the chemical processes which emit GHGs. it will describe most issues that face engineers when they try to reduce GHGs emission from chemical processes. Lastly, the modern techniques and approaches for reduce GHGs emission will be reviewed.

300 years ago, the Industrial Revolution began, accompanied by deforestation. This revolution depended mainly on fossil fuel to move forward. Coal was the main kind of fossil fuel used. Wilcock (2005) points out that the carbon content in coal is approximately 74.6%. This percentage seems to be high in comparison with other kinds of fossil fuel. Consequently, atmospheric concentrations of GHG have dramatically increased since the eighteenth century[3]. Atmospheric GHGs are considered as heat-trapping gases which lead to the phenomenon called “Global Warming”. The Global warming acts like a blanket which covers the Earth and the temperature of Earth increases. Since 1900, the Earth’s average surface temperature has increased by about 1 °C [5].

Currently, the main source of GHG is the energy plants, particularly, the electrical energy plants. In spite of the development of new sources of the electrical energy, fossil fuels will still be a significant source by 2050[1]. Generally, 40% of global CO_2 is released from the energy plants [1]. Additionally, CH_4, N_2O and HFCs are

emitted from the fossil fuel combustion in the electrical energy plants [1].The second source on the list of GHGs sources is the crude oil refining plants. Undoubtedly, some stages of the crude oil refining system, also, natural gas system, emit vast amounts of CH_4 and CO_2[4]. For instance, in 2011, 23.9% of total U.S. emitted methane from the natural gas purification systems [4]. Finally, the third source of GHGs is the chemical industries. The emission of GHGs occurs in the different stages of industrial processes such as: pre-process, in-process and post-process stage. The emissions from the industrial sector accounted for 4.9% of total U.S. GHG emissions in 2011[4]. Industrially, the largest amounts of GHG are emitted from the petrochemicals industry. Furthermore, there are other considerable industrial sources for instance; steel production, cement production, ammonia manufacture and lime manufacture [4].

Significantly, the combustion process of conventional and unconventional fossil fuels is a major cause of the GHGs production. The conventional fuel includes the natural gas liquids (NGL) and light products of the crude oil such as gasoline, kerosene, and gas oil [6]. While, the unconventional fuel includes heavy crude oil products such as tar and oil sands, and coal. According to the high carbon content, the unconventional fuels combustion produces GHGs greater than the conventional fuels. Thus, the price of the unconventional fuels is lower than the conventional fuels [6]. Therefore, the majority of the developing countries prefer the cheapest fuel in various chemical processes such as the generation of electricity [7]. In general, this may explain why the GHG emissions in the developing countries are higher than in the developed countries [7].

Generally, engineers face a number of issues in how to reduce GHGs emission from the chemical processes. Mostly, these issues relate directly to cost of the processes [3].In reality, the cost of the recycling and treatment systems of GHGs in chemical processes is approximately similar to the cost which is paid as GHGs taxes. But, the chemical processes with recycling system may help to mitigate the greenhouse gases concentration in the Earth's atmosphere [3]. In the last two decades, some developed countries applied policies to force the energy and industrial companies to reduce their emission of GHGs[2]. Thus, new equipment of GHGs separation from total waste has been designed. The separation of GHGs from total waste can be an important stage of the reduction process [3].

After the separation stage, two methods are used to prevent GHGs from the discharging to the Earth's atmosphere. Firstly, GHGs are absorbed into specific liquids, for example, the capturing of CO_2 by Monoethanolamine (MEA) system [8]. Secondly, some GHGs are used as a feed stream to other processes. For example, methane is used as fuel, such as liquefied petroleum gas, or asa direct injection material in the oil fields to enhance oil recovery [9]. Both these two methods still involve risk. Both the absorption process of carbon dioxide into ammonium solution and the combustion of natural gas may lead to environmental contamination. For instance, the neutralization of N_2O with sodium hydroxide solution produces sodium nitrate which may cause water and soil contamination [10]. Accordingly, the environment pollution is the most significant industrial problem faced by designers and engineers.

Furthermore, the second issue is the capital and operating costs of techniques and plants, which are used to recycle and mitigate the GHGs. Greenhouse gases removal equipment, is not small size equipment. Thus, the equipment itself is expensive, and requires high rates of energy [11]. Also, some pre-process equipment is a necessary to change some operating conditions such as temperature, pressure, etc. Pre-process equipment like compressor, heat exchanger, vacuum pump, etc., demand a high level of energy, in other words, demand a high cost[11].

Clearly, the products of the reaction of greenhouse gas with the reactants needs some treatments to prevent additional pollution. For instance, ammonium carbonate is the main product of reaction of ammonia with carbon dioxide in removal of CO2 by NH3 solution in a scrubbing process [12]. Ammonium carbonate is a solid material, and very soluble in water, therefore, under moist air, converts to liquid. According to environmental safety policies, ammonium carbonate should be controlled to prevent water and soil contamination [12]. Moreover, in the case of methane combustion fuel, the GHGs are separated from the flue gas by some techniques [11]. These techniques are called "post-combustion capture" ([11], p.21).Post-combustion capture consists of two stages, firstly, the separation between GHGs and other flue gases stage. Secondly, the compression and dehydration stage [11].

Usually, designers face issues, which are difficult to cope with. The carbon content of fuels is one of the factors influence the emissions of GHG in the combustion [13]. The carbon content of fuels determines how much greenhouse gas amounts may be

released from the combustion of the fuel[13]. The correlation between the carbon content and the price of fuel can be considered as an inverse correlation[13]. Therefore, the greenhouse gas emissions are mostly controlled if the companies and power plants use low carbon content fuel, but, this may mean increasing inthe fuel cost[13]. Secondly, a replacement of hydrocarbon fuel power with nuclear power and renewable energy can contribute the reduction of the GHGs emission from energy plants and oil refineries[14]. Consequently, GHGs emission mitigation costs are reduced.

Before starting with review of the solutions, the detection systems of greenhouse gases are considered as an essential part of the greenhouse gases mitigation techniques [15]. The detection systems determine the concentration of greenhouse gases which are released from chemical process. According to GHGs concentration in flue gas a correct decision to reduce GHGs emission is made [15]. Generally, various detection systems have been used, like Photoacoustic Spectroscopy (PAS), Gas Chromatography (GC), Non-Dispersive Infrared (NDIR), etc. [16]. These systems already exist in different sectors such as, the energy stations, the oil refineries, and petrochemicals industries [16]. Particularly, Photoacoustic Spectroscopy (PAS) is regarded as an effective system for the measurement of GHG emissions, high sensitivity, and the possibility for continuous flow systems [15]. A study by Kang et al. (2014) shows that GC is high-quality regarding the measurement accuracy, but PAS is superior in cost efficiency, convenience, and mobility of the device.

On the whole, various techniques have been applied to deal with the issues of greenhouse gases emission control. According to Tan (2014), the control techniques are divided into three types: pre-combustion, in-combustion, and post-combustion. Firstly, the pre-combustion emission control techniques include the fuel cleaning, fuel substitution, fuel conversion, and clean energy sources. Coal washing, oil and gas refinery are the most common applications of the fuel cleaning[2].Coal washing means the reduction of content of ash-forming, sulfur, and other elements like Pyrite (FeS_x), Se and Hg. Approximately, 60% of ash-forming materials and 50% of the pyretic sulfur can be removed by coal washing [2]. However, high energy is required for the drying and the grinding in the coal washing process. Also, the boiler efficiency may be reduced because of the moisture is added to the coal [2]. The natural gas sweetening is one of the most effective approaches in the pre-combustion stage [2]. Besides Sweeting processes, Benfield process and Pressure Swing Adsorption (PSA) are used to remove H_2S and $CO_2$from raw Natural Gas and flue gas[17]. The heating value of natural gas is improved by removing CO_2.In addition to the heating value of natural gas, the corrosion in the chemical equipment is reduced by removal of H_2S from the fuel [2].

The second technique of the pre-combustion stage is fuel substitution. In reality, GHG emissions from fuel combustion are mainly relied on components of the fuel [2]. In other words, the natural gas is cleaner than the diesel fuel, and coal is the dirtiest fossil fuel [2]. The cleanness level of the fuel is identified based on the impurities amount in fuel. Gaseous or liquid fuels are cleaner than solid fuels, because the impurities content like carbon or ash-forming elements in the gaseous or liquid fuels are lower than the solid fuels [13]. Therefore, the fuel substitution can contribute the reduction of the GHG emissions from combustion process [2]. Particularly, the partial substitution of the fuel includes two different fuels or more are used in the same process, such as co-combustion of gasoline and coal [2]. But, the cleaner fuel can be existed in higher cost. Also, if the fuel type has been changed in a process, the efficiency of the combustor may be affected [2].

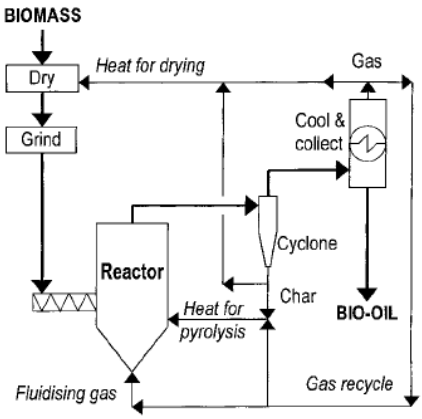

Figure 1: *Pyrolysis process diagram ([18], p.4)*

The third technique in the pre-combustion stage is the fuels conversion. The conversion of the fuel from one phase to another by the thermo chemical conversion (TCC) process may be contributed to mitigation of impurities in the fuel[2]. For example, the solid fuels such as biomass or coal can be converted to liquid or gaseous fuel. A TCC processes mainly consist of three sub-processes: pyrolysis, gasification, and liquefaction [2]. Firstly, the pyrolysis is defined as thermal reaction operating in great temperature in which the feed is quickly heated in the absence of oxidation agent [18].

The wood and other forms of biomass fuel are used as a feed stream to the pyrolysis process. Dark brown liquid and gaseous fuels are produced from the biomass pyrolysis process, (see figure1) [18]. However, this process requires high temperature of around 500 °C, the vaporization and condensation units. So, the significant disadvantage of the pyrolysis is a high cost process [18].

Secondly, in-combustion stage, the GHG emissions control techniques may be associated with convenient operation conditions. The limitation of GHGs emission in the combustion process depends primarily on how the combustion takes place and the process conditions[2]. Mainly, a number of technologies have been developed to control the GHG emissions in the combustion stage. Pulverized solid fuel combustion is a traditional technique, which is used to make a combustion process faster[19].By this technique, coal or biomass is crushed to fine particles (50-200 µm) then, is fed to the combustor[19]. The forming-ash is produced in the burner bottom as combustion waste. A short time of the fuel combustion means less GHG emissions[19].

In order to restrict products of the combustion to only $CO_2$and water, oxy-fuel combustion is an engineering application of the GHGs mitigation, that has recently been developed[20]. The oxy-fuel combustion includes combustion of fossil fuels with sufficient concentration of oxygen (nearly 95% O_2), instead of air [11]. Air approximately consists of 79% nitrogen and 21% oxygen. The combustion in the oxygen-rich environment may reduce production of GHGs, except CO_2 and steam as combustion products [20]. This application is mostly applied in energy and the cement production plants [20].According to figure 2, after the oxygen separation from air, oxygen is fed to the burner with a fuel such as a coal. Then, the combustion products are separated, CO_2 goes to the electricity turbine or to the compressor [11].The significant benefits can be released when the oxy-fuel combustion is accompanied by the pulverized solid fuel technology [11].

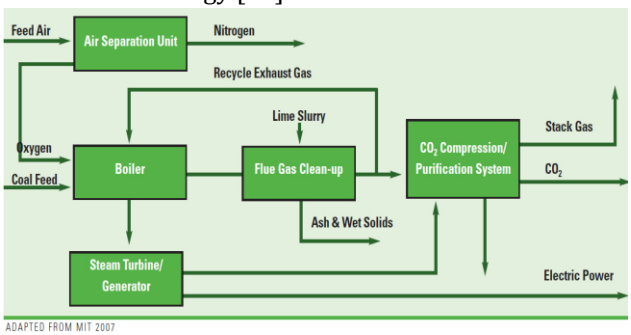

Figure 2: *Oxy-fuel combustion process diagram ([11], p.12)*

The GHG emissions are greatly reduced by pre- and in-combustion stages. But, in the post-combustion stage, gases in general and GHGs in particular are mostly treated. Generally, the post-combustion stage includes two main parts: separation and treatment[2]. In the first part, the greenhouse gases are separated from other harmless gases by different technologies such as absorption, membrane separation, and Cryogenic process[11]. The absorption process of the GHGs which are released from chemical processes is considered a common process to separate specific gas by specific solvent [11]. In general, the absorption process is divided into physical and chemical absorption. In the chemical absorption, a solvent reacts with a gas such as the absorption of CO_2 by monoethanolamine (MEA)[14].

In the physical absorption, a gas dissolves in a solvent without chemical reaction. For instance, methane gas is absorbed in ionic liquid (IL) as solvent[21]. However, further pollution can happen through the absorption processes. The Ionic liquids in the methane absorption process are classified as volatile organic chemicals (VOCs), which are less green than non-volatile organic chemicals [21]. Furthermore, the energy cost of the absorption processes can be high[21]. Occasionally, other methods may be used as separation methods of the GHGs, such as the adsorption and the distillation process[22].

In the second part of the post-combustion stage, the products of the first part require further treatment to make these products useful and safer for the environment. Mostly, when the GHGs are removed from flue gases or wastes that may mix with liquids or solids. So, the treatment units separate the GHGs from these liquids and solids. For example, after the absorption of CO_2 in water, water output stream contains not less than 80% of CO_2 in input gas stream [23].. The water and CO_2 stream is fed to stabilization column, CO_2 comes out from the top of column and the water comes out from the bottom. CO_2 may be compressed for storage purpose, and the water can be recycled asa solvent of the absorption process [23]. Another example, the liquefaction process of HFCs. HFCs are compressed under high pressure to liquids, which can be used as refrigeration gases[3].

2. CONCLUSION

In overall, this paper has focused on general issue of the greenhouse gases emission from different chemical processes. It has showed risks of increase the GHG concentrations in the Earth's atmosphere. A variety of

techniques of the GHG emissions mitigation have been reviewed, and advantages and disadvantages of each technique have been stated.

However, as results of a rapid rise of the population, the consumption of energy and the need for industry has increased recently. Therefore, the concentration of GHGs has expanded in the Earth's atmosphere. One of the most serious issues in the way to reduce the emission of GHGs is how it a possible to get an economic reduction process of the GHGs. The cost of each reduction technique has increased according to the GHG amounts which emit from the chemical process. Furthermore, another challenge is how can avoid other kinds of pollution. Occasionally, air pollution control systems cause other kinds of pollution such as soil or water pollution.

Finally, global warming may have a great negative affect on our future. The GHGs emission reduction technologies demand more developments and update to be more effective and economic. Also, clean sources of energy should be evolved, and fossil fuel should be replaced with renewable energy. These approaches can protect the environment and reduce the GHGs cost.

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