Evaluating Cost of Air Pollution from using Fossil Fuels in Some Industries in Egypt

Dalia M. Ibrahiem[1]

Abstract

To achieve industrial development, Egypt is facing a major problem which is limited energy resources, leading the Government to think of the necessity of heading towards using coal as source of energy. As coal is an important source of pollution and Egypt suffers from industrial pollution this paper evaluates the cost of air pollution for four pollutants SO_x, NO_x, PM_{10}, and $PM_{2.5}$ emitted from using fossil fuels (diesel and natural gas compared to coal) in three energy intensive and polluting industries which are Steel, Aluminium and Cement in Egypt in 2013. The study finds the following: *first*, using coal produces more emissions in the form of the three pollutants SO_x, PM_{10}, and $PM_{2.5}$ emitted from the three industries but in the case of NO_x using diesel produces more emissions. *Second*, cost of air pollution resulted from using coal is the highest cost compared to that from using diesel and natural gas, while using natural gas produces the least cost.

1 Introduction

Energy sector is an essential one for all countries especially for developing ones that are in industrialization stage, however many social and economic factors affect the growth of industrial sector and its energy consumption as population growth, increase in industrial product's consumption per capita, the increase in high energy intensive industries (ESCWA, 2005), changes in factors of production, changes in technology used and changes in average income and so forth (Nkmo, 2005). Although main sources of heat and electrical energy come from fossil fuels which are non-renewable resources (mainly petroleum, natural gas, coal and shade oil) (Chmielewski), combustion

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[1]Faculty of Economics and Political Science, Department of Economics, Cairo University, Egypt.

of fossil fuels have a negative effect on health and environment in form of hidden costs or externalities that are not reflected in market prices and so not counted by the society and National Research Council in United States calculated these hidden costs and found that monetized damages totaled more than 120 billion dollar in 2005 (The National Academies, 2009).

Also, Carbon dioxides (CO_2) emitted from burning of fossil fuels are major source of global warming as the total carbon dioxides emitted since industrial revolution were not absorbed completely in the atmosphere (Lackner, 2010).

In addition to CO_2 emissions, specific dangerous pollutants as Sulphur oxides (SO_x), Nitrogen oxides (NO_x) and particulate matters (PM_{10} and $PM_{2.5}$) emitted from burning fossil fuels have very negative consequences on health in the form of damaging respiratory system which leads to inflammation and cell death burdening the society with high cost (Burt *et al.,* 2013) and there are several studies aimed at estimating these costs. For example Wang and Mauzerall (2005) estimated the impact of air pollution in eastern China in Zaozhuang (heavily depends on coal) on public health in 2000 and found that total health damages was equivalent to 10% of Zaozhuang's GDP (Wang and Mauzerall, 2005). Also Environmental Health Engineering Inc. (2011) estimated the Michigan-specific health damages[2] as a result of $PM_{2.5}$ emissions from the nine coal-fired facilities to be 1.5 billion dollar annually.

In addition Cropper *et al*. (2012) concluded that fine particles resulting from SO_2 as a result of 92 coal fired power plants in India for the years 2000-2008 were associated with 75 percent of premature death (Cropper *et al*., 2012) and also Al-Moafy (2014) estimated cost of air pollution (in 2009 prices) from using fossil fuels (coal, natural gas and diesel) in Cement industry and in generating electricity in Egypt, and the study concluded that using coal instead of natural gas will lead to increase in emissions of NO_x, SO_x, PM_{10}, $PM_{2.5}$ and CO_2 in both cement industry and in generating electricity, and social costs will be between 2.8 and 3.9 billion dollar/year for cement industry and between 1.6 and 5.9 billion dollar/year for generating electricity and the study concluded that in case of using renewable energy resources (as solar energy) in generating electricity, social cost will decrease to a great extent (Al-Moafy, 2014).

In this context, the paper seeks to evaluate the cost of air pollution for four pollutants SO_x, NO_x, PM_{10}, and $PM_{2.5}$ emitted from using fossil fuels (diesel, natural gas compared to coal) in three energy intensive and polluting industries (Steel, Aluminium and Cement) in Egypt in 2013.

The paper is organized as follows: Section 1 is an introduction and the next section presents an overview of the energy sector in Egypt. Section 3 discusses environmental regulations in Egypt facing polluting industries. Section 4 discusses methodology used to evaluate cost of air pollution for three energy intensive industries (Steel, Aluminium and Cement). Section 5 describes data sources. Section 6 is concerned with evaluating cost of air pollution in three energy-intensive industries. Section 7 discusses the results and section 8 concludes.

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[2]Premature mortality, hospital admissions for cardiovascular and respiratory disease, emergency room visits for asthma, asthma exacerbation, chronic bronchitis and minor restricted activity days.

2 Structure of Energy Sector in Egypt

Energy is very important for Egypt's economic growth for two reasons: the first one it is an essential driver of domestic development, and the second one it represents an important source for foreign earnings from fuel exports (Environics, 2010).

Two ministries are responsible for energy sector in Egypt which are Ministry of Petroleum and Ministry of Electricity and Energy. Ministry of Petroleum oversees upstream and downstream gas and oil activities, while the Ministry of Electricity and Energy (MOEE) acts as the owner of the state entities in the energy sector and is responsible for generation, transmission and distribution of electricity (Rasazi, 2010). Egypt's current primary energy sources are oil products, natural gas, hydropower and to a very limited extent renewable resources (solar and wind) (Environics, 2010).

"Egypt is the largest non-OPEC oil producer in Africa and the second-largest dry natural gas producer on the continent and also it is the largest oil and natural gas consumer in Africa, accounting for more than 20% of total oil consumption and more than 40% of total dry natural gas consumption in Africa in 2013 " (EIA , 2014).

Egypt's energy production are increasing rapidly between 2000 and 2011, as net primary energy production rose from 2.5466 quadrillion Btus to 3.8637 quadrillion Btus (EIA, 2014).

As for Crude oil production, it has peaked in 1996 reaching 921.6667 thousand barrels per day, then it continues to decline to reach 539.48 thousand barrels per day in 2012 as shown in Figure 1, and despite new discoveries and improvements in oil recovery, production continues to decline as it operates below capacity (EIA, 2014). Starting from 2006, Egypt's consumption (658.44 thousand barrels per day) is more than production (535.057 thousand barrels per day) making Egypt net importer of crude oil.

Figure 1: Crude Oil Production and Consumption in Egypt (1980-2012)
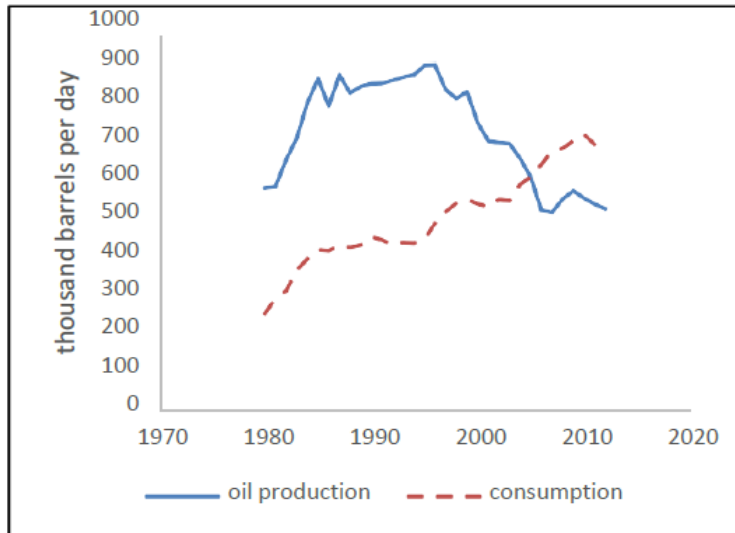
Source: EIA, 2014.

Figure 2: Natural Gas Production and Consumption in Egypt (1980-2012)
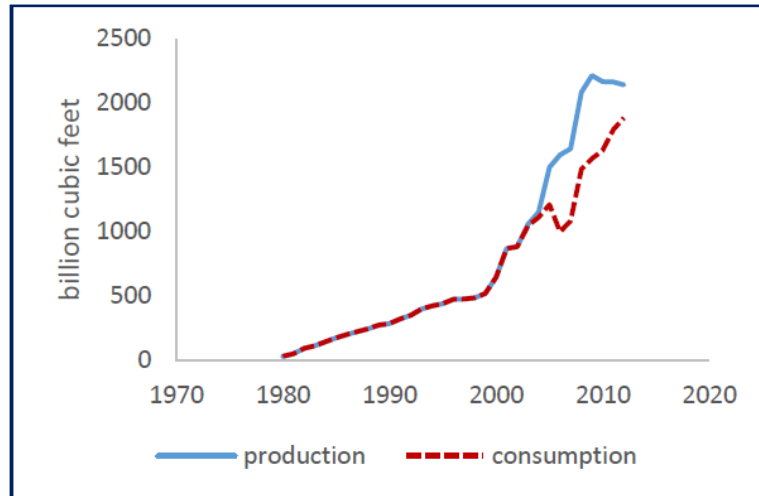
Source: EIA, 2014.

As for natural gas, Egypt's production (1058.3906 billion cubic feet) began to exceed its consumption (1046.0303 billion cubic feet) in 2003, and by 2006 the country became a major exporter, but due to increasing consumption and declining production, as shown in figure 2, Egypt's natural gas exports have declined since 2009 (EIA, 2014).

But there are two challenges facing the Egyptian government concerning its production of oil and natural gas, the first, concerning projections of some experts about depletion of fossil reserves making Egypt face great challenges in meeting its growing energy needs in the near to the medium term (Environics, 2010), and the second, concerning overusing scarce sources of energy as according to the Middle East Economic Survey (MEES), Egyptian government spent 26 billion dollar on fossil- fuel subsidies in 2012[3], ranking as the eighth-highest spender of fossil fuel subsidies in the world contributing to rising energy demand and a high budget deficit (EIA, 2014) leading to chronic energy problems (Jochem *et al*., 2008) .

In this context it is shown that energy-intensive industries[4] suffer from shortages of energy and couldn't work at full capacity so government is thinking about using coal (importing it, as according to EIA Egypt is net importer of coal) as an alternative energy source but the greatest problem related to using coal is increasing pollution especially that environmental regulations adopted were not strictly implemented as shown in the next section.

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[3]But beginning in July 2014 Government began removing subsidies on petroleum products by 22% during the fiscal year 2014-2015 (EIA, 2014).
[4]According to the Prime Minister Decree 1795/2008 amended by Decrees 446/2009 and 2130/2010, energy intensive industries are aluminium, iron, cement, fertilizers, copper, and petrochemicals (Environics, 2010).

3 Environmental Regulations in Egypt

The Egyptian Environmental Affairs Agency was established under the Cabinet of Ministers by Presidential Decree 631 for 1982 but the Agency has a weak authority until 1990 when the   Egyptian government announced two important initiatives for environmental regulation which are the National Environmental Action Plan (with the assistance of World Bank) and the Environmental Law (Law 4/ 1994) (Genena, 1996). In the early 1980s a number of environmental Laws existed as Law 48 of 1982 for the protection of the Nile and Law 102 of 1983 for natural protectorates (Genena, 1996) but Egypt still did not have strong history of environmental laws until 1994 when Egypt passed Law 4/1994 amended by Law 9/2009 for the protection and regulation of the environment (Megacom,   2008) in   an   attempt   to   fill   gaps   in previous environmental legislation (Genena, 1996).
And although appropriate regulation and legal standards are included in this Law, but still few firms have complied to these standards and a 2006 survey of the fifty-five largest industrial firms in Alexandria found soft enforcement of Egyptian environmental regulations although most firm managers emphasized the importance of these regulations (Sowers, 2013).
And certain factors may hinder the implementation of this law as lack of trained human resources, high costs of environmental monitoring (Genena, 1996) and also Egyptian authority did not succeed in implementing credible sanctions as high polluting firms used their pollution loads as an asset in bargaining with donors for aid packages promising to upgrade their facilities. And so Executive authority for pollution control remained weak among a variety of ministries (Sowers, 2013).

4 Methodology

Following the methodology of Al-Moafy (2014), the study evaluates cost of air pollution in 2013 from combustion of fossil fuels (diesel, natural gas compared to coal) for three energy- intensive industries (Steel, Aluminium and Cement) in Egypt depending on recent European Environmental reports: European Environmental Agency   (EEA) Technical report No 15/2011, and EEA Technical report No 12/2013 and on Al-Moafy (2014) in the following steps:

Step one: Calculating the total energy needed in the production of the three industries (GJ[5]/year).

Total energy= Total production (tonnes/year)* energy consumed per tonne (GJ/tonne)   (1)

Step two: Calculating overall pollution by multiplying total energy and emission factors of four pollutants SO_x, NO_x, PM_{10}, and $PM_{2.5}$ emitted from burning fossil fuels (coal, natural gas, diesel) depending on European emission factors from European Environmental technical report no 12/2013 as shown in table 1.

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[5]Gigajoule.

The study depends on upper limits and average estimation for emission factors excluding lower limits estimation as Egyptian environmental enforcement is lenient and there exists lack of compliance with domestic environment regulations as a result of the lack of enforcement (Sowers, 2013).

Total Pollution=Emission factor (tonne/GJ)*total energy consumed (GJ/year)   (2)

Table 1: Emission Factors (tonne/GJ) for manufacturing industries and construction[6]

Fossil Fuels	Limits	NO_x	SO_x	PM_{10}	$PM_{2.5}$
Solid fuel (coal)	**Average**	0.000173	0.0009	0.000117	0.000108
	Upper	0.0002	0.001	0.00024	0.000220
Gaseous fuel (natural gas)	**Average**	0.000074	0.00000067	0.00000078	0.00000078
	Upper	0.000103	0.00000094	0.00000109	0.00000109
Liquid fuel (oil diesel)	**Average**	0.000513	0.000047	0.00002	0.00002
	Upper	0.000718	0.000066	0.000028	0.000028

Source: European Environmental Agency, EEA Technical report No 12/2013 (It is converted from g/GJ which makes calculation easier).

Step three: Calculating cost of air pollution (by summing the multiplication of marginal damage cost with total pollution for every limit for coal, natural gas and diesel) depending on marginal damage cost[7] from Al-Moafy (2014) study which mainly depends on European Environmental Agency Technical Report No 15/2011 as shown in table 2, but the cost in Al –Moafy (2014) study was expressed in terms of euro 2009 prices so some changes have been made to it in the following steps[8]: *first,* cost is expressed in terms 2013 prices using Data for EU-harmonized indexes of consumer prices 2009=108.4 , 2013 =117, *second,* cost is converted to dollar where 1Euro=1.323 Dollar on average in 2013.

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[6]According to the report this includes iron and steel, non-ferrous metal, chemicals, cement, and others.

[7]It assesses the damage costs to health and environment caused by pollutants emitted from industrial facilities.

[8]Second and third steps are taken into consideration in Al Moafy (2014) but in terms of 2009 prices and in total cost not marginal one.

Third, taking into consideration economic conditions in Egypt that differ from that of European Union, cost is re-calculated using GDP per capita (current international dollar)[9] in 2013 where it is equal to 11085 dollar and 34500 dollar for Egypt and European Union respectively.

It is calculated as follows:
Marginal damage cost $_{re\text{-}calculated}$=Marginal damage cost*(GDP per capita $_{Egypt}$ /GDP per capita $_{European\ union}$)   (3)

Cost of Air Pollution = $\sum$ (Marginal damage cost * Total Pollution)   (4)

Table 2: Marginal Damage cost (dollar/tonne)

Emissions	NO_x	SO_x	PM_{10}	$PM_{2.5}$
Marginal damage cost	5446.066	7261.431	22102.4	34037.96

Source: Constructed by the author from Al-Moafy, 2014.

5 Data Sources

The study will depend on various sources of data. Data for energy consumed per tonne in steel industry and cement industry comes mainly from (UNEP report 2011[10]), while that for Aluminium industry comes from World Aluminium Statistics and they are converted to GJ unit.

Data for total production in 2013 for three industries (Steel, Aluminium and Cement) comes from World steel association, USGS[11], and USGS Mineral Program Cement Report respectively. Data for emissions factors comes mainly from European Environmental Agency Technical report No 12/2013. Data for marginal cost comes from Al-Moafy (2014) study which mainly depends on European Environmental Agency Technical report no 15/2011, Data for EU-harmonized indexes of consumer prices comes from Denmark statistics online, data for exchange rate between euro and dollar depends on OANDA data 2013, and GDP per capita (current international dollar) comes mainly from world bank data.

But there exists an important limitation is that the study is based on European data for marginal damage cost and emissions factors and Egypt differs than that of Europe in degree of strictness of environmental regulations and compliance of polluting firms to these regulations and standards of living and population but the dependence on this data is due to absence of such data in the case of Egypt. The study in attempt to take

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[9]Which is known also as Geary-Khamis dollar, and it is based on the two concepts Purchasing Power Parity (PPP) of currencies and the international average prices of commodities and it is used to make comparisons between countries and over time and it gives a more valid measure to compare between standards of living.

[10]Under assumption data is the same in 2013 due to lack of data.

[11]U.S. Geological Survey

into consideration the differences in standards of living and number of population, marginal cost is re-calculated using GDP per capita (current international dollar).

6 Evaluating Cost of Air Pollution in the Three Industries

Following the methodology described in section 4, the study evaluates the cost of air pollution in three industries as follows:

6.1 Steel Industry

The Egyptian Steel industry is considered one of the cornerstones of Egypt's economic growth and development since it is linked to investments in infrastructure as airports, bridges and other industries as construction and consumer goods that enhance economic growth (Global Investment House, 2009).
The steel sector constitutes of 27 producers but "Ezz Steel" is the largest producer followed by Beshay then Misr National Steel (Global Investment House, 2009). Energy costs account for 20% of the total cost of manufacturing steel where sulphur oxides and nitrogen oxide emissions are the largest fraction emitted as related to energy used (U.S. Environmental Protection Agency, 2007). The previous methodology discussed will be applied on steel industry as follows:

Step one: Calculating total energy needed in the production of steel industry.

Total production of steel industry is 6754 thousand tonnes/year and average energy consumed is 31.15 GJ/tonne[12] so total energy consumed will be **210,387,100 GJ/year.**

Step two: Overall pollution is calculated as shown in the following table 3.

Table 3: Total Pollution from combustion of various kinds of Fossil Fuels in Steel industry

Fossil Fuels	Limits	Emissions(tonnes/year)			
		NO_x	SO_x	PM_{10}	$PM_{2.5}$
Solid fuel	Average	36396.97	189348.4	24615.29	22721.81
(coal)	Upper	42077.42	210387.1	50492.9	46285.16
Gaseous Fuel (natural gas)	Average	15568.65	140.9594	164.1019	164.1019
	Upper	21669.87	197.7639	229.3219	229.3219
Liquid Fuel (diesel)	Average	107928.6	9888.194	4207.742	4207.742
	Upper	151057.9	13885.55	5890.839	5890.839

Source: Constructed by the author based on EEA Technical report No 12/2013 (table 1).

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[12]Equal to 744 Kg Oil Eq/tonne

*Step three***:** Calculating cost of air pollution in steel industry.

Table 4: Cost of air pollution in Steel industry

Fossil Fuels	Limits	Cost of air pollution (million dollar/year)
Solid fuel (coal)	Average	2919.92314
	Upper	4493.43877
Gaseous Fuel (natural gas)	Average	95.9883408
	Upper	133.668457
Liquid Fuel (diesel)	Average	904.900814
	Upper	1266.93829

Source: Constructed by the author based on table 2 and 3.

6.2 Aluminium Industry

Aluminium industry is the most energy intensive industry in Egypt as energy in the form of electricity represents about more than 25 per cent of unit cost. At the macro level, this helps in increasing air pollution and deterioration in the environment (Abd –khaliq, 2001).Egyptalum is the main producer of primary Aluminium in Egypt from its Aluminium smelter at Nag Hammady (Taib, 2010).
The previous methodology discussed will be applied on Aluminium industry as follows:
Step one: Calculating total energy needed in the production of Aluminium industry.
Total production of Aluminium industry is 265 thousand tonnes/year and average energy consumed is 55.9 GJ/tonne[13] so total energy consumed will be **14,813,500 GJ/year.**

Step two: Overall pollution is calculated as shown in the following table 5.

Table 5: Total Pollution from combustion of various kinds of Fossil Fuels in Aluminium industry

Fossil Fuels	Limits	Emissions(tonnes/year)			
		NO_x	So_x	PM_{10}	$PM_{2.5}$
Solid fuel (coal)	Average	2562.736	13332.15	1733.18	1599.858
	Upper	2962.7	14813.5	3555.24	3258.97
Gaseous Fuel (natural gas)	Average	1096.199	9.925045	11.55453	11.55453
	Upper	1525.791	13.92469	16.14672	16.14672
Liquid Fuel (diesel)	Average	7599.326	696.2345	296.27	296.27
	Upper	10636.09	977.691	414.778	414.778

Source: Constructed by the author based on EEA Technical report No 12/2013 (table 1).

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[13]Equal to 15534 (KWh) per tonne

*Step three***:** Calculating cost of air pollution in Aluminium industry.

Table 6: Cost of air pollution in Aluminium industry

Fossil Fuels	Limits	Cost of air pollution (million dollar/year)
Solid fuel (coal)	Average	205.5938
	Upper	316.3861
Gaseous Fuel (natural gas)	Average	6.758605
	Upper	9.411688
Liquid Fuel (diesel)	Average	63.71469
	Upper	89.20599

Source: Constructed by the author based on table 2 and 5.

6.3 Cement Industry

The Egyptian cement industry is considered to be one of the largest in the world ranking the 12th according to USGS in 2013. Cement industries is one of Egypt's most important economic drivers with 21 cement producers providing work for 50000 labor but Egyptian cement industry have difficulty reaching full capacity due to ongoing energy supply shortages (Saad, 2014) and the previous methodology discussed will be applied on cement industry as follows:

Step one: Calculating total energy needed in the production of cement industry.

Total production of cement industry is 46 million tonnes/year and average energy consumed is 5.1 GJ/tonne[14] so total energy consumed will be **234,600,000 GJ/year.**

Step two: Overall pollution is calculated as shown in the following table 7.

Table 7: Total Pollution from combustion of various kinds of Fossil Fuels in Cement industry

Fossil Fuels	Limits	Emissions(tonnes/year)			
		NO_x	SO_x	PM_{10}	$PM_{2.5}$
Solid fuel (coal)	Average	40585.8	211140	27448.2	25336.8
	Upper	46920	234600	56304	51612
Gaseous Fuel (natural gas)	Average	17360.4	157.182	182.988	182.988
	Upper	24163.8	220.524	255.714	255.714
Liquid Fuel (Diesel)	Average	120349.8	11026.2	4692	4692
	Upper	168442.8	15483.6	6568.8	6568.8

Source: Constructed by the author based on EEA Technical report No 12/2013 (table 1)

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[14]Equal to 122 Kg Oil Eq/tonne

Step three: Calculating cost of air pollution in cement industry.

Table 8: Cost of air pollution in Cement industry

Fossil Fuels	Limits	Cost of air pollution (million dollar/year)
Solid fuel (coal)	Average	3247.22
	Upper	4992.754
Gaseous Fuel (natural gas)	Average	106.972
	Upper	148.963
Liquid Fuel (diesel)	Average	1007.423
	Upper	1410.479

Source: Constructed by the author based on table 2 and 7.

7 Results and Discussions

This section presents and discusses the results of the methodology described above to evaluate the cost of air pollution using fossil fuels in three energy –intensive and polluting industries (Steel, Aluminium and Cement) in Egypt in 2013.

As shown in tables 3,5,7 the emissions emitted from using fossil fuels in the three industries differ whereas using coal produces more emissions in the form of three pollutants SO_x, PM_{10}, and $PM_{2.5}$ but in the case of NO_x using diesel produces more emissions.

As for the cost of air pollution it ranges from 95.9 million dollar on average using natural gas to reach the highest level 4493 million dollar using coal in Steel industry as shown in table 4, while in Aluminium industry the cost of air pollution ranges from 6.75 million dollar on average using natural gas to reach the highest level 316 million dollar using coal as shown in table 6, and in Cement industry the cost of air pollution ranges from 106.9 million dollar on average using natural gas to reach the highest level 4992 million dollar using coal as shown in table 8.

8 Conclusion

As industrial development in Egypt is considered the cornerstone needed to achieve higher rates of economic development and Egypt struggles with its chronic energy problems which affect negatively this sector, the government declared the necessity of heading towards using coal as an alternative energy source, but this increases the fear of increasing social cost in terms of more air pollution, so the study estimates the cost of air pollution in Egypt in 2013 resulted from three energy- intensive industries (Steel, Aluminium and Cement) using fossil fuels (diesel, natural gas as compared to coal), given the limitation mentioned previously as the study is based on European data for marginal damage cost and emissions factors.

The study concluded the following: first, the emissions emitted from using coal are more in the three industries in the form of three pollutants SO_x, PM_{10}, and $PM_{2.5}$ but in the case of NO_x using diesel produces more emissions. Second, cost of air pollution using coal as source of energy produces the highest cost compared to other fossil fuels (diesel and natural gas) while natural gas produces the least cost.

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