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Air Pollution Resulted From Electrical Power Plants Gas Emissions & Its Mitigation Methods in Urban AREAS

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Abstract
This study aims to find Air pollution resulted from electrical power plants gas emissions and it is mitigation methods in urban areas. The methodology used is a qualitative methodology based on last studies, books, and papers. The results of this study show that the use of all types of fossil fuel as a source of energy in electrical power plants have a very bad effect on the atmosphere because these power plants are releasing toxic, acidic, and greenhouse gases such as NOx, SOx, and CO2. In addition to the particulate matter (PM10, PM2.5) and the ashes of coal combustion products (CCPs) include fly ash (FA) and bottom ash (BM). The first method of mitigation of these gases that founded by this research is by switching the use of coal in electrical power plants into natural gas with combined cycle technology. The second method is by capturing fly ash (FA) using (wet scrubbers, filter baghouses, electrostatic precipitators), Fluidized bed combustion (FBC), or Flue-gas-desulphurization. The third method is by the chemical absorption of gases by a direct contact of the flue gases that includes CO2, NOx, and SOx with alkaline solvent.The fourth method is by CO2 capturing using a chemical adsorbent such as amino-based adsorbent. The last method is by using renewable energy as the source of energy instead of fossil fuel in the electrical power plants that included Solar PV panels, Microturbines, Micro-wind turbines, Micro Combined Heat and Power (micro-CHP), or Fuel cells.

Keywords: air pollution, electricity generation, emitted gases, GHG, power plants,methods, urban areas.

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I. INTRODUCTION

The world today witnesses many challenges and problems that may effects the future of humanity. Currently, the global has big concerns relating to climate changes and greenhouse gas effects on the environment due to increasing the worldwide demands on the energy supply sector that based on fossil fuel burning. In addition, this sector contributes the world with (56%) of global GHG emission, which is more than half the emissions of all other global sectors. On the other hand, the percentage of Global electricity supply in 2008 represents 15% of the total amount of primary energy supply which makes this sector having a good role in the energy sector within the fields of energy-related GHG emissions and the global primary energy demand (Raadal, 2013).

The biomass and/or the fossil fuels are the most important sources of energy used in the production of electricity in the power plant sector. moreover, in 2018 the percentage of total electricity generation in the united states only is about 65% that produced from burning some types of fossil fuel such as (petroleum, natural gas, and coal), industrial and municipal wastes, and biomass that come from some plants. in addition, the burning of this type of fuel produces a lot of gases that emitted to the environment includes Carbon monoxide (CO), Carbon dioxide (CO2), Nitrogen oxides (NOx), Sulfur dioxide (SO2), Heavy metals such as mercury, Particulate matter (PM). On the other hand, nearly all byproducts that producing from combustion have very bad effects on human health and the environment, the byproducts and their effects are shown in table (1) (U.S EID, 2019).

Table (1): the combustion byproducts that have negative effects on the environment and human health (U.S EID, 2019).

combustion byproducts	The effect of the gas
CO2 is a greenhouse gas	• contributes to the greenhouse effect
SO2 causes acid rain	• Harmful to animals and to plants that live in water. • Worsens heart diseases and respiratory illnesses, particularly in the elderly and children.
NOx contribute to ground-level ozon	• irritates and damages the lungs
PM coupled with ozone results in hazy conditions in scenic and cites areas	• Contributes to chronic bronchitis and asthma. • Fine PM cause lung cancer and emphysema.
Mercury is a Heavy metal	• Hazardous to animal and human health.

According to the importance of the above information, this paper will discuss the Air pollution resulting from electrical power plants gas emissions & its mitigation methods in urban areas.

Problem and questions

The aim of this study is the Air pollution resulting from electrical power plants gas emissions & its mitigation methods in urban areas by answering the following questions:

1. What are the main gases emitted from electrical power plants?
2. How the gases emitted from electrical power plants contributes on the air pollution?
3. What are the methods that use in the mitigation of the gases emitted from electrical power plants?

Methodology

The methodology used in this study is qualitative, based on other studies, books, and articles.

Electrical power plants

Electrical power plants are a power station that used in the generation and distribution of electric power. All countries around the world may have to establish a new power plant to candidates the big demand for electric power, this demand varies with the changes in weather, residential activity, and business. On the other hand, the type of electric generation power plants are classified with the dependence on the type of energy source. Figure (1) describes the total United States Electric Power Generation by Energy Source (Kaplan, 2008).

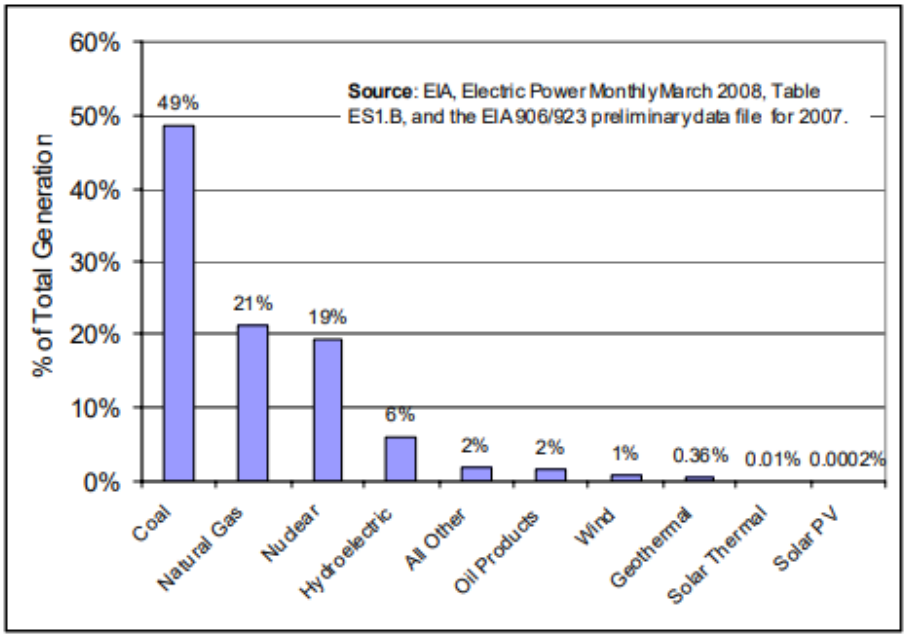

Figure (1): The total United States Electric Power Generation by Energy Source in (2007) (Kaplan, 2008).

Types of electrical power plants

A power plant can be of several types depending mainly on the type of fuel used, the main types will show below (Mansoor-ul-Hassan, 2014):

1. COAL POWER GENERATION: the coals have a vital role in the production of electricity around the world. Currently, the percentage of the electricity produced by power plants using coal as a source of energy is reached 41% of global electricity. In this process, the steam coal or thermal coal have grinded to fine particles in order to have high efficiency in burning by increasing the surface area. The second step, these fine particles of coal are entered combustion chamber of a boiler then the high energy generated from coal combustion is used in heating water-in tubes until it converts to steam the produced steam is used in moving the turbine that produces electrical power.This process steps shown in figure (2).

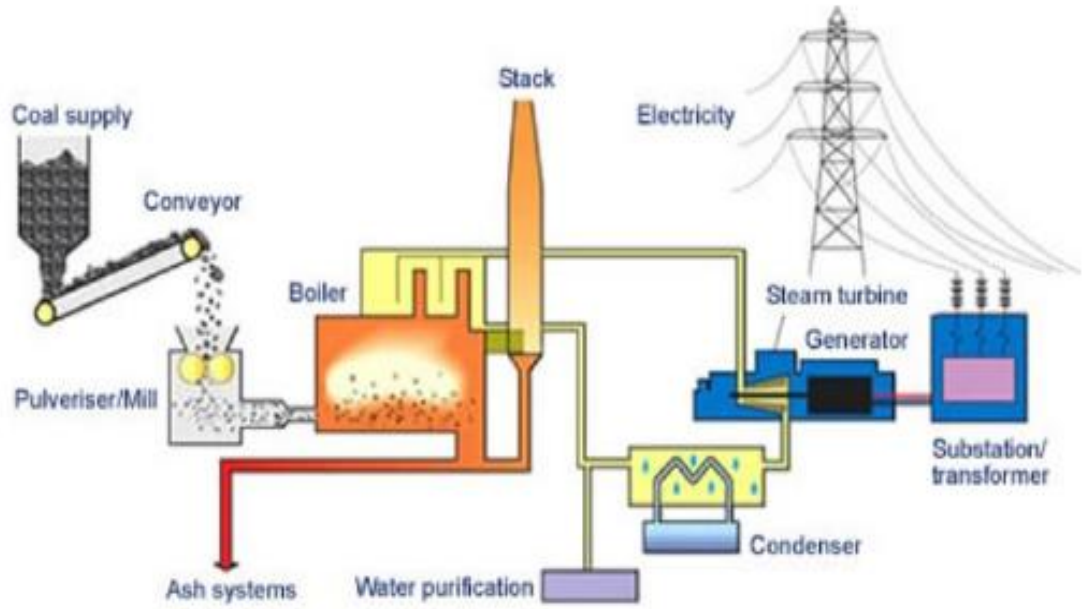

Figure (2): Coal power generation (Mansoor-ul-Hassan, 2014).

2. THERMAL POWER GENERATIONS: in this process the electricity generated by small electricity generators this generators powered using a reciprocating engine that works by burning different types of fuel such as natural gas, biogas, or diesel. Usually, the diesel engines are the most type of engines used in all large power grids, this engines at low voltages are used for Reserve generation, which used originally in some emergencies such as the backup for hospitals and the feed up the power grid during specific circumstances. On the other hand, biogas produced from wastewater treatment plant and a landfill is also used in moving the microturbine or a reciprocating engine included CAT –IE- Engine and a GE-Gas turbine.

3. NUCLEAR POWER GENERATION: in this process, the nuclear energy is used in steam production that is running turbine generators. However, the Uranium-fuelled nuclear power system works like other gas-fired or coal power stations, but the use of the nuclear reactor that works by splitting the atoms of uranium makes this process efficient and clean in steam generation.

4. HYDRO-POWER GENERATION: in this process, a hydro generator used in producing electricity depends on the moving water of streams and rivers, such example of this system is the Three Gorges Dam in China which is the largest power station in the world that can accommodates (22,500 MW).

5. GEOTHERMAL POWER GENERATION: in this process, the electrical power produced by using the earth geothermal energy the process of geothermal power generation shown in figure (3).

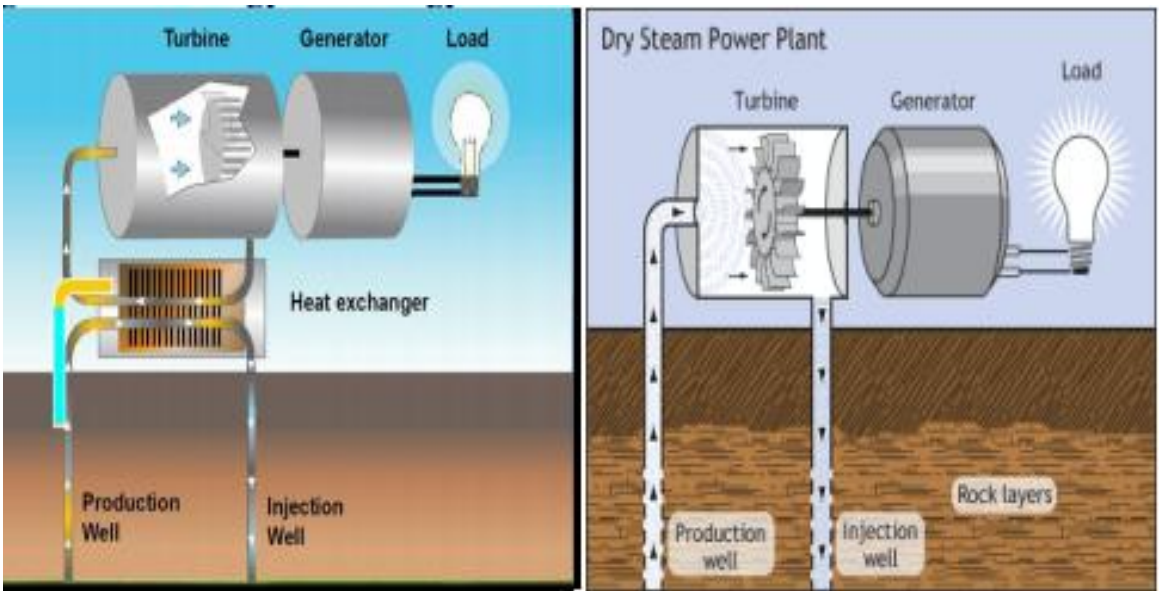

Figure (3): The process of geothermal power generation (Mansoor-ul-Hassan, 2014).

6. BATTERY POWER GENERATION: in this process, the electricity is stored in a chemical form inside a specific type of batteries that can be generated when it needed. However, these type of batteries can be recharged by diesel generator, also these batteries can be used as a power source in machinery and remote locations, small appliances, cars, and submarine.

7. WIND POWER GENERATION in this process, the electrical power can be generating by wind generators called wind turbines that depend on the kinetic energy of wind. Moreover, the most common types of the turbine are a turbine with a horizontal axis and a turbine with a vertical axis that can mainly be used in wind farms both offshore and onshore to generate a huge amount of electricity.

8. SOLAR POWER GENERATION: in this process, the solar panels are used in the generation of electricity. These solar panels are containing a large number of solar cells that collect the sunlight and convert it into electricity; this process is widely used in remote locations and urban areas.

Gas emission from electrical power plants and air pollution

Currently, the electrical power is mainly generated by using traditional sources of energy that included gas, oil, and coal. These types of fuel are discharging a large number of pollutants into the atmosphere that may changes the composition of it. Moreover, coal has a large effect on the concentration of PM2.5 also since the beginning of human use of fossil fuel energy, the global temperature of the atmosphere had increased by 0.85 degrees (Jianguo, 2016).

The electrical power plants have bad impacts in many natural resources such as Air,Water Quantity, Global Climate, Water Quality, Land and Soil, Vegetation, Protected Species, Historical and Archaeological Sites, Wetlands, and Wildlife.On the other hand, the impact of these power plants on air is resulted by burning natural gas, oil, and coal, which emit air pollutants and gases into the atmosphere. The type of gases pollutantsand their effects are listed below (PSC, 2015):

1. Sulfur dioxide (SO2): this gas affected the environment by causing acid rain that can acidify lakes and damage vegetation also SO2 can do a complex chemical reaction in the atmosphere that produces sulfate-based fine particulates.
2. Volatile organic compounds (VOCs) and nitrogen oxides (NOX): NOX and VOCs are components of ozone formation and NOX can do a complex chemical reaction in the atmosphere that produces nitrate-based fine particulates. In addition, ozone is the main component of smog, which can cause many environmental effects and respiratory health effects.
3. Particulate matter (PM): PM includes small particles with a diameter of fewer than 10 microns (PM10), dust, and the particle diameter between 2.5-10 microns (PM2.5). However, these particulate matters can cause respiratory problems due to its ability to penetrate deeper inside the lungs so many societies have monitored the PM emissions.
4. Mercury (Hg): the amount of mercury in nature is very small but it is concentrations are suddenly increased by the great amount due to human activities. However, the main reason behind the huge amount of mercury in the environment is the coal-fired power plants. Mercury can have a pathway to the human body by consumption fishes

contaminated with mercury. The high concentration of Hg in the body will damage the nervous system, specifically in fetuses and children.

5. Carbon dioxides (CO2): the electrical power plants that works using fossil fuel as a source of energy are emitting a large amount of CO2 into the atmosphere. However, CO2 is one of the main human-influenced greenhouse gases GHGs, so any increase in CO2 it leads to an increase in GHGs, which is the main reason behind the global warming and variety of global climate changes. In addition, it can have substantial impacts on the human health and environment in many places on the planet such as melting of polar ice caps and glaciers, rising sea levels, altered ocean currents, wider ranges for insect-borne diseases of crops and humans, and climate alteration. also, it may have other effects included drier and warmer summer weather, lower water levels in streams and inland lakes and the Great Lakes, increased frequencies of severe storms, increased average water temperatures, increased forest fires.

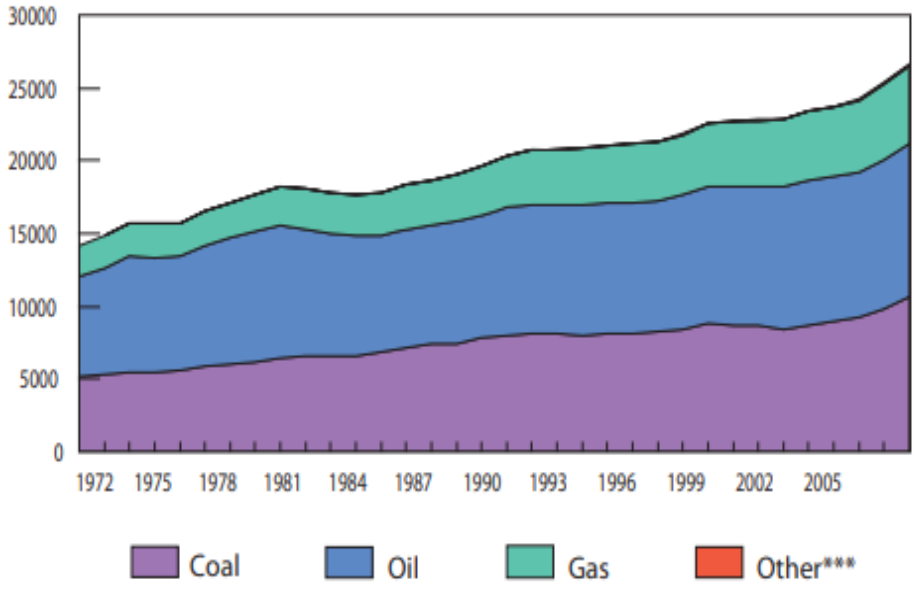

Figure (4): gas World CO2 emissions from different fuels (Mt of CO2)(snarheim, 2009).

Many electrical power plants burning coal as a source of energy in pulverized fuel furnaces. The by-product resulting from burning coal in pulverized fuel furnaces in coal-fired power station (CCPs) are classified as shown below(Seshadri, Bolan, Naidu, & Brodie, 2010):

1. Fly ash (FA): represents the main part of ash produce with a percentage of 90% this type of ash could be pick up from the flue gas that Characterized by its fine texture. it is composed of non-combustible oxidized elements that have light to mid-grey in color and spherical shape ranging between (1-200)µm in volume. Fly ash chemical composition ranges shown in table (2) and fly as solid components shown in table (3).

table (2): Normal range of chemical composition for fly ash produced from different coal types (expressed as percentage by weight)

Component	Bituminous	Sub-bituminous	Lignite
SiO_2	20-60	40-60	15-45
Al_2O_3	5-35	20-30	10-25
Fe_2O_3	10-40	4-10	4-15
CaO	1-12	5-30	15-40
MgO	0-5	1-6	3-10
SO_3	0-4	0-2	0-10

Table (3): Groups of solid components in fly ash

Groups	Properties	Components
Group I	Low water reactivity , possess surface charge	Oxides of Si, Al, Fe and Ti
Group II	Adsorption to oxides	Metals and metalloids
Group III	High water reactivity	Oxides of Ca, Mg, K, Na, Ba, SO_3, Gypsum

2. Bottom ash (BA): represents the remain part of ash that collected at the bottom of the pulverized furnace. Bottom ash characterized by it is grey to black color and large volume with a porous surface structure and quite angular, so it cannot be carried in the flue gas and settle down in the bottom of the pulverized furnace.

The combustion process in the electrical power plants produced a waste solid particles which classified as coal combustion products (CCPs), the type of coal ashes produced is depend on the type of coal used that may produce siliceous ashes it consists of a complex of glassy spheres, unburnt carbon and some crystalline matter. In addition, it is composed from iron, aluminum, and silicon. The percentage of oxides is near to 75-78% of the material and the lime content is less than 10%. Calcareous ashes hve the same oxides of siliceous ashes but the lime content is more than 10%(hedrich, feuerborn, & weir, 2013).Table (4) show WWCPN global definition for coal combustion products.

Table (4) WWCPN global definition for coal combustion products(hedrich, feuerborn, & weir, 2013).

Term	Definition
Coal Combustion Products	Coal combustion products (CCPs) include fly ash, bottom ash, boiler slag, fluidized-bed combustion (FBC) ash, or flue gas desulfurization (FGD) material produced primarily from the combustion of coal or the cleaning of the stack gases. The term coal ash is used interchangeable for the different ash types..
Fly ash	The finer ash produced in a coal-fired power station, which is collected using electro-static precipitators. Sometimes spelt as 'fly ash'. This is also known as Pulverized Fuel Ash (PFA) is some countries. About 85+% of the ash produced is fly ash.
Bottom ash	The coarse ash that falls to the bottom of a furnace. The molten ash adheres to the boiler tubes, eventually falling to the base of the furnace. In many furnaces there is a water system that rapidly cools this ash, so-called 'wet bottomed' ash. Usually <15% of the ash produced is bottom ash (BA), in some countries also known as furnace bottom ash (FBA)
Cenospheres	Hollow ash particles that form in the furnace gas stream. Sometime these particles will contain smaller ash spheres. They float on water and are usually collected from lagoons, where ash/water disposal systems are being used. Only 1 to 2% of the ash produced are cenospheres and with the reduction in ash/water transportation, fewer are collected/available
Conditioned ash	Where fly ash is mixed with a proportion of water (10 to 20% by dry mass typically) in order that it can be transported in normal tipping vehicles without problems with dust for sale or disposal or interim stockpile.
Flue Gas De-Sulfurisation	Where a source of Calcium is injected into the furnace gas stream to remove sulfur compounds. In wet systems a slurry with ground limestone is sprayed in gas stream. After decomposition of the limestone the sulfur reacts with lime and after oxidization forms calcium sulfate. This flue gas desulphurization gypsum (FGD) is used in the gypsum industry as replacement for natural gypsum.

Mitigation methodsof electrical power plants gas emission in urban areas:

The unrestricted use of all types of fossil fuel in electrical power plants will lead the world to a dangerous situation. The increased concentration of CO2, which is one of the main three components of Greenhouse gases that have the largest contribution in the global warming and climate changes.In addition, other by-products that resulted from burning all type of fossil fuel such as coal, oil, and natural gas will affect the air and all environmental components. Figure (5) World energy usage based on different types of fuel (Mtoe)(snarheim, 2009).

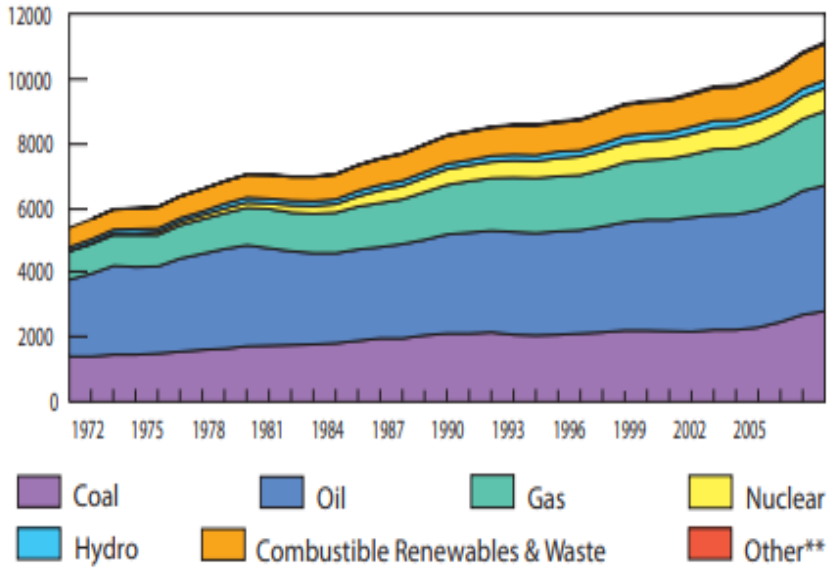

Figure (5): World energy usage based on different types of fuel (Mtoe)(snarheim, 2009).

On the other hand, there are many methods could be used to mitigate the effect of gaseous material exiting from electrical power plants. One method done by (de Gouw, Parrish, Frost, & Trainer, 2014) in order to reduce CO2, NOx and SO2 emitted from U.S. power plants by switching the use of coal in electrical power plants into natural gas with combined cycle technology. This method gets beneficial resultsas shown below:

1. The percentage of carbon dioxide produced is 44% compared with coal electrical power plants.
2. In 2012, a decrease in the percentage of CO2 emission from the United Statesfossil-fuel power plants to 23% compared with the CO2 emission in 1997 because of using natural gas power plants equipped with combined cycle technology instead of coal power plants in the US.
3. Natural gas power plants with combined cycle technology produces a far less SO2 and less NOx per unit energy produced compared with coal power plants.
4. the emission percentage of NOx and SO2 have reduced to (40%) and (44%) due to the use of natural gas power plants equipped with combined cycle technology instead of coal power plants in the US.
5. Useful advantage toward the atmosphere includes air quality and climate.

Figure (6) shown theUnited States power plants average emission intensities of CO2, NOx and SO between 1995-with using coal power plants and 2012- with using natural gas power plants equipped with combined cycle technology instead of coal power plants in the US.

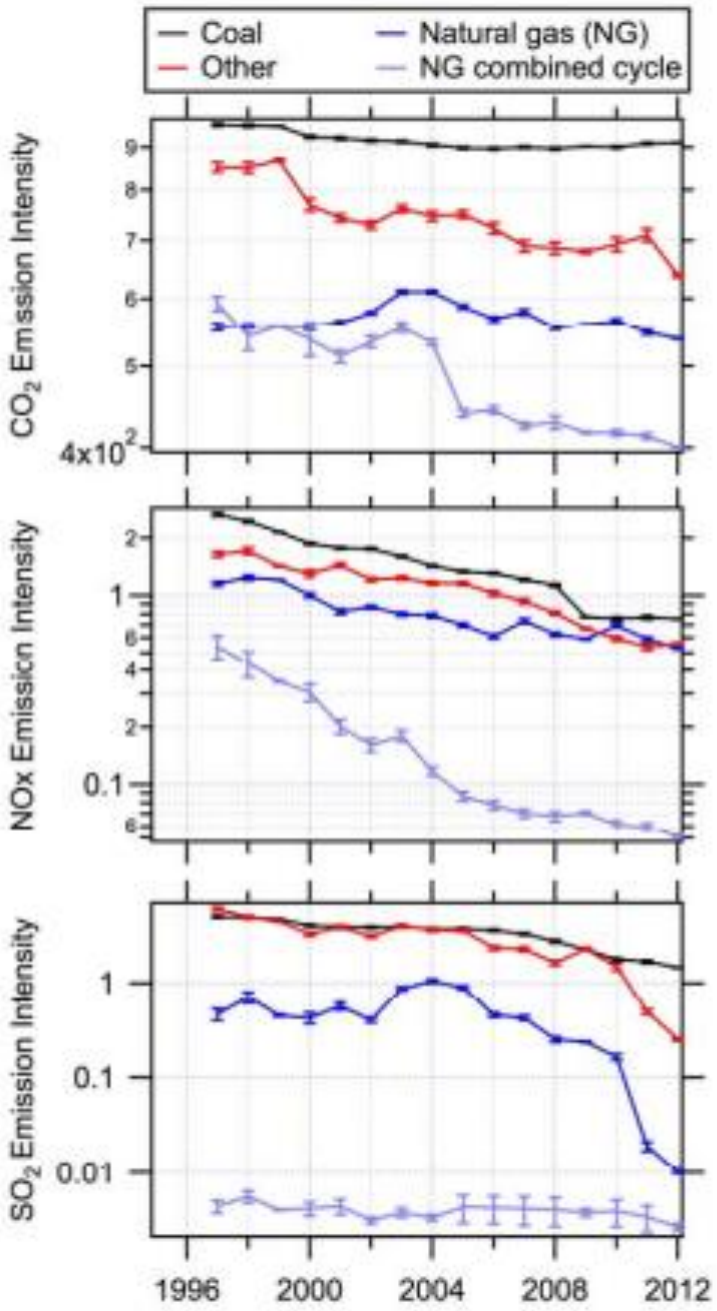

Figure (6): Average emission intensities (in units of g/kWh) of CO2, NOx and SO2 from U.S. power plants between 1995 and 2012(de Gouw, Parrish, Frost, & Trainer, 2014).

Other method could be used to mitigate the coal combustion products CCPs such as (Seshadri, Bolan, Naidu, & Brodie, 2010):

1. Capturing fly ash (FA) using wet scrubbers, filter baghouses, electrostatic precipitators.
2. Fluidized bed combustion (FBC) which is a technology used to decrease the amount of S emitted to the atmosphere due to the burning of S-rich coal. The SO2 emitted during the combustion process will be subjected to multiple reactions to have CaSO4. FBC is widely used in electricity-generated plants because it has a low cost.
3. Flue-gas-desulphurization process can remove more than 95% 0f SO2 emitted to the atmosphere. On the other hand, other acid gases

included hydrogen chloride and sulfur trioxide removed also.

The chemical absorption is a useful method in the mitigation of the flue gases from a combustion power plant. A direct water contact with the flue gas is needed in order to decrease the temperature of the flue gas. after cooling the flue gas it is subjected to a direct contact with alkaline solvent such as amine all flue gases components includes CO2, NOx, and SOx will have a chemical interaction with the alkaline solvent, which convert these acidic gases into heat stable salts. On the other hand, CO2 will chemically bond with the solvent to have very low values of CO2 emitted into the atmosphere.Figure (7) show the CO2 capture system (Thambimuthu, Soltanieh, & Abanades, 2018).

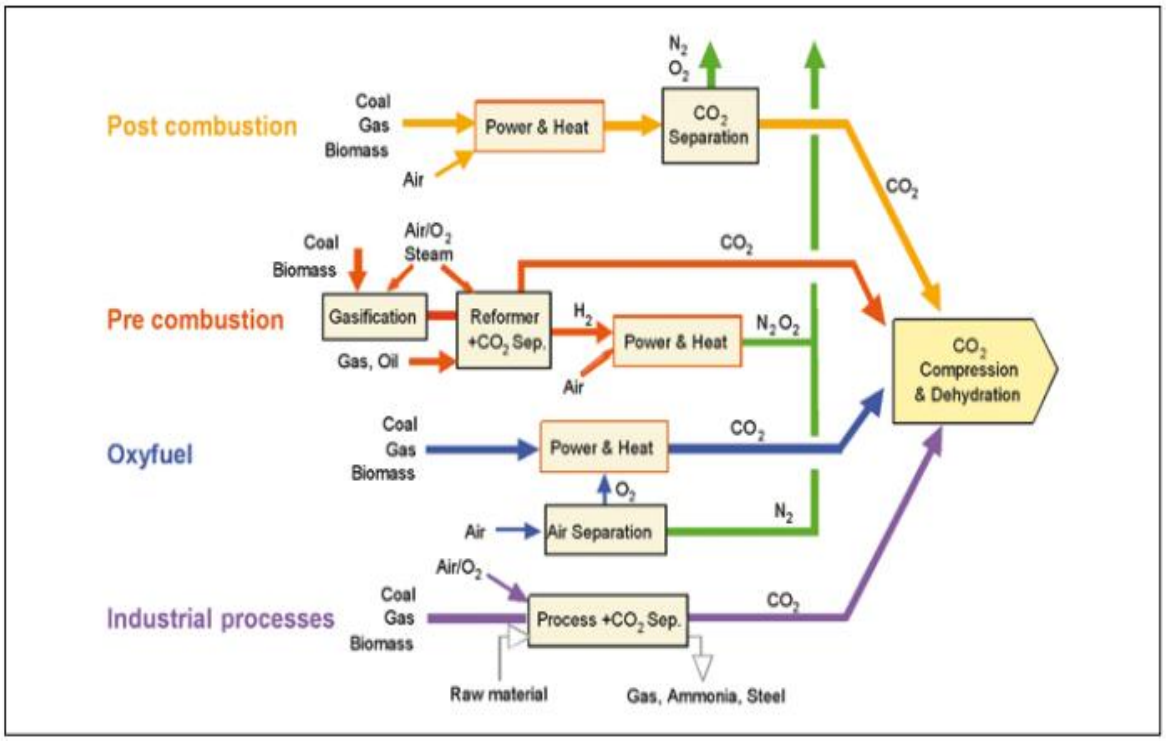

Figure (7): CO2 capture system(Thambimuthu, Soltanieh, & Abanades, 2018).

CO2 can be captured using a chemical adsorption method, this method depends on many types of solid adsorbent that can adsorb CO2 such as amine-grafted sorbents, microporous organic polymers, amine immobilized mesoporous silica types of SBA-15, MCM-41. On the other hand, the amine groups are the most convenient and popular chemical absorbent because the adsorption of flue gas carrying CO2 after combustion is done at ambient pressure. Moreover, they provide fast rates of adsorption for CO2, high adsorption capacities and good properties of desorption, like easy regeneration (Ünveren, Monkul, Sarıoglan, Karademir, & Alper, 2017).

All countries can transform into a low-carbon economy by using eco-friendly and renewables generators. These generators depend on other sources of energy instead of fossil fuel energy. Moreover, the eco-friendly generators generated electrical energy without any gaseous emission that may pollute the atmosphere. Currently, the common use of renewable energy limited to small, distributed generating units in the form of electric prosumer communities and microgrids.on the other hand, until the end of 2016 the renewable energy sources have provided energy reached to 2 million of MW from the total installed power capacity in the world, also the percentage of global electricity production from these sources are reached to 24.5%. The common technologies of renewable energysources for current microgeneration systemsthat may useful in the mitigation of air pollutants released from the electrical power plants are listed below(Marulli, 2017):

- Solar PV panels.
- Microturbines.
- Micro-wind turbines.
- Micro Combined Heat and Power (micro-CHP).
- Fuel cells.

II. CONCLUSIONS AND RECOMMENDATIONS:

In this study, many sections used to explain the Air pollution resulting from electrical power plant gas emissions and its mitigation methods in

urban areas. The first section discusses the power plants and the types of power plants. The second section discusses the gas emission from electrical power plants and air pollution, and the last one discusses the mitigation methods of electrical power plants gas emission in urban areas. The research found out that the use of all types of fossil fuel as a source of energy in electrical power plants have a very bad effect on the atmosphere because these power plants are releasing toxic, acidic, and greenhouse gases such as NOx, SOx, and CO2. In addition to the particulate matter (PM10, PM2.5) and the ashes of coal combustion products (CCPs) include fly ash (FA) and bottom ash (BM). The first method of mitigation of these gas that founded by this research is by switching the use of coal in electrical power plants into natural gas with combined cycle technology. The second method is by capturing fly ash (FA) using (wet scrubbers, filter baghouses, electrostatic precipitators), Fluidized bed combustion (FBC), or Flue-gas-desulphurization. The third method is by the chemical absorption of gases by a direct contact of the flue gases that includes CO2, NOx, and SOx with alkaline solvent. The fourth method is by CO2 capturing using a chemical adsorbent such as amino-based adsorbent. The last method is by using renewable energy as a source of energy instead of fossil fuel in the electrical power plants that included Solar PV panels, Microturbines, Micro-wind turbines, Micro Combined Heat and Power (micro-CHP), or Fuel cells.

Based on the above results it recommended to have more studies about the mitigation methods of the electrical power plans pollutant, also the communities need to raise awareness about using the benefits of using renewable energies.

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