



MSC Thesis

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*Assessing Economic and Environmental in the coal mining area  
under economic fluctuations and volatility energy market*

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Thesis to obtain the International Master Degree in  
“Advanced Mineral Resource Development” Programme

Submitted by  
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## Declaration of Authorship

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„I declare in lieu of oath that this thesis is entirely my own work except where otherwise indicated. The presence of quoted or paraphrased material has been clearly signaled and all sources have been referred. The thesis has not been submitted for a degree at any other institution and has not been published yet.”

Author,  
Sara Mohamed

## *Dedication*

*To the great martyrs of the Arab nation the symbol of sacrifice, from the far north to the south, from Iraqi to Morocco. To the martyrs of occupied Palestine*

*Peace be upon you in your graves. Peace be upon your honorable blood, which has guided our pure lands to sprout hope and freedom. To your lives, the pure.*

*To My homeland Egypt.*

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Thank you very much, everyone!

Author

Sara Mohamed

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## Abstract

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This research project investigates the global fossil fuel energy market and its components through comprehensive understanding the challenges and opportunities of the energy supply and demand. To identify energy pathway three scenarios would be considered the Policy scenario, Environmental and Sustainability scenario, and Economical scenario. The paper provides a description the current status of global fossil fuel energy markets in particular coal. Recently, the supply of conventional energy resources being depleted at their fastest rates and their environmental impacts have gained scholars' attention. Develop and employ alternative energy technologies is essential to achieve the objectives of reducing the environmental undesirable consequences and raise economic performance.

This dissertation presents a critical assessment evaluating the economic fluctuations of coal mining and utilization at different phases of the coal life cycle in fossil fuel energy system market based on the analysis of the vulnerability in coal mining industrial ecosystem in China from environmental footprint, economic stability and social risks aspects, which influence on the coal demand. And highlighting the energy supply problem which faces the Chinese government.

**Keywords:** Industrial ecosystem, energy market, environmental impact, social, economy and environmental vulnerability, China.

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## Abbreviation

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**BP:** British Petroleum is a British multinational oil and gas company headquartered in London, England

**CSC:** conservation supply curve

**DSM:** demand-side management

**EIA:** Environmental Impact Assessment

**EKC:** Environmental Kuznets curve

**GHG:** Greenhouse Gas emissions

**GDP:** Gross domestic product

**IPCC:** Intergovernmental Panel on Climate Change

**MACC:** Marginal Abatement Cost Curve

**MA:** Marginal Abatement

**MC:** Marginal Cost

**MMSD:** Mining, Minerals and Sustainable Development

**Mtoe:** Million Tons of Oil Equivalent

**OECD:** Organization for Economic Cooperation and Development.

**PPM:** Parts Per Million

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## Chapter 1

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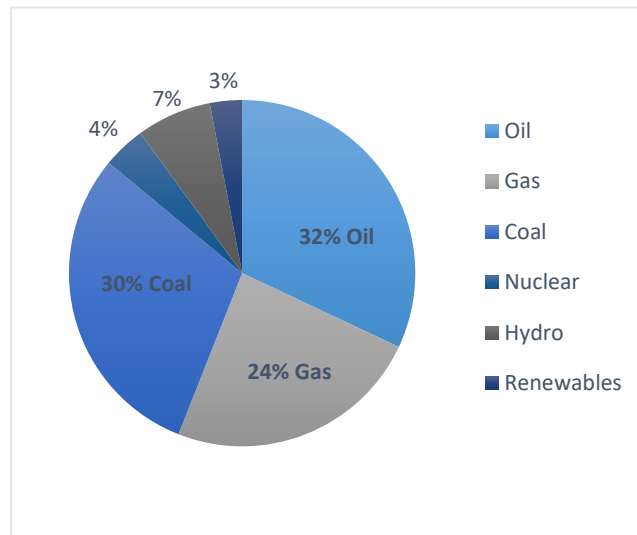
### Introduction

This thesis presents a deeper understanding of fundamental interactions between long-term reliability supply and demand in a specific market (the market in this paper represent the energy market) under the market volatility, market capacity undergrounded in economic theory in mining industry, especially mining industry which related to energy minerals and then estimating the market risks.

Normally Raw Materials classified into more than one group depends on the classification type, the typical and classical classification type divided raw materials into two groups (a) Energetic Raw Materials or Mineral Fuels, and (b) Non-Fuel Raw Materials which include Metals and Non-metals materials. This paper focus on the Energy (Fuel) Raw Materials. The fuel raw materials include Coal, Crude Oil, Natural Gas, Lignite and Uranium, all of this materials sharing the same the main role, which is energy-potential through chemical or physical transformation and the same characteristic features, they are non-renewable raw materials in other word they have limited time and age and whose supply and price have been subjected to variability. That's why, in my point of view, this materials could be categorized as a critical materials the reasons will be explained and showed later in the upcoming parts.

The resources are not distributed homogenous with unequal amount over the world each country has its own resource, for example, crude oil and natural gas are concentrated in the Middle East countries, United States and Russia the total resource of oil and natural gas accounted as, conversely coal deposits distributed worldwide coal is widely equal distributed and the resource is counted as 17.204 Gt in 2010. Fig (1) shows the world's fuel shares outlook of total primary energy supply in.

Energy demand has always been and remain driven by world population growth, it will continue rising long-term with increasing in the world population. The fuel minerals are deemed vital commodity for energy generation. The most striking thing is in 2014 the total of  $\frac{3}{4}$  of the global production value of all raw materials comes from energy raw materials,



**Figure 1: World's fuel shares of total primary energy supply**

wherein the total minerals production of mineral fuels was approximately 15 billion (14.961.685.957) metric ton according to world mine data 2016.

The world's population is projected to increase by around 1.5 billion people to reach nearly 8.8 billion people by 2035 (*bp energy outlook 2017*). The processes of the industrialization, urbanization and population growth have led to raise the demand for the energy minerals, notably demand for fossil fuels. That means the demand of energy minerals will increase more and more over the coming years seeking for more development. Therefore, as more nations develop and the world economies grow, the demand for scarce energy resources increases too. Simply no energy no civilization.

Economic pressures, social and environmental concerns, and development goals set energy access as key priority, many nations aim to secure their energy supplies by applying and adjusting a new and different technology, reducing the dependency on one fuel source, and exploration new alternative sources that increase the efficiency and the productivity of energy, making world is moving towards using energy mix market. The energy mix is shifting, driven by technological improvements and environmental concerns. More than ever, our industry needs to adapt to meet those changing energy needs. Several nations have changed their strategies to put energy security as a top priorities to be able to adapt with any change that will happen in the future. For instance, United States pursues to create balance

in the energy consumption and energy capacity attempting to reduce the dependency on traditional oil production. When most of European countries have pursued nuclear power, as Sweden and France in the middle of the last century. Other nations have taken other pathways to increase their chance of survival including investment performance, clean environment and lower risk, this pathway includes renewable energy sources such as solar energy, wind power, hydropower.

The linkage between economic growth and the consumption of energy was and is potent and effective. Likewise, the relation between the environmental aspect and economic growth. Using fossil fuel as the main source of power during the industrial revolution not only effected the level of economic output but also changed the human society. The central role of energy in evolution of social and economic systems has been highlighted by some scholars. As increased human activity accelerates the potential for economic growth meanwhile it increases the volume of material waste and puts more pressure on the natural environment. On an industrialisation timescale, given the state of global demand for energy practically the fossil fuels, emissions of greenhouse gases especially CO<sub>2</sub> become one of the contentious issues, which therefore influence the price of commodity on long-term scale, CO<sub>2</sub> emissions are positively correlated with energy consumption, economic growth, and population growth, evidence for this is the developing countries of Asia, led by India and China, which have attained not only the highest growth rate of energy consumption in the world but also the highest growth rate of CO<sub>2</sub> emissions in an attempt to reform their economy depending on the energy related to coal inasmuch as they have a massive resource and reserve of coal. In absence of technology and environmental policies in using fossil fuels, the energy market imbalance will implement inevitably. Issues related to environment have attracted much attention recently from governments, policy makers and NGOs from a long time ago.

Over the past 20 years, China was and remains the world's largest consumer of energy and has been the most important source of growth for global energy (bp energy outlook 2017). Chinese energy in particular the electricity generation sector is driven by coal, coal consumption in China accounted for 70% of the total energy consumption, while production was approximately 3,161 Mt in 2010 and with expansion of heavy industries for the domestic and export markets and urbanization in the growth process created a high demand for energy.

## ***1.1 Problems Statement***

- The energy sector in China based mainly on coal since 1980s making significant contribution to ecosystem development including economic and social development. The main problem faces the government is to meet energy demand with an environmentally sustainable. China is suffering from the natural resource pollution and high amount of greenhouse gas emissions due to excessive hard-coal production and consumption. Energy alternatives in China are very limited and this poses a future threat. The balance between energy demand and maintaining environmental sustainability is not easy to achieve according to Supply-Demand curve.
- In economic context, the recent rapid fluctuations of coal in the energy market have led to lower prices compared with alternatives for an instance, Natural gas, which theoretically has led to an increase in the cost of production to the producing countries, including China. With the reduction in the demand rate for coal led to the rate of over-supply increased in China.
- In the local scale, the severe pressures of environmental damage resulting from the use of coal in the production of electricity was a warning to the Chinese government for the need to act and initiate the process of development and environmental reform, which led to a new financial burden on the government and became as an indirect cost of coal production.

The exponential increase of energy utilization witnessed over the past century has led to raise the fuel mineral explorations. That raises important questions, the questions are addressed in this paper such as whether

- Should we be concerned about the long-term availability of fossil fuel minerals?
- Has coal consumption really peaked or closed to peak?
- Is the global used energy at the economically optimum level?

## ***1.2 Limitations***

Because of limited resources, and the use of Chinese as official language in writing in most official reports and its use in the official sites of the government and the institutions responsible for the coal industry, which was difficult to reach. For the reason, it was difficult to communicate

with coal industry representatives such as mining companies, academia researchers and power utilities companies, and due to the lack of time and scientific accuracy requirements I could not translate all these official documents. It was planned to conduct a survey to measure the side effect of the coal mining in the miners and the surrounding population and attached to the research paper but for the same reason is the lack of a common language to communicate, it could not be conducted. And was only using data from former Chinese academics who have searched in the same aspects and use English language in their research papers.

### ***1.3 Thesis outline***

The goal of this study is to identify the coal's contribution to environmental, social and economic vulnerability of the coal industry in its two phases, firstly, Coal manufacture and mining secondly, coal utilization. Examine the requirements of the global energy market towards the energy materials with providing outlook for each one of them.

This paper is organized in six main chapters:

- Chapter one is divided into the general background, problems statement, overview about the energy economics and market and provides an overview about the energy minerals Classified by type types.
- Chapter two is an overview about the previous literatures review which dealt with the same subject of the thesis.
- Chapter three focus more on preparing the conceptual, theoretical base and fundamental concepts of the research.
- Chapter four is more specific in its focus on providing a general study about coal industry and utilization in China.
- Chapter five provides the research methods to measure the vulnerability mechanism of coal in ecosystem including Environmental vulnerability, Social vulnerability, and Economic vulnerability.
- Chapter six conclusion.

### ***1.4 Energy Economics***

Energy economics studies energy resources and energy commodities and includes: forces motivating firms and consumers to supply, convert, transport, use energy resources, and to dispose of residuals; market structures and regulatory structures; distributional and

environmental consequences; economically efficient use. It is similar to the normal economics is divided into two disciplines. Microeconomics which studies aggregate indicators about economy such as energy supply and demand, and examines the price level of energy commodity and level of real output using supply curve of conserved energy. Macroeconomics which deals with the financial and investment concerns. Energy is often described as an essential commodity because human activity sustainability would be impossible in absent use of energy.

The first energy crisis in the 1970s and the dramatic increase in oil prices was a motive to highlight the importance of the energy economics not only for governments and researchers and also for the policymakers. Energy economics includes topics related to supply and use of energy or demand of energy in society to develop the human life. The energy economics is a complex sector, it is influenced by interactions at different issues at different levels (international, regional, and national) such as, elasticity of supply and demand in energy market, environmental and energy policy, sustainability and energy forecasting. The energy sector itself is composed of different industries (or subsectors), each of which has different technical and economic characteristics. They are also not depending on each other to a great level and each industry tries to have a balanced operation considering demand, investment, prices, supply and the institutional environment (Bhattacharyya, 2011).

The investors and economists differ in the way of evaluating performance of energy system, investors assess performance according to the principle of cost and profit, either, the economists evaluate based on the impact on the economy in many aspects, including policies and environment and market study.

### ***1.5 Energy Market***

In fact that, energy fuel market exhibit high volatility makes the enterprises have groundswell of concern about their investment. The cost of fuel minerals could be influenced by some factors have to be taken into account such as price fluctuation, policy and regulations, market concentration, environmental impact and anticipated external events. Practically, in case of imperfect market. The need to secure the environmental and meet energy demand in parental helps to create a new energy opportunities in the market. The entry of green energy, nuclear power and hydropower to the energy market has assisted to achieve the two ends of the equation between the uninterrupted energy demands and



preserve the environment to ensure sustainability of energy and deviate from the fossil fuels. Even the nuclear power does not fully manifest its safety, what happened in Japan during the nuclear station installation could not be neglected. Partial equilibrium analysis examines the effects of policy action in creating equilibrium only in that particular sector or market which is directly affected, ignoring its effect in any other market or industry assuming that they are being small will have little impact if any.

Understanding the market dynamics not only required to estimate the anticipated demanded quantity, but also required for investment and production planning task which lead to efficient outcome and production supply. The market economy main focus is the people, the society members who buy goods and services from firms; which their life cycle is a normal operation consist of inputs, process, and output (the good or service they provide) (Stiglitz and Walsh, 2006). Firms seek to develop their investments by deeper understanding the relationship between the demand and supply to find efficient decisions, they should be willing about the minerals price in the market which is considered as the main driver for purchasing decision. That's not only for the mining industry companies which provide the fuel minerals, but also for final used energy firms such as electricity firms, eventually the cost of electricity production comprised of the fuel cost.

Often demand for the minerals is derived from demand for finished products, the availability of the energy materials plays a significant role in the industry sector in particularly electric power generation, the manufacture of steel, building material, transportations' fuel and heating. With this dramatically increasing demand for such material, electricity generation and manufacturing sectors leads to increase competition for scarce resources and puts pressure on enterprises and government. Consecutively, the supply-related risks are increasing which dramatically effect on the stability of the market where the supply side and demand side meet each other. These materials are easily exposed to crisis and volatility in the market, so it is necessary to put these materials under observation and pay a lot of attention to avoid any fluctuations or risks in the market.

Markets do not operate effectively under numbers of conditions, some of them are stated as the following:

- i. *Lake of information*: when there is a failure in the information that effect on the decisions of consumers and entrepreneurs. Consumers are supposed to have a clear

vision about the net benefit will derive, entrepreneurs build their decision to invest based on a whole range of information gathered over the past and the present together with a prediction of the future. There may be many situations where a significant gap in knowledge regarding the product is available to the entrepreneurs, and in this case choices may be irrational.

- ii. *Profit- motive*: when the firm does not gain revenue which exceeds the cost of the production, higher price creates an incentive for the producers to increase productions.
- iii. *Rivalry*: competitive market forces many the entrepreneurs and producers to compete each other to satisfy the demands of consumers, it is clear that demand should exist to create competitiveness, in fact this type of market is regarded as ideal one. In contrast of this, Oligopoly-market and Dominant-market where a small number of suppliers control the whole market under absence of competitiveness or where the supplier dominates around 30% or 40% of the total production. In oligopoly market firms set prices in a cartel or under the leadership of one firm, instead taking prices from the market, the most famous example for that is oil companies.

## ***1.6 Energy demand management***

It also known as ***demand-side management*** (DSM). DSM activities are those which involve actions on the demand (i.e. customer) side of the electric meter, either directly or indirectly stimulated by the utility. These activities include those commonly called load management, strategic conservation, electrification, and strategic growth or deliberately increased market share (Gellings, 1993). Abroad definition of DSM is proposed to include current policy objectives for emissions reduction, energy security and affordability, and encompasses energy efficiency, demand response, and onsite back-up generation and storage (Warren, 2014). Energy demand is found to be closely linked to energy price, GDP, population to name a few. Achieving a sustainable economic development should be done by a good energy demands management which focuses on an effective cost reduction and resource management (Suganthi and Samuel, 2012).

Generally, alternative classifications of energy consists of ***Primary energy***, “the term primary energy is used to designate an energy source that is extracted from a stock of natural

resources or captured from a flow of resources and that has not undergone any transformation or conversion other than separation and cleaning” while *Secondary energy* the is converted from the primary energy in the form of electricity or fuel (Demirel, 2016) such as electricity, heating, and oil products.

### ***1.7 Primary energy resource potentials***

The rapid increase in the energy industry over the past 30 years has been impressive. Technology has a significant role to expand the energy sources, all the evidence refers to that there are more energy resources in the world today than ever before. For comparability, the generation of energy was exclusive to the use of fossil fuels, but recent technology has allowed to renewable energy and nuclear power revolution to become a reality. Energy has a main aim to improve standard of living and raise the growth rate of GDP, use of energy has powerful economic. Many factors can potentially interrupt supply of materials, they are obtainable for limited period and in restricted amounts. Energy access, the various concerns about the future security of energy, and increase supply to meet the increase in energy demand, all this factors and more have encouraged all the nation to exploit all owned abundant energy resources. In addition to, this factors have prompted both of private, domestic and international investors to raise investment in energy sector to achieve the sustainable energy and economy development, with full disregard for unfavorable results or disorderly symptoms of the spectacular expansion of exploration such as local and regional environmental, and social impacts.

The potential energy demand of users whatever, on individual scale or industrial scale is required to estimate by manufacturers (suppliers) the given input information which is in fact essential as manufacturers’ decision depends upon it, not only to define the most appropriate capacity for production and to develop new plans for supply facilities that could be able to adapt to the requirements of the future generation. The world total primary energy supply in 2015 was 13647 Mtoe, OECD countries was the major emitter with 38.5% followed by China which shared by 21.9%, according to IEA, key world energy statistics report 2017.

### 1.7.1 Fossil fuels (Oil, Natural Gas, and Coal)

Global Combustion of fossil fuels persists to dominate a global energy market aiming to meet the growing demand for energy Global. Fossil fuel resources are considered as a substantial non-renewable resource, they are abundant, and obtainable for limited period and in restricted amounts, fossil fuels are distributed unevenly. Table (1) shows the estimations of the fossil fuels reserves and production according to reported in bp statistical review of world energy report 2017. This numbers are certainly not very clear and could be misleading, especially when reported in mass units (tonnes) and without mentioning their specific energy contents, which can vary considerably. Moreover, it's tricky to anticipate the lifetime of consumption of fossil fuels separately before reaching to the peak because it is governed by several factors, and volatility is one of their characteristics, for instance the ability to persist in supply , the dynamic evolution of demand, depletion and the market fluctuations.

The Global independency of fossil fuel is leading to over-releasing in the greenhouse gasses emission, mainly fossil fuel-related electricity generation. Encourage unconventional lower carbon-emitting technologies, and carbon dioxide capture and storage (CCS) technologies, which can recently be widely developed, has become an incentive for reductions in carbon dioxide (CO<sub>2</sub>) emissions. Innovative supply-side technologies not only enhance environmental protection, but also improve supply security by reducing the gap between both of supply and demand sides by improve energy end-use efficiency.

	<i>Proved Reserves</i>	<i>Production</i>
<i>Oil</i>	240710 Million Tons	4382.39 Million Tons
<i>Natural Gas</i>	6588.7 Trillion cubic feet	3212.9 Million toe
<i>Coal</i>	1139331 Million Tons	3656.39 Million toe

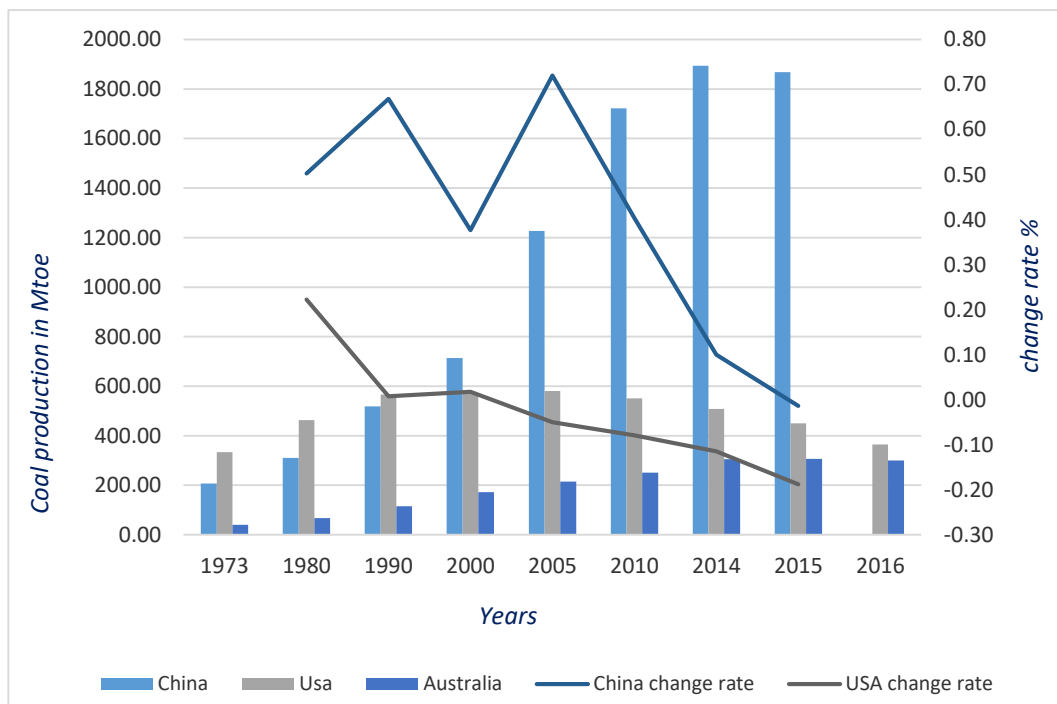
**Table 1: The Estimation of freserves and production of fossil fuels**  
**Source: bp statistical review of world energy report 2017**

### 1.7.1.1 Coal

Coal is sedimentary rock formed underground over millions of years ago, it is subject to directly for mining operations, is extracted from the ground by mining operations using both of mining methods open-pit mining method or underground mining method. Moving towards deeper and inclined uniform coal seams increase the challenges for mining to extract the coal deposit which are likely leading to increase in the cost of production followed by increase in market price. Generally, Coal is classified into four general categories based on carbon content percentage. The four ranks of coal include lignite, sub-bituminous, bituminous and anthracite (Montgomery, 2003). Lignite “Brown Coal” has the lowest carbon content about according to Parker 31.4% it is mainly used for electric power generation, Sub-bituminous contains about 44.9% to 78.2 % carbon, Bituminous “Black Coal” contains around 44.9% to 78.2% carbon, and Anthracite contains approximately 80.5% to 85.7% carbon (Parker, 2014) and is preferred for heating.

Historically, the Industrial Revolution which has been boomed exactly in Great Britain in the early 1800s, have played a significant role for the emergence of coal. Hence, the coal has played a distinctive role in the development of Britain's economy at the time. Accordingly, coal consumption is inherently tied up with the economic growth, both of them have co-benefits relationship. Coal has been used since the industrial revolution and remains continuously increasing, the world has burned more much amounts year after year, the coal production and consumption has risen in the last decade driven mainly by economic growth in emerging economies. Since then, coal has played a major role as source of energy. Recently, coal is produced in over 50 countries, consumed in over 70 countries and traded globally, it is a low-cost fossil fuel used primarily for electric power generation. The top 5 countries have access to an affordable coal resources are U.S., Russia, China, Australia, and India. Coal is typically significantly less expensive than any other fuel source. Coal has a main role in industry, it is considered as a main feed in the steel manufacturing, cement plants, paper mills, and chemical plant, and it is used excessively in electricity generation particularly in Asian countries which relies mainly on coal as a source of energy. Wherein, coal resources is concentrated in abundant in developing countries and China comes on top of them. As, coal production and consumption has risen in the last decade driven by China not only in Asia, but over the world. Figure (2) shows the coal production in China, USA and Australia, and the production change rate from 1973 to 2016.

Coal mining processing is correlated with releasing several impurities such as, sulphur content is around (0.4% - 0.7%) of the coal weight depending on the coal type, ash content range from 3.3% reaches to 20.2% (Parker, 2014), and methane gas which the major gas released in coal mines. During the burning in coal-fired plant, generates more CO<sub>2</sub> emissions per unit compared with any other fossil fuel. Open pit and long-wall underground mining methods are used to extract the coal deposit. The coal companies have shifted to use underground mining method to increase productivity, as coal mines become deeper and deeper the amount and concentration of toxics gasses (mixture of carbon dioxide and monoxide, nitrogen, and methane) may be increased, and controlling the gasses and coal dust become more difficult. That needs high awareness of ventilation system to duct the essential fresh air to workers to achieve mine safety principles, which consequently increase the total cost of production.



**Figure 2: The Coal production in China, USA and Australia, and the production change rate**

**Source: for China's data, National Bureau of Statistics of China. China Energy Statistical Yearbook China 2016 for USA and Australia data , BP Statistical Review of World Energy June 2017**

In early 1973, U.S. dominated the coal market it supplied with total production of the coal was 333.36 Mtoe when the China's production was 206.79 Mtoe. In the 2000s, China's production surpassed the world's production even surpassed those of the United States reached to 713.5 Mtoe. While China's coal rebounded and peaked, the world announced that it was abandoning the use of coal or at least limiting it to necessity (excluding the rest of Asian countries). In 2011, 30% of global primary energy consumption comes from coal which the highest share since 1969. Most of the global coal demand is driven by Asian region dominated by China followed by India and Japan which consumed in sequence 1887.5, 411.9, and 119.9 Mtoe in 2016, the region has experienced rapid growth over the past 30 years. In sharp contrast to that, over the past 46 years the European coal industry has been declining and shifted away in terms of coal consumption growth and production. Most of European countries for instance, France, Holland and Belgium have completely shut down their coal mines and other remain limiting coal using, it has fallen by 44% since 2005 in E.U. region. For instance, France, Denmark and Switzerland their coal consumption in 2016 was in sequence 8.3, 2.1, and 0.13 Mtoe. E.U. energy from coal has fallen during most years between 1990 and 2013. In the U.S. it declined as well over 13%. Appendix (A) provides the global coal production over the world in 2016 in unit million tons.

In the last few years, the global coal demand was cut off and the global consumption looks set to peak, the growth in the demand for coal and its energy to slow sharply, although China remains the largest growth market for energy. Coal consumption dropped by 15%, the largest annual decline ever, to levels not seen in more than 30 years. The increasing rate of cut off coal-based electricity and shift away to low carbon sources in Europe and U.S. as expected due to the new environmental policies. Regardless of the coal consumption has peaked or closes to peak in China, will continue to be the largest coal consumer by far over the period to supply electricity demand.

In other hand the coal production in USA was declining since 2000 much of this slowdown in the USA production is driven by shifting to away from coal towards cleaner, lower-carbon fuels. The production of renewables other than hydropower, natural gas, and crude oil are increasing and their contribution in total U.S. energy production. Jacob L. Brinkman has provided a study about the USA coal mining and demonstrated the declination in the USA coal mining production. The US coal mining industry has suffered a recent decline in profits caused by a combination of decline in commodity demand and more

restrictive government regulation, forcing coal mining companies to cease production in numerous mines, the total number of coal mines decrease overall by 40% from 1994 to 2000 (Brinkman et al., 2017). Substantially the USA coal industry is dying due to competition from natural gas and the government administration regulations to protect the environment.

**Global coal demand.** Growth rate dropped for its first time in 2015 by around 2.6% than 2014, and kept dropping in 2016 by 1.7% than 2015. In 2016 the growth rate of coal demand in E.U. dropped by 8.9% and followed by OECD by 6.4%.

**The coal forecast.** According to bp outlook the coal sharing in primary energy continues to decrease significantly until it reaches its dominance to almost 20% by 2035 after a slightly higher rate of 30% in a year 2015 to be replaced by natural gas. By 2035, coal consumption will be limited to India and other non-OECD Asia, India is pursuing China's approach to its coal-based economy reform in the first place. The world no longer burns as much coal as before, the growth path now depends on China only. Most of new policy agreements (which provide for environmental rights against climate change from greenhouse gases emissions) attempts to shift towards clean low-carbon energy in addition reduce the electricity- based renewable energy. The coal demand in the coming years will be less than the level it reached in a year 2013, this reduction in demand negatively affects exports which plays a major role in reviving the domestic economy of exporting countries, including China.

### ***1.7.1.2 Oil***

Oil is the most important energy source up to now across the globe. This is because it is used in many applications like: heating, electricity generation, making fertilizers, making plastics, and transportation; with approximately 95% of all global transport being dependent on it. In 1973 over 46% of total primary energy supply came from oil. Recently, the demand decline to 31%. Most of demand has been shifted to natural gas which is used today to generate nearly a quarter of all global electricity. The global demand for oil will significantly shrink in the coming decades. The demand of oil gradually decline due to introduce the electric vehicles in the market and shift away from the normal transportation system which consumes most of the world's liquid fuel, recently potential of non-oil fuels will increase in China. (Bp energy outlook, 2017).



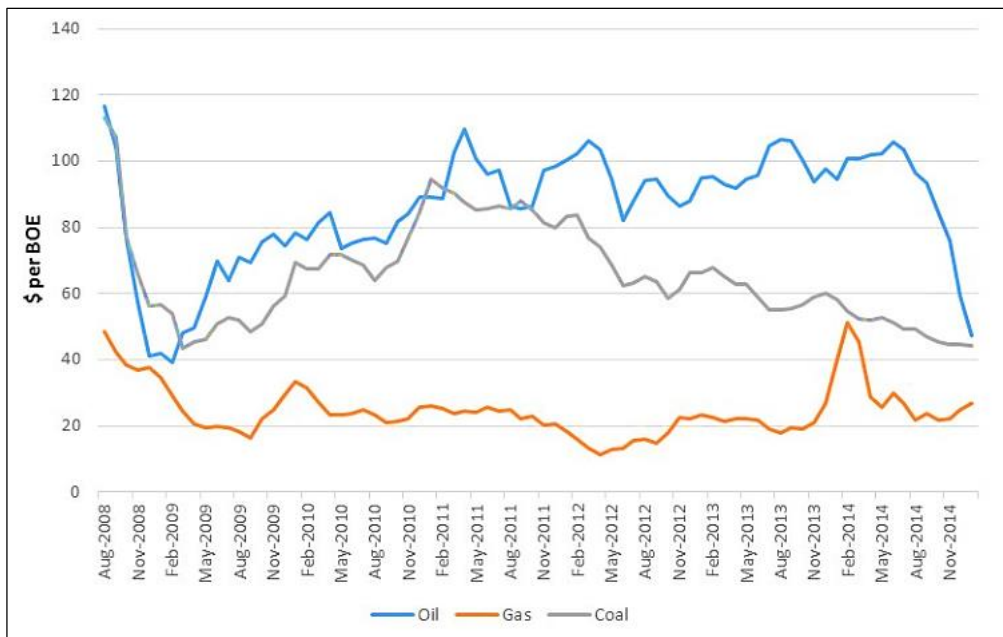
According to the IEA 2035 projects, China will become the world's biggest importer of oil and gas to meet its upcoming enormous energy needs. In National Bureau of Statistics of China's 2016 data, the Chinese investment of petroleum and Natural Gas extraction have evolved gradually in period from 1995 till 2015, which implies that the Chinese government pay more attention on creating more alternatives energy sources. Growing the Chinese investment in oil and gas investment leads to Increase the number of competitors in the market. The investment in fixed assets in oil and gas mining sector in China increased by 30.3% in 2016 than 2015.

### ***1.7.1.3 Natural Gas***

Natural gas is no less important than other fossil fuels resources. Not only, it has an important role in residential and commercial electricity and heating market, but also, it serves an input into other industries. Natural gas provides 23 % of global energy consumed in the world. It is expected to grow faster than oil or coal reaching to more than 67 % through 2030, the global gas demand growth rate is projected to reach to 1.6% per year in the next years. China will contribute the highest percent reaching to 40% of this growth. Natural gas is less harmful, during the burning in gas turbines and steam turbines, the CO<sub>2</sub> emission is about 30 % less carbon dioxide than burning petroleum and about 45 % less than burning coal for an equivalent amount of heat produced. Rising shale natural gas production output more quickly than oil and coal driven by U.S. shale gas exploration projects.

The European natural gas market has recently been exposed as a result of several obstacles, the disruption of production resulting from the civil war in Libya in 2011 and the Russian-Ukrainian conflict 2009 which is causing disturbances in the European natural gas market, this various variables could be influence on gas prices in the market (Nick and Thoenes, 2014) under natural gas high demand growth and disruption in the supply. The question is addressed here would the gas demand lead to market risk in the near future? Will these global events in natural gas producing countries affect the supply of natural gas and lead to other energy crises? The answer here depends on how much the notions have been learned from the past. There is a close the relationship of the natural gas price and the prices of coal and crude oil. Rising shale natural gas production and the expected dramatic growth in coming years may be lead to falling natural gas prices which impact on the coal and crude oil price in the market. That may be lead to rank the natural gas as a global energy commodity.

This is clearly shown in the below chart figure (3) which shows oil, gas and coal prices relationship in period 2008 and 2014 in U.S. energy market.



**Figure 3: U.S. oil, Gas, and coal price from 2008 to 2014**  
 Source: energy & carbon blog.

### 1.7.2 Nuclear power

Uranium is a vital mineral for nuclear power plants for electricity generation. During 1945 -1958 uranium exploration driven by military power for military purpose, then during the period 1974 -1983 exploration driven by civil nuclear power. In 2011, the world's known recoverable resources of uranium was estimated by 5,327,200 tonnes U. Australia ranked number one with total sharing in the world by 31% followed by Kazakhstan 12% then Russia and Canada 9% (OECD NEA & IAEA, Uranium 2011). The mineral exploration investment develop gradually year by year since 2003, furthermore, the number of countries which enter the market increase in turn. For instance, the primary production of uranium in Kazakhstan witnessed a rapidly increasing since 2004 the production was about 3719 tonnes, in 2011 the production was estimated at 19451 tonnes, moreover, China's uranium production doubled from 2004 till 2011. This unanticipated roses in uranium mines investment implies that the high demand of nuclear power plants. The problem in generating electricity from nuclear power plants would be relatively expensive, the total investment costs around 1700 Euro per

KW, and it is more expensive than the same amount which generated from fossil fuel. However, Nuclear power is essentially carbon-free, but the disposal of radioactive waste and radiations remain the main obstacles of nuclear energy.

Uranium mining in the first step in the nuclear fuel cycle to produce energy. Uranium is extracted by several mining methods open pit method, underground mining method, In-situ-leaching, Percolation Leaching, and Heap Leaching. The risk potential concerning using nuclear power may epitomize in two level, the first one during the uranium mineral extraction, the second during installation the nuclear power plant. Uranium exploration and mining have a significant environmental footprint, economic and social impacts, and influence on sustainable development. Radon emission and disposal of old radioactive contaminated may spray in water and air flow causing accidents and disease, lung cancer due to the exposure to radon decay products which is the primary hazard to underground uranium miners (Hornung, 2001) Kreuzer has provides a clear evidence of a linear relationship between lung cancer and cumulative radon exposure using data from the German uranium miners cohort, several miner studies have consistently shown a significant relationship between exposure to radon and the risk of lung cancer (Kreuzer et al, 2010).

China's most recent Five-Year Plan also set a target for the addition of 58 GW of nuclear capacity by 2020. Currently, China has 38 operational nuclear power reactors, with another 19 under construction. In 2015, China's nuclear power plants generated an estimated 161 billion kilowatt-hours of electricity, representing 3% of China's total net electricity generation.

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## Chapter 2

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### Literature Review

In literature most of the researchers investigated only the relationship between energy consumption and economic growth.

#### ***2.1 Energy consumption, Economic growth and Environmental impact nexus***

Over the past two decades especially after the energy crisis in 1970s, numerous energy economics literature seems to provide advanced considerable studies which have investigated the causal relationship between energy consumption and several independent variables such as, economic growth (GDP) environmental impact (CO<sub>2</sub> emissions), and population growth. Energy-Economic studies were not limited to a particular region or country. Different studies have focused on different countries, time periods, proxy variables and the different econometric methodologies used for energy consumption, environment and growth relationship (Saidi and Hammami, 2015), although they were more focused on Asia where the energy consumption have increased with the rapid population growth. From an economic point of view, the relationship between energy consumption and economic growth lies in two aspects: the growing dependence of economic growth on energy, and on the other hand, economic growth can promote energy technology advances and large-scale development and utilization of energy. (*Zhang-wei and Xun-gang, 2012*).

Saidi and Hammami have investigated the impact of economic growth and CO<sub>2</sub> emissions on energy consumption for a panel of 58 countries during 1990–2012 by using dynamic panel data model (Saidi and Hammami, 2015). Shuyun and Donghua has examined the causal relationship between energy consumption and economic growth (GDP) in China by using updated China provincial panel data for the period 1985–2007 within a multivariate framework. The results showed that, in the case of China, the results of panel cointegration test reveal that there is a long-run equilibrium relationship between real GDP, energy consumption, the labor force, and the real gross fixed capital investment. This long-run relationship suggests that a 1% increase in energy consumption increases real GDP by 0.57%;

and 1% increase in capital increases real GDP by 0.16%; and a 1% increase in the labor force increases real GDP by 0.53%. (*Shuyun & Donghua, 2011*).

Nasreen and Anwar have applied panel unit root tests to investigate the linkage between three variables, energy consumption, economic growth and trade openness for 15 Asian countries over the period, including China. However, in the usual energy economics literatures, causality between only energy consumption and economic growth have been provided. The analysis have confirmed on a positive relationship between energy consumption and income growth, energy consumption and trade openness whereas, an inverse relationship between energy consumption and energy prices is observed. Results of FMOLS indicate that 1% increase in income growth Increases energy consumption per capita by about 0.42%. Similarly, a 1% increase in trade openness increases energy consumption per Capita by 0.06% in the Asian countries. The effect of oil prices on energy consumption is found to be negative and indicates that 1% point increase in real oil prices decreases energy usage by about 0.19% in a selected panel of the Asian countries. (*Nasreen & Anwar, 2014*). Traditionally, the concept of energy security has been based on ensuring sustainable and reliable energy supplies at affordable prices (*Sahir and Qureshi, 2007*).

## ***2.2 Econometric modeling***

Nations are going to reassess the increase in energy efficiency and conservation, as a result of the constant change in energy prices in the world energy market, which has helped to bring about a rebalancing between energy security and environmental and climate change issues. (*Mundaca and Neij, 2009*). Most of energy models were acquired widespread application in the 1970s and 1980s to analysis the national energy intensity and provide a clear vision to government and policy makers supporting them to issuing public legislation after examine the complex relationship between secure the demand energy, growth in population, and environmental issues under using the high technology. Third world countries had hoped that energy models could be developed for the efficient energy planning, forecasting and optimization of energy sources, and in this case they can secure their needs of energy.

Energy-economy models have attracted the attention of decision makers for a several decades and became necessary tool in last recent years for energy planning and forecasting, they are existing in several formats and have been developed to appropriate a specific implementation. Researchers had developed the energy-economy models to cover all energy disciplines and assessment the factors that bond to energy, for instance (1) Energy planning models (2) Energy supply–demand models (3) Forecasting models and (4) Emission reduction models. These models provide a good starting point for analysing some of the issues related to modern industries in developing countries such as improving processes, the impact of technology development, and the effects of some aspects of privatization (Pandey, 2002).

Tiris determine long-term energy supplies, economy and environment interactions for Turkey energy sector in period (1986-2010) by using a linear optimization model and a multi-attribute value model. The model determines the importance of the relationship between the three indicators “energy consumption, environmental problems and economy” in the determination of the overall decision. The results of his study showed that, high pollution is expected and control measures must be taken into mind during the planning. The results of his paper were as the following: (i) the uses of hydro-power, solar and geothermal energy resources must have the highest priorities; (ii) high-quality fossil-fuel imports are not only economical but are also environmentally friendly; (iii) uncontrolled use of domestic lignite and coal is unacceptable; (iv) nuclear power will be a solution for some environmental problems but requires high capital investments (Tiris et al. 1994). This study has proved the importance of control coal using in energy sector and government’s energy supply strategies should be changed by switching in power plants and increasing the limitations for fossil-fuel production and consumption and emphasizes nuclear power and clean energy as energy options.

Literature is replete with energy policy models developed for addressing various policy and planning concerns. O. Stern in 1977, described a quasi-equilibrium policy-impact model for exploration and development activities of depleted resources with applications to crude oil.

It is noted that if the cost of the extraction process rises significantly and development costs are relatively lower, the cost of the extracted metal may exert stronger pressure on the price (Stern, 1977). Baker and Finizza in 1990 viewed the use and limitations of economic models in the corporate environment. Their paper reviewed “alternative model types and the

applications for business environment analysis, investment alternatives, and strategic decisions” (Baker and Finizza, 1990). M.Shrestha P.Marpaung in 1999, provided a study examines supply and demand side effects of carbon tax and the implications of carbon tax for power sector development in the Indonesian power sector. State tax rate affects CO<sub>2</sub> emissions resulting from changes in electricity prices (Shrestha and Marpaung, 1990). Pohekar and Ramachandran in 2003 presented a review about the application of multi-criteria decision making to sustainable energy planning. A multi-criteria technique that relies on improving the quality of decision-making processes related to energy sector problems, minimizing costs with increased benefits is one of the traditional criteria. A single criteria approach aimed at identifying the most efficient supply options at a low cost was popular (Pohekar and Ramachandran, 2003).

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## Chapter 3

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### Energy Materials Criticality

#### ***3.1 Fundamental concepts***

In this section, the fundamental basic concepts are presented and discussed. It begins with an introduction to explain the concept of criticality and explanation about the fuel minerals are provided to analysis the criticality of this materials and how the nations deal with this issue to secure their demand of energy.

#### ***3.2 Criticality***

##### ***3.2.1 Illustration of the concept of criticality***

Throughout the spectacular expansion of activities, there has been considerable uncertainty as to how to define the concept of “criticality” of materials, according to "Minerals, Critical Minerals, and the U.S. Economy" report it been defined as a function of two variables, importance of uses and availability, effectively communicated by a graphical representation referred to hereafter as the criticality matrix in which the vertical axis reflects importance in use and the horizontal axis is a measure of availability.

In other hand, according to Nassar and others criticality can be defined as the quality, state, or degree of being of the highest importance the availability of needed raw material should be emphasized under economic condition. The traditional definition has been proposed for rare and critical metal materials that takes into account the supply risk of materials depending on the geological reserves to estimate the relative availability of the metal, traditionally criticality is connected with geologically scarcer (Nassar et al., 2015).

Graedel has provided a faithful explanation of the three components with a deeper analysis for metal criticality in his article under named “Methodology of Metal Criticality Determination”. The criticality is being led by the importance of use (high industrial demand) and the lack of supply due to the limited reserves. Recently, it has been developed to expand



including a wide range of related factors, based on the consideration of a three-dimensional framework can be applied to different spatial levels (Graedel, 2011). The three dimensions of the analysis are:

- I. Supply risk is a function in the time scale, varies depending on the time period whether medium or long term. The medium-term period consists of a few years and the long-term consists of a few decades.
- II. Environmental implications on ecosystem.
- III. Vulnerability to supply restriction differs with the local level and international level.

With an initial comparison between the special features of the energy minerals and three-dimensional principle which has been laid their foundation by Graedel we will find out that they are identical and therefore can apply the concept of Criticality on the energy materials.

### *3.2.2 Demonstration of Criticality from Supply-Demand curve (Supply Risk)*

No one can deny the needs of nations and communities to have constant, stable and even safe supply of energy. Not only to ensure the economic and social level but also to ensure sustainability in industry and production. Energy is one of the most indispensable and irreplaceable commodity. However, the problem lies in how to provide the supply of energy continuously and how to meet the demand of energy. The concept of demand for a mineral is not significant in itself for the economic and the end-user perspective, whereas it is the demand for what these mineral ultimately provide. The energy here represents the final commodity that everyone wants to obtain, no matter how it is made or from what it comes from. But, the energy minerals are considered as the main feed for energy and industry. Thus, the criticality in energy minerals lead to problem in energy minerals supply and by virtue of which energy supply problem would be generated. Interactions between energy systems, energy resource consumption, and the economy are complex and they are modelled by applying microeconomic and macroeconomic principles.

The study of supply and demand inside a market is known as micro-economics conservation supply curve (CSC) was proposed by (Meier, 1982) especially after the oil and energy crisis in 1970s. Supply curves of conserved energy offer a framework for incorporating potentials into the traditional supply-demand analysis and to express or measure the quantity of the effect of changes on energy system. In conservation supply curve the x-axis is the price, and the y-axis is the quantity of commodity. There is an inverse correlation between price, and quantity demanded, the high demand for the same commodity leads to an increase in its price.

In other hand the price rises with the increase of the supply as the marginal cost per additional unit is considered, surely supply is an elastic function of the quantity of units. Equilibrium point where the supply and demand meet and adjust the market price when the level of demand is equal to the level of supply in the price and quantity. Figure (4) shows the conservation supply curve.

**Supply-side** describes the quantity of commodity offered for sale at a given price (Stiglitz and Walsh, 2006). It should keep into mind the given price limit should not less than the Marginal cost. The supply function could be determined by,

$$Q_x = F (P_x, P_y, W) \dots\dots\dots Equation 1$$

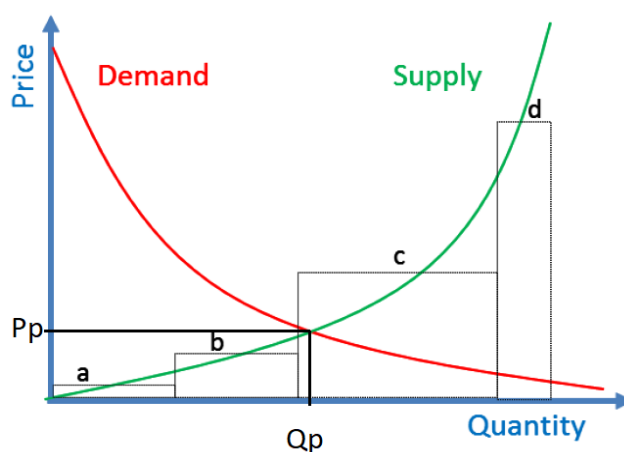
Where: Q: The total supply, P<sub>x</sub>: the price of commodity X, P<sub>y</sub>: the price of production substitute  
W: the price of inputs (raw material, labours, etc.)

**Demand-side** is determined by, the amount that association can spend to purchase specific commodity in a certain quantity. It is remarkable that, is not only significant to focus on the needs of society, but also the limits of spending, which is represented her by the cash flow of the investment and the resulting price of the nation's service which is provided for the people (Stiglitz and Walsh, 2006). The demand function could be determined by,

$$Q_x = F (P_x, P_y, M) \dots\dots\dots Equation 2$$

Where: Q: The total demand, P<sub>x</sub>: the price of commodity X, P<sub>y</sub>: the price of product Y  
M: the income

Recently, conservation supply curve has proportionate to environmental matters. Jackson submitted a proposal about marginal abatement cost curve in climate change context and CO<sub>2</sub> emission. (Jackson, 1991).



**Figure 4: Supply - Demand curve showing the equilibrium point**

In the context of energy, the decision-makers whether electricity companies or governments or private investor, take into consideration the performance condition for any project under demand market curve and put the limit acceptable cost by comparing all alternative options and nominate the preferable one, in terms of sustainability, the least impact on the environment, and which provides the conditions of safety. For deeper explanation, these materials are used mainly in the generation of electricity, the total amount of generated electricity and its efficiency in addition to the price of the unit of electricity are function in the type of used source in case there are more than one source. It is obvious that, the lowest cost source would be selected for this aim, to increase the total produced quantities and thus increase the demand. The terms of performance requirements and the evaluating technical performance must be taken into consideration when comparing sources of supply that meet the functional limitation at a reasonable cost.

Decision-making in the field of energy refers to the range of decisions taken during the process, the source of the energy produced, the type of power plant, the identification of technology and the systems used, and the investment aspects to achieve the demand for energy aim to reaching to the optimal efficiency. The feasibility study for each source and energy system for long term is needed in an urgent manner to avoid the supply risk. Decision-

makers use all available information such as evaluating the performance, pre-market energy study, available affordable supply sources, and energy demand limit to identify investment aspects.

Occasionally, the performance cost of the system operations is misleading, apparently seems as the best offer for investment, but in meanwhile in its interior carries a lot of extra burdens of extra cost, in other words “indirect cost”. The misleading information about the performance cost of any system operation which means “direct and indirect cost” together puts the decision-makers in a big jug in long term, where they are forced to bear this extra cost. This is extra cost could be in form of taxes, or environmental treatment and reform, or compensation to workers as a result of disasters and hazards.

Criticality is not simply dependent on the balance between the supply and demand of a minerals. The relationship between price and volume is also feature of the criticality and it has a direct influence on the market. Eventually, the degree of criticality helps the stockholders and policymakers to evaluate the risks related to availability. Supply curves of conserved energy offer a framework for incorporating potentials into the traditional supply-demand analysis. In effect, we have shifted a portion of energy demand to the supply side of the equation.

**Political Events and supply risk.** Supply risk could be occurred because of external political events. Price volatility of energy minerals effects on the energy market volatility and cause economic fluctuations. When the demand raise for a commodity, no enough supply to meet that demand, the production of this commodity may be reached to the “peak”, which leads to supply shortages and price deflection in the market. For historical instance, the oil and energy crisis in 1970s. In result of that, volatility of energy mineral market leads to volatility in the energy supply capacity. When a defect takes place in the anticipated supply (supply risk), the demand directly shifted away and finding other supply sources. This option could not be happen in all types of industry, some of them could manage and change design system, but other could not and the shifting needs long term, such as, power plants for electricity generation. Some scholars have forecast. Most of external event increase:

**Depletion Index and supply risk.** “How long can this consumption be sustained?” (Steinbach and Wellmer, 2010). The main problem has been assessed in energy materials is the amount which can be extracted. Whether, which could be extracted directly by mining methods (coal and uranium), or which extracted by other way (oil and natural gas) are enforceable materials. Thus, taking oil For example, 10 billion tonnes of oil equivalent are consumed by us per year (Steinbach and Wellmer, 2010).

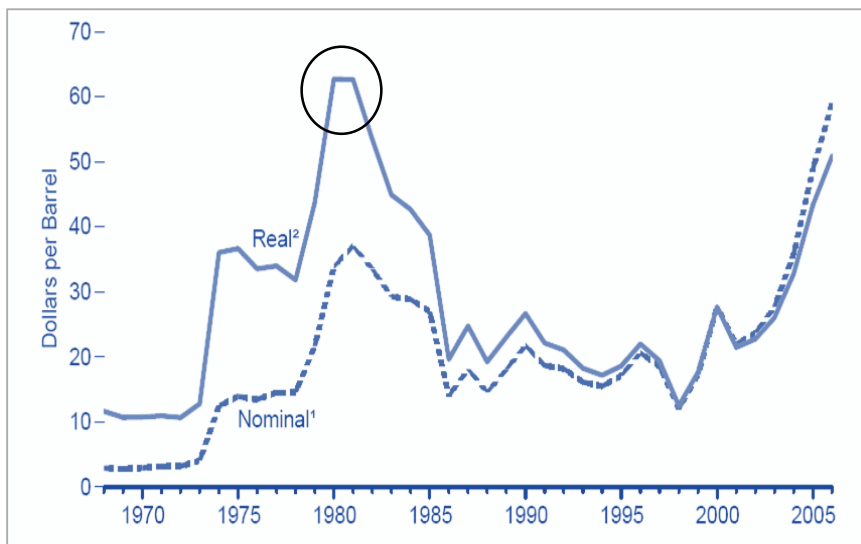
The forecasting of future supply ability for energy not only depends on remain amount of energy resources on the earth, but also on the used technology. Developing countries face a different kind of energy crisis does not related to energy material depletion time, for example India where the energy generated capacity could not meet the rapid increase in demand due to the lack of using the technology of execution. Some scientists predict a new energy crisis will take place in the coming years in China, the gap between supply and demand in energy sector, the conventional oil production is declining and reaches to maximum point when about half the reserve is depleted. It does not mean China running out the fossil fuels, but the exploration to unconventional fuels gets more expensive. In addition to, China’s coal resources supplying will peak around 2020 under the existing policies and the risk of environmental crisis concern climate change.

**Recycling Rate and supply risk.** Fuel minerals which include fossil minerals are non-recyclable resources. Which it means, the consumed amounts of this minerals are irretrievably it could not be produced again. Non-recycling processing increase the supply risk of the fuel minerals and that makes us extremely cautious on the aspects of consuming.

#### *3.2.2.1 Oil crisis as example for supply risk due to external political events*

Since the early 1970s, the energy approach gained the attention of policymakers especially after the consequences of the oil crisis, the researchers have attempted to improve the understanding of the energy demand principles and the effects of suddenness external events which occur in specific time on the demand response (Pindyck, 1979). The lively debate between engineers and economists of that era led to important methodological developments that enriched the energy decision-making process as a whole, and a wide variety of models became available for analyzing and forecasting energy demand projection of the future coal demand has been cut back. During the 1970s, when the Organization of Petroleum Exporting Countries (OPEC) shut off and freeze the supply flow of oil to the

United States due to the Arabian war in 1973 and then the Iranian revolution broke out and overthrow of the shah of Iran in 1979 led to a disruption in oil supplies. The combination of this events in this time in addition to the raise in the oil demand - as had no alternative in this time- with constant supply source and gradually decline in the quantity led to sharply raise in price and supply risk. U.S. oil production could not persist for a long time to meet all this demand and created supply shortfall. Eventually, it gendered what is known as the energy crisis. Figure (5) shows the historical oil price profile from 1970 till 2005. Oil crises and improved computational capabilities created a demand for new models to quantify the effect of changes on energy systems and the economic performance of energy markets. Oil prices got higher twice in the end of 1970s reached to 60 \$ per barrel.



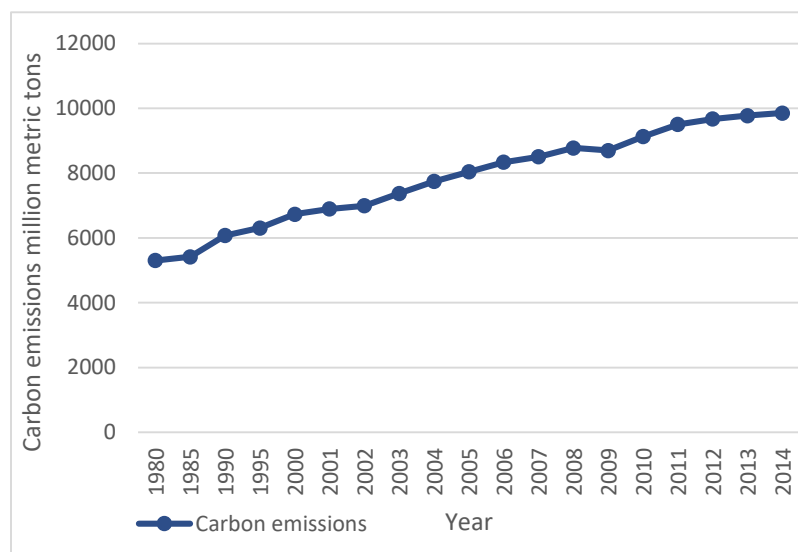
**Figure 5: Real and nominal historical price of oil in USA from 1968–2006**

**Source: Annual Energy Review 2006, EIA**

### *3.2.3 Demonstration of Criticality from Environmental Performance*

Intergovernmental Panel on Climate Change (IPCC) have highlighted in its reports that, the impact and the change of the surrounding environment have caused by human activates. The energy supply sector was and remain the largest sector responsible GHG emissions, it contributed by approximately 35 % in 2010 of total GHG emissions around the world. Global greenhouse gas emissions which related to electricity and heat

production from burning of the fossil fuels (coal, natural gas, and oil) accounted for 25% of 2010. And from GHG emissions from the industry sector accounted for 21% of 2010 due to the same reason burning of the fossil fuels, most of the emissions are mainly concentrated in China. In 2014, the global emissions reached to 9855 million metric tons of carbon have been released to the atmosphere from the consumption of fossil fuels and coal burning during cement production. With this high rate of global emissions will causes economic crisis through the continuity of energy consumption. Figure (6) shows the historical Global carbon emissions from fossil fuel consumption and cement production emission from 1980 till 2014.



**Figure 6: Global carbon emissions from fossil fuel consumption and cement production from 1980 to 2014 (million metric tons)**

**Source: Boden et al., 2017**

Bottom line, many scientists have pointed out the energy supply sector especially the ones that depend on the fossil fuels is the largest contributor to global greenhouse gas emissions. Permanently this emission is pursued because of the harmful environmental effects and the general imbalance in the ecosystem that it can cause, the most important of these effects are global warming, climate change, destruction of ecosystems, and ozone layer depletion. The impact of the energy supply system (electricity generation sector) on the environment is often measured by the emitted gas per unit of output (t CO<sub>2</sub>/KWh).

Included GDP, CO<sub>2</sub> emissions, financial development, capital stock, labor force, and total population variables as independent variables in their empirical models to study the impact of these variables on energy consumption, in other words, they have proposed energy consumption is a function in all these variables.

$$ENRC = f(GDP, CO_2, FD, POP, K, L) \dots\dots\dots \text{Equation 3}$$

Where: ENRC: Energy Consumption, GDP: economic growth per capita, CO<sub>2</sub> emissions (metric tons per capita) (CO<sub>2</sub>), capital stock (K), total population (POP), labor force (L), and financial development (FD).

Carbon emissions are not evenly sourced. They cannot be placed in one basket. Coal is the most damaging effect on the environment followed by oil and then natural gas. During the burning they don't emit the same amounts of gasses, and even during the extraction don't have the same impact. The whole impact on coal will be illustrated in details further later. This clearly explains the importance of both natural gas and high oil in the global market and the high price of oil from now on. To the other because of its economic importance in the first place and they do not interact with the environment dangerously in the second place. Multiple mitigation technology options must be used to reduce the emission level by next years, according to the analysis of CO<sub>2</sub> emissions by sector.

Energy minerals can be of high importance to the economic development as whole. Energy minerals play an important role to growth of economy, in particular the main role in the heavy industry, in one hand. But, from the economic scope, these environmental problems have also been recognized as major economic problems of the present era, and a number of studies have analysed the potential effects of these environmental problems on economic advancement as they have a direct impact on GDP, it is translated into CO<sub>2</sub> emissions per capita. There is a close relationship between economic growth and carbon emissions. Due to the economic reform in the developing countries and economic growth target they have resorted to consume higher rate of energy which basically depends on fossil fuels resources. Eventually, no human action without cost, and this cost is paid from GDP.

European framework related to climate and energy issues aims to reduce the GHG emissions in 2020 by 20% than 1990 and by 80 - 95% in 2050, by improve the renewable energy market. European energy framework attempts to improve the energy efficiency (Moreno et al., 2014).



Several models and techniques have been developed to measure and evaluate the impact on the environmental performance due to the continuous supply of energy. The models examine the relationship between the economic growth, environmental cost and energy consumption. The results come quite different from notion to other depending on the energy resource and the technology which applied in addition to the energy market there which correlates with the investment and policy. The upcoming part presents some of this model briefly.

### 3.2.3.1 Environmental Kuznets curve (EKC)

Many studies have investigated the long-run dynamic relationship between the economic growth which represents in (GDP) and environmental impact in various indicators emissions due to under fossil fuels using as energy resources under the presence of Environmental Kuznets Curve (EKC). The notion of the Environmental Kuznets Curve (EKC) hypothesis is to examine the existing relationship between economic growth (real GDP per capita) and the environmental degradation (CO<sub>2</sub> emissions) could be built as an inverted-U shape relationship first rising and then falling passing through turning point of income. The results of EKC is different from the country to other, and the responds are not constant through the pollutant substances, (Tiwari, 2012) in indeed, the U-shape differs from substance to other, EKC have applied in many countries. Figure (7) shows the typical KEC U-shape. The aim behind applying EKC in long term is to get a more realistic view of the effect of economic growth on environmental degradation and the role of the technology to change and reduce this impact.

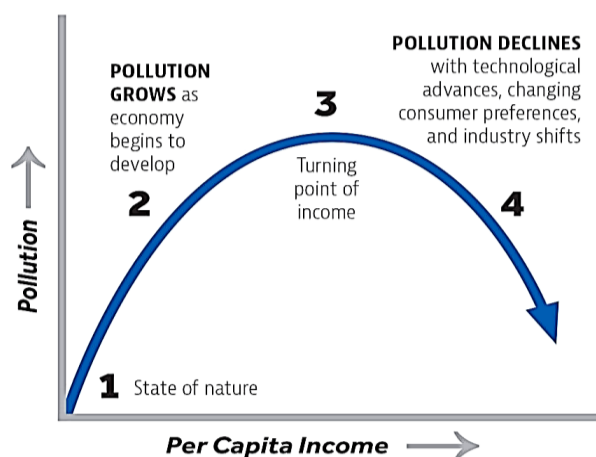


Figure 7: The typical U-shape Environmental Kuznets Curve

**Theoretical background.** In late 1954 the curve has been described by Simon Kuznets to examine mechanisms of economic development for three countries. The notion of environmental Kuznets curve have been proposed by Grossman and Krueger in early 1990s with the World Bank were the first who popularized this idea. Opinions have argued about whether the increase in economic activity was actually damaging the environment or not. Some views have supported the theory that economic development will inevitably be detrimental to the environment, which would definitely require technological development and improvements. Others have believed that environmental degradation must become the first processes of economic construction, once the country becomes rich, it will help it to reach a decent environment (Stern, 2004).

**The Framework.** If as an economy grows the scale of all activities increases proportionally, pollution will increase with economic growth. The empirical equation is

$$Y = B_0 + B_1X + B_2 X^2 + U \dots\dots\dots \text{Equation 4}$$

Where: Y: Indicator of Environmental degradation, referred to CO<sub>2</sub> emission

X: economic development measured by GDP Per Capita at market prices.

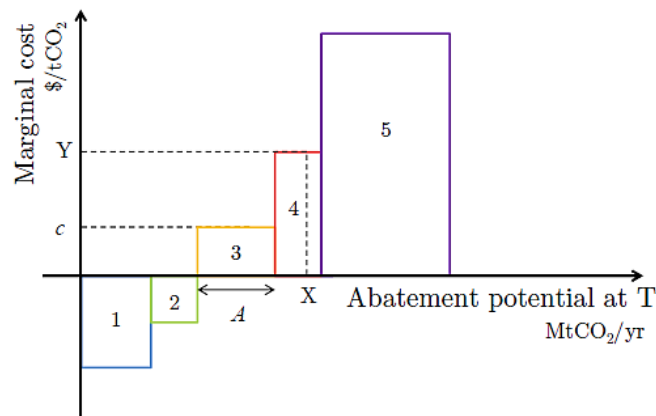
From this equation, it's possible to infer that the indicator of environmental degradation increases with economic activity and energy consumption. It would be happen only in the initial levels of development to decrease later on to get this u-shape. One of the controversial studies that were proposed related to EKC hypothesis, proposed by Kang and others, 2006

### 3.2.3.2 An Economic Analysis of Environmental Regulations optimisation

Within the context of targets for reducing the CO<sub>2</sub> emissions for reducing the environmental damage, Marginal Abatement Cost Curve (MACC) has been proposed and developed by McKinsey (a global management consulting firm). The purpose of the MAC curve is to evaluate different policies to reduce CO<sub>2</sub> emissions and to provide a guideline for the policy and decision makers to optional energy investment aspects, and improve their ability to find the best option with minimum CO<sub>2</sub> emissions to reach effectively to their target which here is meet the energy demand of energy with high efficiently. MAC curve provides various different calculation of supply and demand for energy options. Each option shows its contribution to reduce greenhouse gas (GHG) emissions. This model provides a clear view for investors and policy makers about all the highlighted strategies options and technologies in function of the amount of reduced CO<sub>2</sub> and the marginal cost, thus, finding

the co-benefits relationship between emission reductions and economic development. Many countries have used MACC such as U.K., U.S., Greece, Sweden and Denmark to assess the potential of different options. MACC curve consists of a sequence of boxes, each box represents each option or considered action, the marginal cost (MC) is located in Y-axis and marginal abatement (MA) of CO<sub>2</sub> is located in X-axis. Figure (8) shows the MACC.

According to the MACC, the option listed furthest to the left is the most efficient, the option second from the left is the second most efficient, and so on. That means the option number one depends on the previous figure is the most efficient, then number two, and so on. The aim of MACC to provide us the information about the cost and abatement amount, for example, if the supply aim to reduce (X) Mt of CO<sub>2</sub> it means the option number 4 should be applied and the MC will be (Y) \$/ton.



**Figure 8: Marginal Abatement Cost Curve MACC**

**Vogt-Schilb et al., 2014**

In case of China, MACC could be used to conclude that it would be possible for China to reduce CO<sub>2</sub> emissions related to electricity generation and coal mining without inflicting a significant economic burden and put all the possibilities available for that through different investment options. CSC/MACC is a two-dimensional problem wherein the cost of reaching a goal is optimised. In the context of the climate change, CO<sub>2</sub> emission migrate in the goal. MAC curves have proven powerful tools to highlight that large amounts of low-cost emission reductions

### 3.2.3.2 Life Cycle Assessment

Life Cycle Assessment (LCA) is the most common tool systematically evaluate the environmental performance of a product through the life cycle stages (Sonnemann et al., 2004). The traditional model of LCA has been structured for rare and critical metal materials that takes into account the supply risk of materials depending on the geological reserves to estimate the relative availability of the metal. The criticality is being led by the importance of use (high industrial demand) and the lack of supply due to the limited reserves. Recently, it has been developed to expand including a wide range of related factors, based on the consideration of a three-dimensional framework can be applied to different spatial levels. The three dimensions of the analysis are supply risk, environmental implications, and vulnerability to supply restriction, which marks as main pillars to define the criticality.

### A study of Chinese coal exploitation and utilization

#### ***4.1 Coal Reserves and Distribution***

China is the world's largest population with a population of around 1.404 billion, the total area approximately 9,600,000 square kilometers. Due to the huge population census, the demand for energy increases. After the energy crisis in 1970s which caused by the peaking of oil production in major industrial nations, the world has shifted to coal to supply the energy sector. The huge resource of coal which was concentrated in China made China it and still the biggest supplier of coal which has been one of the factors behind the economic reform and raise the GDP of China.

It is well known that, the different international energy institutions have different classifications and definitions of coal reserves. For instance, the concept of proved reserves used by the International Energy Agency (IEA) and British Petroleum (BP) is equivalent to prove recoverable reserves defined by the World Energy Council (WEC) (Lin et al. 2010). World energy council (WEC) quoted in the context of an estimate of (988 billion tonnes) for China's coal resources, the total proved reserves (114.5 billion tonnes) was quoted at the 11th Session of the UN Committee on Sustainable Energy (Geneva, November 2001) while, the Chinese Yearbook in 2008 provided the ensured reserves estimated by (326.1 billion tonnes) produces 114.1 billion tonnes. Otherwise, British petroleum (bp) statistical review of world energy report for 2017 quoted the total proved reserves at end 2016 in China was estimated by (244.01 billion tonnes). Coal reserves witnessed an increase of 16.8% in the end of 2015 compared to 2014. According to the statistics made by National Bureau of Statistics on coal reserves, the total China's coal reserves showed a downward trend from 3025 billion tons 2003 to 2010 billion tons in 2011.

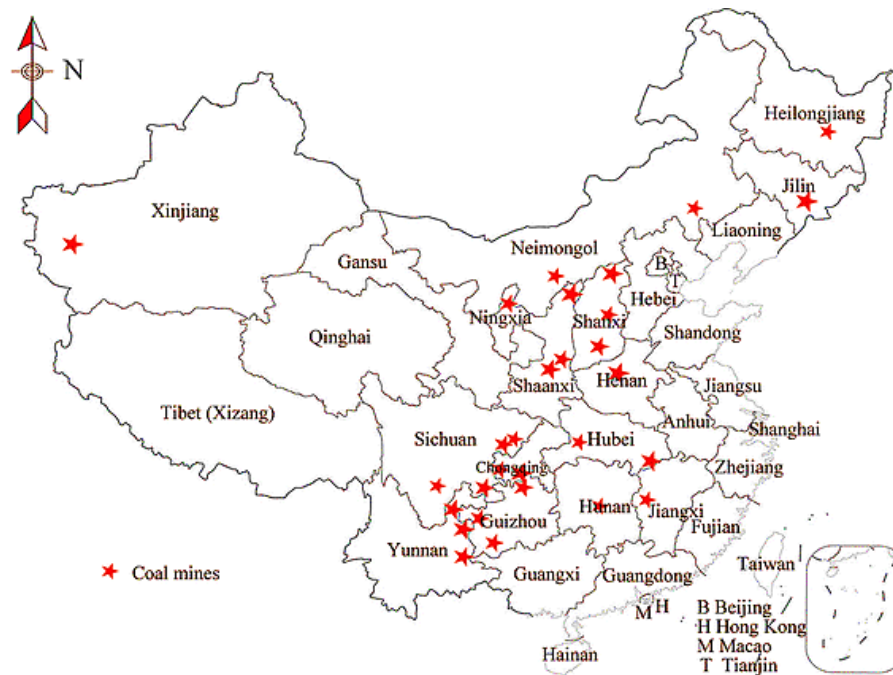
China is endowed with significant coal reserves, with limited availability in coal-rich regions (Qin et al, 2015). The majority of proven recoverable reserves have been located in the north and northwest provinces of the country in huge quantities, volume and quality. Particularly, in the provinces of Shanxi, Shaanxi, Ningxia, Henan and Inner Mongolia where

the main coal-producing regions in China. Figure (9) shows the distribution of coal mines area in the whole provinces in overall China. Coal reserves in China are distributed broadly but unevenly.

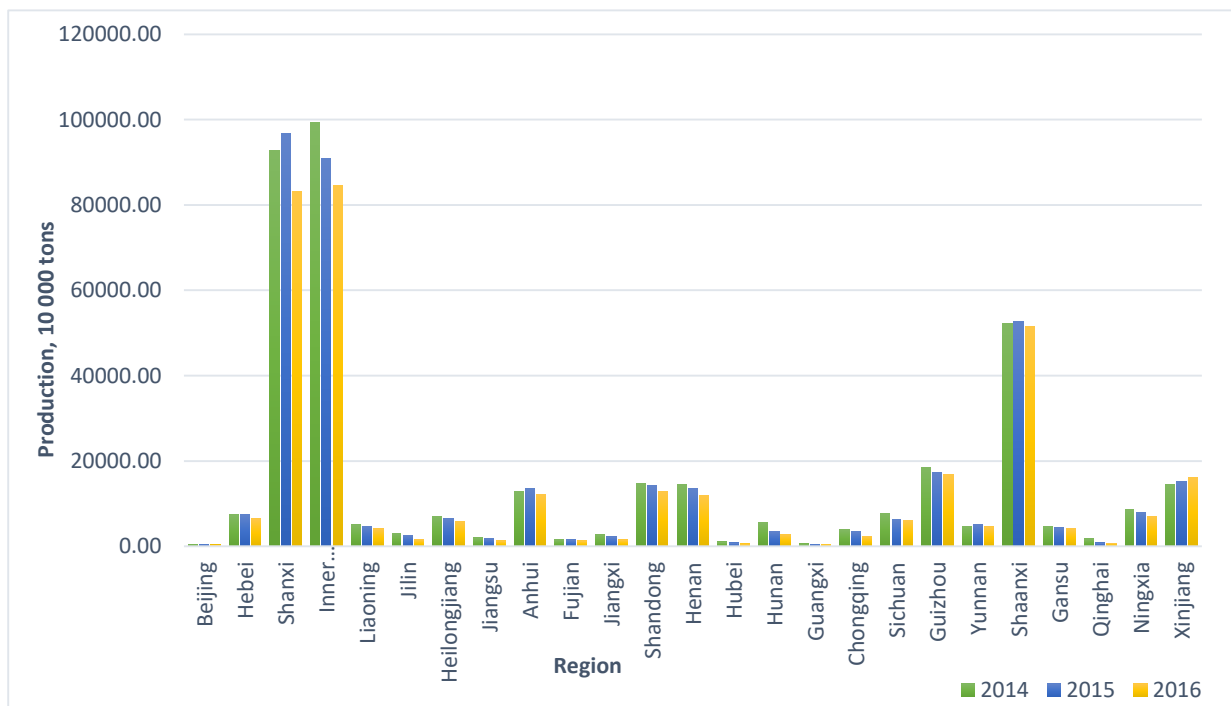
Not all the coal resources are reachable or mined in China, wherein is located in some region is further complicated in its geography where the mountains are located, the geographical distribution of coal reserves throughout the country have important implications for energy strategies and for the industry distributions, for instance, coal-electricity power plants. Due to high transportation costs, coal is most often both produced and used in the region of origin . Uneven regional distribution of coal has created uneven coal supply is that coal must be transported long distances before it can reach the end user due to, the large area of the country and that needs transmission facilities to meet the demand overall the country, power losses especially higher quality fuel such as petroleum products have resulted from a mismatch of the generating capacity. Figure (10) shows the total amounts of coal production in 25 provinces from 2014 to 2016.

The situation of coal-forming is tacky in China. Most of coal reserves need to underground mining method to excavate, the coal reserves convenient for open-cast mining method are slight accounts around 7% of the total reserves. Most of mines are excavated mainly by the long wall underground mining method.

In this section, a general assessment and examination of coal production in China will excavate be presented for the past more than 30 years. Each year, descriptive data statistics are presented in several organizations' annual reports about the coal industry, such as U.S. Energy Information Administration (EIA), British Petroleum (BP) energy outlook, Mine Safety and Health Administration (MSHA), National Bureau of Statistics, China and World Mining Data, Vienna, some of this data have been used in this part to provide a systematic and detailed study on coal mining in China.



**Figure 9: Distribution of coal mines area in China**



**Figure 10: Raw Coal Production by Region from 2014 to 2016, showing that the highest production rate is concentrated in Shanxi, Inner Mongolia, and Shaanxi. Beijing's data is not shown in the chart inasmuch as its small value comparing to the others. The Chinese government has projected to cut the exploration of coal mines in Beijing in last few years due to suffer of the excessive amount of pollution.**

**Source: Using the numbers from National Bureau of Statistics of China. China Energy Statistical Yearbook China, 2016**

## ***4.2 Vital statistics of Coal Production***

China is the world's largest coal producer and consumer since 1986 and has remained on top since the beginning 2000s. The domestic coal production in China increased rapidly from 1980, almost doubled in 2005 than 2000 reached to 1227.3 mtoe, amount to the productivity peak in 2013 wherein the total production reached to 1894.5 mtoe driven by the high domestic demand. Since 1980, China's coal production had increased year by year on the whole and China had become the largest coal producers in the world. In the early 2000s, coal investment boom in China and the coal industry experienced the problem of overcapacity, which was strongly related to the weak economic situation at that time (Bai et al. 2018). With the expansion of coal production in the large scale (large mines' areas) and illegal operation on small mines under the lack of technology and safety issues have led to many problems, not only at the local level but also at the global level. The most important of which were on the environmental aspect, market and investment aspects.

Surprisingly, after the enormous output before 2013 reached to 19691.1 million tons by 2013, the production have declined slowly but surely year after year since 2013, the change rate became in negative value, in 2015 the production declined by -2.1% than the production in 2014, and -1.4% in 2016 than 2015. As shown in figure (4) the production amounts in millions of oil equivalent in period between 1981 till 2016 with the change rate percentage. The Chinese coal mining industry will suffer next years a recent decline the production caused by a combination of decline in commodity demand, coal prices, and the government's new environmental regulations. China has promised to stop approving all new coal mine projects for three years in a bid to control capacity. After the declining in the coal production since 2013 China's macroeconomic will slowdown.

The government is reconsidering and re-evaluating small mines which owned by small and inefficient companies or as known in some reference "zombie companies" companies which are inefficient, have poor technology, and or don't meet safety standards and caused unnecessary overcapacity of coal production which will eventually be required to close under a policy banning aiming to tackle overcapacity and giving the market more room to regulate output. Owing to closing down a lot of illegal small-scale coal mines the incompetent output is falling down. Once over-capacity is reduced, our projections assume



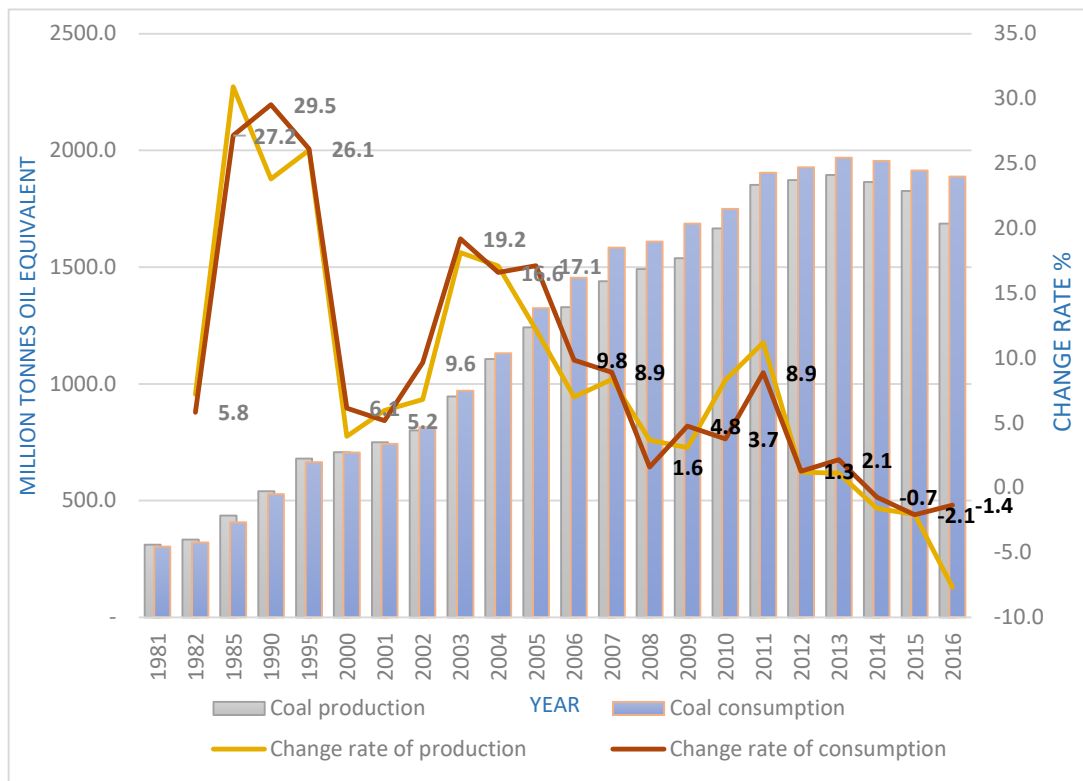
that the coal sector in China becomes increasingly market-driven. The projected gradual reduction in output remains a challenge for an industry that directly employs around 4 million people, although prospects are helped somewhat by a shift in coal demand away from coastal areas and towards inland regions, where domestic coal is more competitive. (International Energy Agency, World Energy Outlook 2017: China).

### ***4.3 Vital statistics of Coal Consumption***

China has experienced rapid increase in growth of coal consumption, China's coal consumption grew from 1.36 billion tons per year in 2000 to 4.24 billion tons per year in 2013 with an annual growth rate of 12 percent. In 2015, the country accounts for approximately 50 percent of global demand for coal, in other word, more than two times that of the second largest user, the United States. However, China's coal consumption shrinking by 2.9 percent in 2014 and 3.6 percent in 2015. China's coal consumption declined by 1.5 percent in 2015 according to BP in its Statistical Review 2016. The National Bureau of Statistics, declared coal consumption had fallen 3.7 percent in 2015 compared with the previous year. It was the second straight year of decline, according to the bureau, which declared coal use had dropped 2.9 percent in 2014.

Figure (11) shows that China burned 1.4% less coal in 2016 than in the previous year, meaning that annual coal consumption has dropped for the third year in a row since 2014 which recorded a decline by 0.7% over the previous year. However, there is a lack of compatibility or similarity in the data between the sources, wherein, the National Bureau of Statistics publicize that the coal consumption fell 1.9% in 2016 measured in energy units, this difference can be due to data discrepancies. Eventually, no doubt on the fact that the motion for coal in the energy mix dipped year by year.

Coal contributed about 69 percent of the total energy needs in China in 2011, coal was and remains dominating on the energy coal in China. As mention in World Bank data coal source provided about 81 percent of the Chinese electricity in 2007, it was the highest point the coal reached. In 2016, the total generated electricity in China was 1,625 GW, coal provide. China turns away from coal consumption aiming to reduce carbon emissions per unit of gross domestic product (GDP).



**Figure 11: The coal production and consumption outlook in China**

**Source: Author's calculation based on BP Statistical Review of World Energy June 2017**

From 2006 to 2010, coal production and the main coal consumption industries in China contributed about 15% to the GDP and 18% to the GDP value added (Bai et al. 2018). In the beginning 2000s, China coal industry experienced the problem of overcapacity of coal production, this was a result of strong motivation from government and stockholders to improve the domestic economy. During this period, a significant and distinctive relationship was created between coal production rate and GDP growth rate.

China's coal is consumed mainly in electricity generation, industrial sectors (cement industry, steel manufacturing, and chemical fertilizer production) and heating supply, electricity generation without dispute is the largest coal consuming since 1990s over than 70 percent.

Due over-consumption of coal a major impact on the environment and public health caused. The world has blamed China's actions on carbon emissions, since it is responsible

for about half of the world's coal consumption. In turn, the government is enacting policies to reduce the use of coal in large population centers to reduce massive levels of pollution. This tremendous coal combustion creates air pollution and carbon emissions that threaten China, its neighbors, and the rest of the world. In 2010, China accounted for 17.5% of world's total primary energy consumption and 24.1% of the world's total CO<sub>2</sub> emission (*International Energy Agency, 2011*).

#### ***4.4 Energy Outlook and Consumption***

Coal has dominated China's primary energy supply since industrialization began in China in the 1950s, it is inevitable that coal as fuel with its massive resource plays the major role in supplying China's energy needs. Coal has a truly a significant role in China's primary energy system, it is not only offering relatively affordable source of energy, but it is also cheap thus reducing the production costs. Coal's share declined for the first time to about three quarters in the late 1980s. Indeed, the environmental issues remain the obstacle to the development and consumption of coal, and however the China's energy policies to reduce environmental pollution associated with coal production and use, the share of coal in total primary commercial energy has never fallen than 60 percent. Eventually, coal has an important for energy security and domestic economic growth in China, growth in coal use has been driven by the economic growth.

Coal the main feeds of the thermal power generation from coal-fired power plants in China which accounting for approximately more than half of total consumption, coal has gained its significant role driven by heavy industry expansion, for instance, steel and cement industry followed by construction and chemical industry. The demand for coal in the iron and cement industry sector has declined recently, but in chemical industry sector the coal demand remains as it.

In comparison to the other energy source, China is poor is other fossil fuel. In 2016, oil reserves were estimated at 25.6 in thousand million barrels, China was the world's sixth largest oil producer with a production 200 Mt, and it was sharing by 4.5% of the total world production. While, natural gas reserves were estimated at 189.5 trillion cubic meters production was 137 bcm sharing by 3.8% of the total world production (*International energy*

*outlook, 2017) (bp statistical review of world energy, 2016) the most reserves of oil and gas are concentrated mainly in Northern China.*

Energy consumption increased at an average annual rate of 6.8% from 1987 to 2007. Over half of the increment happened from 2002 to 2007, when energy consumption in China increased 14% annually (*Lahr et al. 2014*). As mention in World Bank data coal source provided about 81 percent of the Chinese electricity generation in 2007, and it was the highest point the coal reached. In 2016, the total generated electricity in China was 1,625 GW, coal provide approximately 58% which is more than half Installed power generation capacity. To meet the enormous demand for electricity, China will need to burn more coal to increase the additional generating capacity in next years. Rapid economic development has seen the country's total primary energy production more than double between 2000 and 2010 (*National Bureau of Statistics of China, 2011*).

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## Chapter 5

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### Methodology: Assessing vulnerability in coal mining and industry

The chapter identifies and analyses the conceptual vulnerability in coal mining industry in China. This chapter represents an attempt to highlight the impact of coal industry on the life in China and put layered assessment system for vulnerability (economic, environmental and social vulnerability) in coal mining utilization. This chapter introduces an evidence that China's scheme to rely on coal as a source of energy is not optimal option.

#### ***5.1 Evaluating coal industry ecosystem (CIE)***

Over the ages there has been a surge in urbanization and industrialization and increase in number of the population which correlated with increasing demand on raw materials and primary commodities, thus the exploitation of the natural resources was inevitable result. This stochastic exploitation has caused serious distortions in the ecosystem that needs recently to be repaired. The researchers focus on analysis and evaluate the ecological and environmental loss resulted from resource exploitation and estimate the economic loss because of environmental damage, they set up an effective plan and system concerning ecosystem reform and sustainable using of resources and to improve the ability of policymakers and industry to accommodate the anticipated scale of contaminations.

For a long time coal has took up an important position in energy sector in the world. The economic value of mined coal resource is spectacular, it has helped rapid social and economic development, but on the other hand, the corresponding loss of ecosystem is controversial and becomes out of control and causes groundswell of concern, in fact, the expansion of the coal industry has broken the ecological balance.

The economic system of coal mining is an open and complex system consisting of sub-systems, in such one the slightest change in economic or environmental factor can cause a big impact (Martin and Sunley 2014). The coal industry ecosystem (CIE) is formed by optimizing industrial chains

vertically and horizontally according to the principle of material cycling and harmonious symbiosis between biology and industry in a coal mining area (Wang et al., 2017).

## ***5.2 The structure of coal industry ecosystem (CIE)***

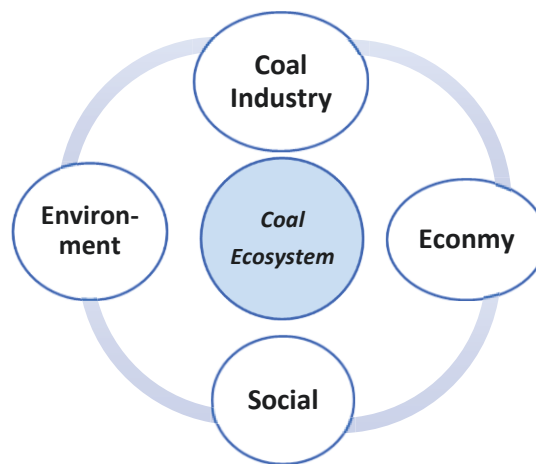
Figure (13) illustrates the subsystem of CIE to examine the relationships between the coal development (mining sector and the coal industry), economic growth and the environmental issues which takes a part of the social subsystem. In my point of view, the structural of CIE contains of four elements or subsystems which effect on each other as following. Some references also discussed the structural of CIE for example, Mathews and Tan (2011) and Yao et al. (2015).

First of all, the fundamental attributes of CIE should be defined as following:

1. **The coal Industry subsystem:** refers to the coal mining activities which contain (exploration, production, and mineral processing) in addition to the heavy industries related to coal mainly such as, the manufacture of steel, building material and the manufacture of chemical products and the main one especially in China electric power generation.
2. **Environmental subsystem:** which boils down to environmental damage and loss caused by coal industry, coal mining activities cause chemical alterations in soil, underground water, and fresh water resources and can include also land subsidence and soil deterioration. Ultimately air pollution couldn't be ignored numerous quantities of polluted greenhouse gas emitted into the atmosphere during the mining activities and utilization such as, methane and CO<sub>2</sub> causing natural disasters. Coal is a fossil fuel that's burned to generate electricity and heat, or liquefied to produce gas and diesel fuel.
3. **Economy subsystem:** which has two different relationships in two different levels. First, the positive relationship between coal consumption and GDP and it's so clear in Chinese market. Second, the negative relationship between environmental damage cost which caused by coal washing and economic growth. Consequently, global

climate change warning. That in the domestic level, but in international level and under market control, coal lose its position in energy market and it is suffering from market fluctuations.

The vulnerability of the coal mining industrial ecosystem cause a great effect on the sustainable development of the regional economy (Wang et al., 2017) and the sustainable dependency of energy supply of China, this dependency requires sustainable energy solutions and may be cause other energy crisis as I mention before. The development and evolution of CMIES is the collective effect of collaborative development of the above four subsystems.



*Figure 12: The coal industry ecosystem structure*

### ***5.3 The approaches to vulnerability***

In the 1970s the concept of vulnerability was introduced within the discourse on natural hazards and disaster by O'Keefe. The concept of vulnerability is defined generally as inability of society (includes the social activities, economic, environmental) to avoid the risks or the disaster or the degree of the suffering of society from the risks and resist and recover from the impact of a natural hazard. In other word, the state of susceptibility to harm from exposure to stresses associated with environmental and social change and from the absence of capacity to adapt (Adger, 2006). Vulnerability has gained variable definitions according to the researchers trend, each field has defined the concept differently. O'Keefe defined the vulnerability as “the degree to which a community suffers from the risk in the occurrence of extreme physical or natural phenomena, socio-economic phenomena and

social-political phenomena affecting a community's capability to avoid and recover from extreme phenomena" (Westgate, O'Keefe et al. 1976), that presents the a point of view of human scientists. Under the background of natural science, the description has stemmed from natural aspects such as climate change and natural disaster, the definition of vulnerability may be extended to the "integrated vulnerability" to anthropogenic climate change (McCarthy et al., 2001). Furthermore, the social scientists tend to use it in socio-economy system on building resilience of restraint, elusion and adaptation. And from the angle of defining vulnerability, some scientists cited the vulnerability as "degree" of adverse effect when disasters happened (Timmermann, 1981); some scientists pointed out that vulnerability is the "token" which is a country's ability to suffer from damages and disadvantages (Adger, 2006); and other scientists defined vulnerability as "loss" (Downing et al., 2001).

The vulnerability is a contribution between three main systems; natural system, social system and economic system. Vulnerability is defined from the concepts mentioned before by three elements exposure, sensitivity to perturbations or external stresses, and resilience or the capacity to adapt. For deeper understanding Exposure is the nature and degree to which a system experiences environmental or socio-political stress (Adger, 2006). Sensitivity is defined as "the extent to which a human or natural system can absorb impacts without suffering long-term harm or other significant state change (Gallopín, 2006). Adaptive capacity is the ability of a system to evolve in order to accommodate environmental hazards or policy change and to expand the range of variability with which it can cop (Adger, 2006)

Through this framework we can estimate the danger degree of vulnerability and its effect and elucidate the interaction between the components and their influence each other. The researchers recently pay attention to understand and explain the roots causes which create vulnerability, and to modify the models to reduce the effect of vulnerability. The role of vulnerability in determining natural hazard risk levels.

#### ***5.4 Vulnerability mechanism of (CIE)***

It was widely noticed that the middle of the last decade, some economic activities related to community development and urban industrial structure face multiple difficulties in sustainability as a result for not taking environmental dimensions into account. Behind



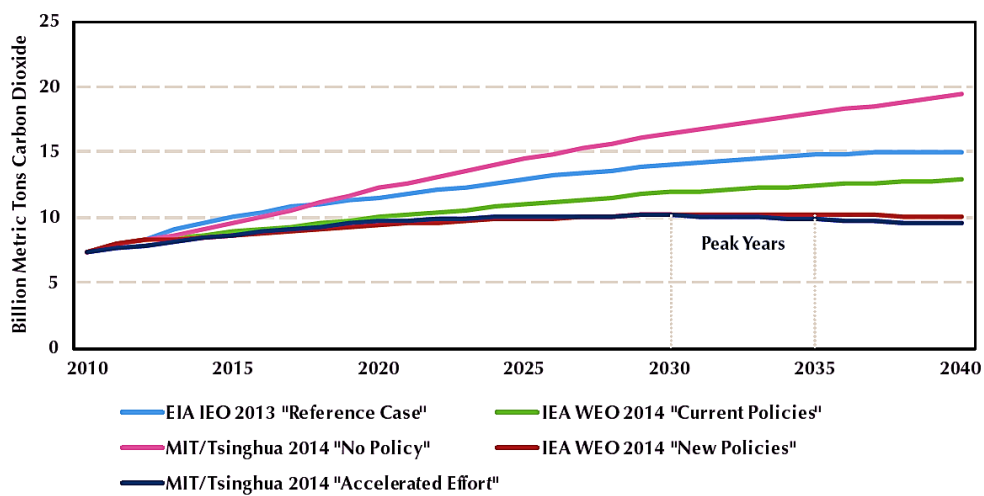
this development activities, coal has played the main role as a main energy mineral in many of countries, China comes ranked as number one followed by India, they are considered the largest countries in coal consumption and the largest countries suffering from environmental impact of coal mining and industry. This industry development has relied on a boom in coal exploration, which lead up groundswell of concern on natural-economic-social system.

#### 5.4.1 Environmental Vulnerability

Environmental Impact Assessment (EIA) is defined as “process helps identify the possible environmental effects of a proposed activity and how those impacts can be mitigated” (Environmental Law Alliance Worldwide, 2010). In absence of the overall effect of advanced coal technology and according to vulnerability phenomena coal mining and industry could be identified as hazard, assessing ecosystem vulnerability of coal industry system in coal cities which suffering from high disturbance of urban industrial structure is used to illustrate the relationship between the coal industry and environmental and social-economy, in fact any defect or weakness in this system represents a real danger and threat at the social and environmental level which could affect on other parameter economic. The degree of vulnerability due to any kinds of natural hazard partially depends on its special social, economic, cultural, and political weakness, and in coal area I think the initial weakness was in the policy and regulation which increased external pressure in demand for industrial development. Environmental assessment has gained recently significant importance at the global level, it guides the policy makers In order to lay the foundations for sustainable development, many countries have adopted as an approach to protecting the environment and natural resources and ensuring sustained economic development, such as the European Union, Canada and Australia. The Intergovernmental panel on Climate Change (IPCC) recently sets a definition of vulnerability through the latest report in term of the climate change as the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes (McCarthy et al., 2001)

In case of China, environmental assessment study has proceeded to emerge in the last decades, particularly after China formally submitted its intended nationally determined contribution "the new global climate agreement " which was concluded in December, 2015 and has been held in Paris. China has committed to enact new policies to curb excessive use

of coal which is one of the most important sources of greenhouse emissions that have led to climate change in China. Figure (14) shows the five carbon dioxide emissions forecasts scenarios and represent the different points of views about using the policies and influence on carbon dioxide emissions. The chart will provide a help to understand the five forecasts scenarios, the first one no policy scenario, China's carbon dioxide emissions will continue to rise around 4 times by 2040, by contrast, new policies scenario emissions peak or plateau at 10 billion metric tons about 2030. In terms of scientific evidence, the policy is fundamentally the preferable solution to control the extent of pollution and greenhouses gasses emissions.



**Figure 13: Forecasting China's Carbon Dioxide Emissions**

**Source: U.S. Energy Information Administration, International Energy Agency, Massachusetts Institute of Technology, Tsinghua University**

The environmental vulnerability resulting from both of expansion and utilization of coal resources and usually done to the whole cycle of coal starting from land occupation to the end use as a secondary energy. Environmental degradation and destruction occur in two stages first, during the process of coal mining and second, during the process of coal utilization.

### 1. Coal mining process

Mining processing includes many different mechanisms of action divided into five phases, the typical asset lifecycle should include exploration, planning, development, extraction, and reclamation. Coal mining has the potential to cause a range of environmental and social risks. Thus, the life cycle of should be considered from this prospective (Ritsema,

2002). Through the life cycle of coal implausible pressure put on the environment involving joint probability to loose ecosystem system. The environmental damage that caused from active mining needs to cooperation between the environmental authorities and mining company which contributed to the expansion of the injustice related to coal mining to migrate the impacts (Cardoso, 2015), mining companies have admitted that their social impact on local communities have been turned out an integral aspect of their business strategies (Morrice and Colagiuri, 2013). Li and other in 2011, interviewed a study to evaluate and feasibility analysis for the ecosystem losses of coal mining Mentougou district of Beijing, China in term of eco-environment, determining three key factors: solid waste, geological environment and coal mining sinks, and soil, biology and landscape. The results of the study demonstrated that, “in the indirect ecological and environmental loss resulted from coal exploitation was far more than its direct economic benefits”. Wherein the damage of ecosystem which occasioned by coal mining services was coasted around \$2001 million in the last 50 years (Li et al., 2011).

## *2. coal transport and utilization process*

The electric power generation is the largest toxic pollute sector in China because of the enormous quantities of coal burned each year in coal-fired power plants, electricity generation almost consumes 50% of the total coal consumption (Zhao et al., 2017) coal-fired power plants accounts for 95% of in the thermal power amplitude (Zhang, 2017). Coal power plants also emit large quantities of the greenhouse gas mainly carbon dioxide (CO<sub>2</sub>) which responsible for climate change. As it was illustrated before, due to incommensurate distribution of coal source, it needs to transport over long distances from the west to the east and from north to south across the whole China by Chinese railway. Coal storage and transport are essential to coal use without taking into account environmental protection, thus, countless amount of coal dust and fine particles are emitted in air drives from coal transport from the mining or processing plants to coal-fired power plants.

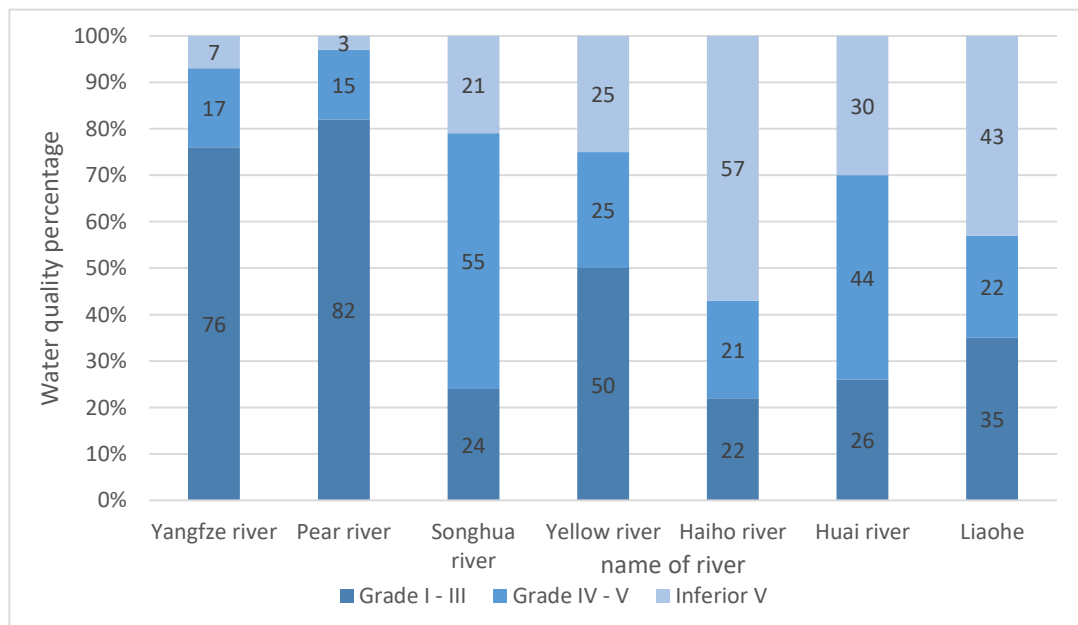
### *5.4.1.1 Ecological impact*

The extraction of underground coal seams cause critical ecological and biodiversity destruction mainly present in land degradation and pollution of water sources. Solid wastes resulting after coal production and extraction processing. Coal gangue estimated as 3.6 gigatons (Gt) by 2007, almost accounting for 40% of solid waste.

## 1. Water Waste

Coal mining activities reduced the quality of underground water by causing a defect in PH balance, and drain toxic solid materials to water source surrounding to coal mines. Also of concern is the impact mining has on groundwater, including acid mine drainage is a particularly founded if the coal mine has quantities of pyrite that infiltrates into groundwater causing contamination to water aquifers. The extraction of coal causes lowering in the groundwater table.

Based on the Chinese statistics data about the water issue, it estimates that only 40% of the surface water sources are available for agricultural use purpose, China faces recently serious water challenges to supply clean water with acceptable quality. Due to the contaminated untreated water waste discharge to fresh river water sources by directly and indirectly way, the quality of fresh water is reducing the quality of potable water because it is being flooded with many contaminated and toxic substances. The water quality of water in China divided into five grades based on “Environmental Quality Standards for Surface Water” (Grade I) represents the highest quality grade and (Grade V) represents the worst quality grade (Lu et al., 2008). Figure (15) shows the variable differences of the water quality for the main 7 rivers in China. Table (2) shows the sea water areas in China with water quality based on the same grades quality standards in 2016.



**Figure 14: Water Quality percentage of Rivers in China in 2006**

*Source: Lu et al., 2008*

<i>Item</i>	<i>Water area with quality at grade 2</i>	<i>Water area with quality at grade 3</i>	<i>Water area with quality at grade 4</i>	<i>Water area with quality below grade 4</i>
<i>Bohai Sea</i>	9950	5690	3130	5000
<i>Huanghai Sea</i>	12160	7440	3260	2530
<i>Donghai Sea</i>	22740	8070	8060	21950
<i>Nanhai Sea</i>	4460	9820	3320	7940

**Table 2: Sea area in China with water quality in 2016 in unit Km<sup>2</sup>**

## **2. Land Loss**

The problems of land loss in mining area are related to the sustainable development of mining and society, pollution extends to destroy the agricultural land. Landscape damage is one of the initial

The expansion in mining exploration increase the loss of lands and the destroying surrounding land and soil. Land subsidence one of the most important phenomena that appears on the soil and land after taking the ore what is inside of the ground leaving a vacuum causing imbalance in the surface layers of the land. Land subsidence is harm surrounding construction for instance, roadway, bridge and even the stability of building in some cases cracks could be founded in the near houses of the mine working area. Respectively, that these losses caused an extra encumbrance on the total cost project. The owner of the mine whether the government or a private company undertakes all the reforms repairs the damages subsequent to the public or private facilities. In 2006, coal mines caused damage worth up to 50 billion RMB (approximately equals 6.4 billion US Dollar refers to exchange rate in 2006).

Blasting is one of mining exception technique could be used in some mine to extract the thick coal seams could be used in both of open pit or underground mining methods . Ground vibration and land disruption are induced by blasting. It severs damage impact on the environment such as crack, rock fragmentations fly, air explosion, dust and noise (Tomberg and Toomik, 1999).

Coal washing one of the main causes of environmental hazards such as land disposal. Large amount of rejected materials are generated during coal washing normally dumped on the ground, furthermore, lead to degradation of fertile land.

### **3. Waste solid Residues**

Extraction of targeted coal deposits results in the waste material production, including tailings which remain after getting the economic ore. Tailings is defined as, the mixtures of remain mine stone and solid residues produced from washing coal processing used to construct dams. In fact, coal tailings have harmful contaminants materials. Traditionally, the tailings in China are dumped in “cone-shaped” on the surface without any proactive isolation facilities and ignoring the environmental impacts of this waste material on land, water and air (Kossoff et al., 2014) and (Bian et al., 2007). The situation in China is so critical the rate of solid waste increase is radically linked to the rate of increase in coal production. According to the data, China has dumped almost 4.5 billion tons coal mining wastes which occupied around 15 thousand hectares lands (Bian et al., 2007). Tailings collapse. Coal gangue is accounted as 10% of the total coal production, around 4.2 billion tons produced per year.

#### *5.4.1.2 Air pollution*

Coal mining activities at different stages of coal mining industry are contribute either directly or indirectly to air pollution whatever, in mining processing or coal utilization. Such as, Coal exploration by drilling or blasting, transport, storage, and electricity generation. Numerous gasses and dust emitted in air, thus reducing the air quality and subsequently disturb the life system balance which led to occurrence the acid rain and climate change.

- ***Coal Exploration and Production***

During the underground extraction phase, coal bed gas trapped within the strata would be emitted that accounted around 15.33 billion cubic meters (m<sup>3</sup>) by 2005, bed gasses contain mainly methane gas which considered as a robust greenhouse gas and Carbon dioxide. Coal-rich in coal dust resulting from coal production and transport, the total coal dust produced account for 10 million per a year. Coal gangue contains harmful gases such as SO<sub>2</sub>, CO<sub>2</sub> and CO leads to air pollution. Table (3) summarizes the gasses emissions amounts which caused by coal mining and washing industry in China. Coal combustion accounts for 75 percent of total SO<sub>2</sub> emissions, 85 percent of NO<sub>2</sub> emissions, and 60 percent of NO.

- ***Coal transport and Storage***

In China, around 6000 sites could be founded for coal storage purpose, the aims of coal storage are secure the continuously supply the feed for power plants and to meet the high demand in winter, but due to coal fluctuations in energy market the amount of coal stock increases and produces more amounts of dust specially without using any anti-dust facilities. Around 10 million tons of dust were produced because of this purpose. Removed coal ore is being transferred from the rich area and disturbed in the whole China and power plants and bears coal dust have been released into the air which saturated with mercury.

- ***Coal Consumption (Thermal power plants)***

Coal fly ash is one of the largest solid waste residues generated in China resulting from combustion of coal in coal-fired power, which produces “enough toxic ash to fill an Olympic-sized swimming pool every two and a half minutes” approximately 375 million tons of coal ash every year. Furthermore, the majority of coal ash disposable areas are located closer to villages (Zhu J., 2016). Mercury (Hg) is one of the most important heavy metal produced by coal combustion in the power plants. Wang and others have provided a study aimed to test mercury emissions and behavior, the test was carried out by taking coal samples were collected from six typical coal-fired power plants across China coal-fired power using both of coal types ‘Bituminous, Anthracite and Lignite’. Basically, the type of coal is a key factor affecting on the emissions amounts of mercury due to the difference of the carbon percentages between the coal types. The results of tests showed that, the concentration of mercury caused by coal burning range from 1.92 to 27.15  $\mu\text{g}/\text{m}^3$  (Wang et al., 2010)

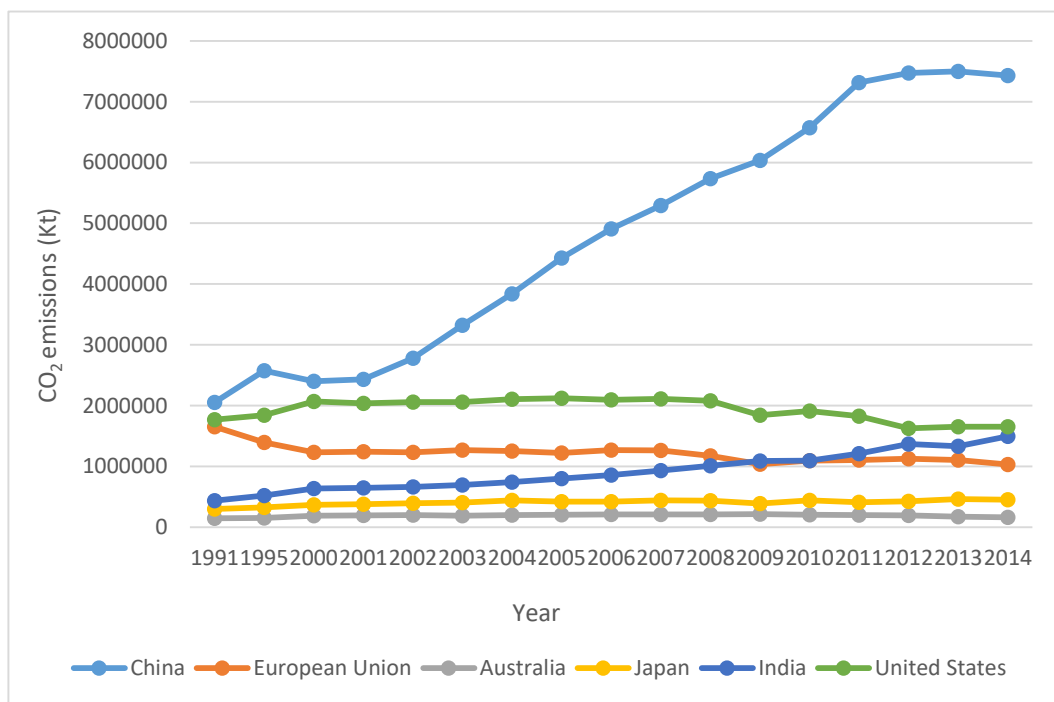
<i>Year</i>	<b>Industrial flue gas (10<sup>8</sup> cubic meters)</b>	<b>SO<sub>2</sub> Emissions (10<sup>4</sup> tons)</b>	<b>NO<sub>x</sub> Emissions (10<sup>4</sup> tons)</b>	<b>Smoke and Dust Emissions (10<sup>4</sup> tons)</b>
<i>2011</i>	2039	12.93	4.48	20.89
<i>2012</i>	3249	12.49	4.55	33.30
<i>2013</i>	2363	12.62	4.57	38.19
<i>2014</i>	2088	11.43	4.60	38.51

***Table 3: Emission of air pollutants gases due to coal mining and washing industry  
Source: Zhang et al., 2018.***

- **Acid Rain**

Sulphur oxide and Nitrogen oxide which mainly from burning fossil fuel realized to atmosphere and react with water and oxygen producing acid rain. After acid rain falls to land as contaminated rainfall, it settles down in the ground and could reduce the pH of surface waters and also depletes soil by toxic substances. When acid rain enters to ground soil it causes nutrients such as calcium and magnesium to be leached from the soil and that deprives the plants of their basic feed.

In figure (16) a comparison of CO<sub>2</sub> emissions from solid fuel consumption between China, European Union, Australia, Japan, India and United States was being provided.



**Figure 15: CO<sub>2</sub> emissions from solid fuel consumption (kt)**  
 Source: World Bank CO<sub>2</sub> emissions from solid fuel consumption by country data sheet, 2018



#### 5.4.2 Social vulnerability

Mining sector is categorized as high-risk industries. There are a large number of hazards in the mining sector that can pose a potential risk the state of inhabitants of being comfortable, healthy. Social challenges caused by coal mining include mine safety and coal mine accidents caused by gas explosion or collapse of coal seams, labors heath and coal-related diseases. The domestic coal production in China was and remain playing a dominant role in economic development and social life. Coal mines cause a several problems in individual scales and according to *NIMBY* is an acronym for the phrase “Not In My Back Yard” phenomena express on the opposition of residents to propos installations have malignant impact close to his living-place, the residents would be supportive to the development but under conditions to be far away from them to avoid the influence of the impacts, the same in the coal mining area where is located close to village or near to living areas, where the ground subsidence could be founded and some houses are breaking apart and falling into the ground, practically in Shanxi province.

The scholars and researchers provide many studies which examine the impact of coal mining on social life are focusing on the impact on the health for both of worker and residences surrounding the mining area and care about testing the illness related to coal industry. International Institute of Environment and Development by Stephens and Ahern has provided a rapid review of available literature which discussed the risks and safety of mining. Over 250 studies have carried out to evaluate health labor and social hazards regarding to coal mining, the results of studies show that 12% of coal miners suffer from deadly diseases “from explosions to black lung” (Stephens and Ahern, 2011). A few studies cited some unique health harms of coal mining, one of the most controversial studies has been carried out in 2011 by applying cytokinesis-blocked micronucleus test and the comet assay to analyse the effect of coal open-cast mining on the destruction of DNA of the workers, the authors investigated the potential genetic toxic effects of workers who work in open-cast coal mines and tested the microcores as an indicator of genetic biology (León-Mejía et al., 2011). Other studies concentrated on illustration the linkage between the environmental damage and human mental and psychological health which appear in symptoms such as feelings of powerlessness (Morrice, 2013).

Inhabitants were concerned about dispensing some of the quality of daily life which take for granted in other countries such as European countries and U.S. because of potential pollution. For instance, the opportunity of getting clean drinking water which led to resorting boiling and filtering water, or imperative to buy drinking water, and opportunity of practicing luxuries activities including fishing, swimming (Walker et al., 2006) and outdoor activities due to the presence of polluted air.

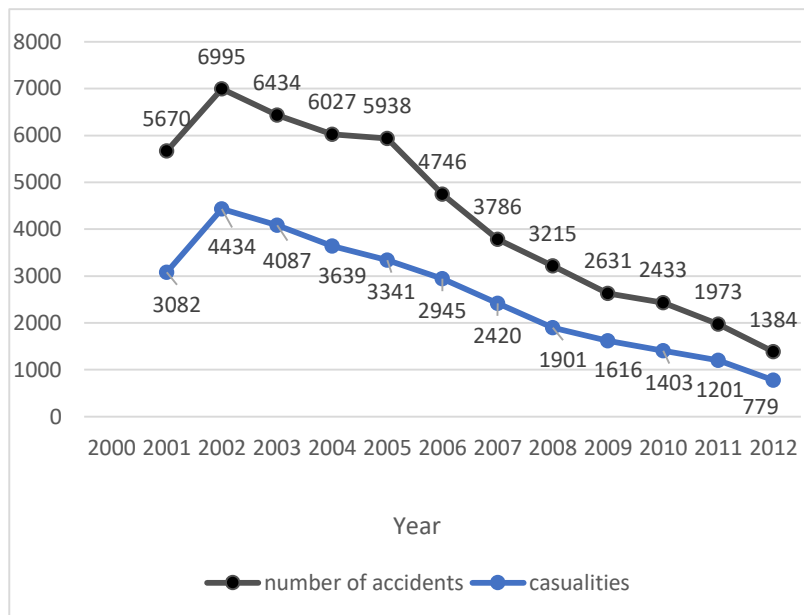
#### *5.4.2.1 Risk Assessment and Mining Accidents*

Annually, thousands of miners die due to underground mine accidents, range between 80% and 80.4 % of the World's total deaths caused in China (Bian et al., 2007 and Chu et al., 2016), there is a positive relationship between coal explorations and mine accidents in China. The average of coal deposit has been formed in high depth which range from 700 to 1200 meter underground, the majority of coal mines contain high amount of gas concentration (Chu et al., 2016). In 2006, the coal mining accidents claimed the lives of 4,746 mine workers which 5 times higher than in India.

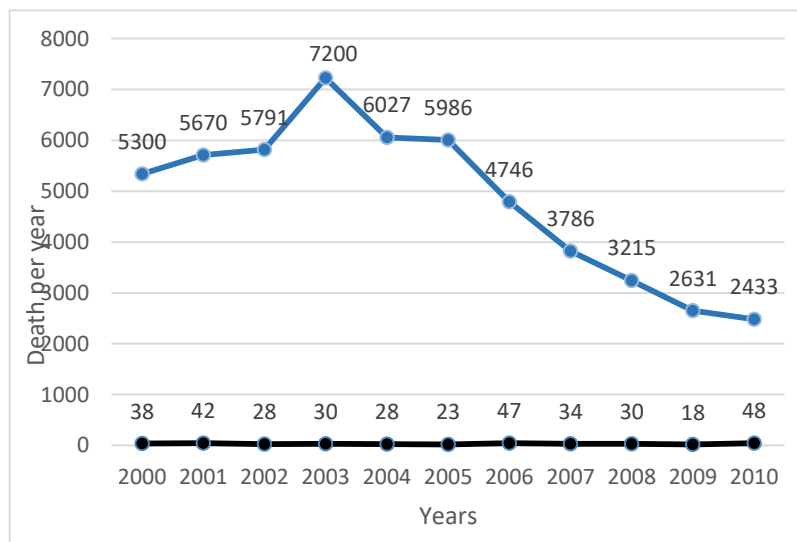
The high productivity rate of coal and state of safety are indicators reflect the situation of the unsatisfactory work condition which labors incur to it during the working hours especially, in underground mines. Occasionally, the labors ought to work for long hours most days of year with lack of health benefits or legal safety protection. Coal miners often suffer from hard jobs with earning so little livelihood, usually observed in small villages more than one member of family work in the same mine with reason lack of job opportunities in these areas. The labor productivity (tons per exposure hour) in China in 2010 was 0.42 while it was 6.05 in U.S. for the same year. Although, there is a gap between the total number of accidents related to coal mining in China and U.S. the real reason behind that is due to the use of technological development innovation effectively, to ensure the workers safety. Figure 14 shows the total number of coal mine accidents and casualties in China.

Underground coal mine accidents are classified into 9 types “gas explosion, flooding, gas and coal dust explosion, fire, dust explosion, gas outburst, cave-chip, poisoning and suffocation” (Dai-ying and Bai-sheng, 2011). For an instance, gas explosions responsible for

71-83% of total fatalities. Coal dust (with the high concentration probability) is considered the most serious casualty substance since it causes dust explosion which leads to dramatic increase in the mine accidents and death rate in in the Chinese’s mines. Whereas, they are two kinds of the coal dust explosion “explosion with methane and explosion without methane”.



**Figure 16: Casualties and number of mine accidents from all in Chinese coal mines.**  
**Source: Chu et al., 2016**



**Figure 17: Number of death in Chinese coal mines and U.S. coal mines**  
**Source: The future of strategic natural resources website ( for China data ) and Mine Safety and Health Administration – MSHA ( for U.S. data )**

In the previous two chart (Figure 17 and Figure 18) which shows the total mine accidents and mine death cases in period from 2000 to 2012, it is noticeable that, the total number of accidents reached to the peak in 2002 and 2003. The death of coal mine accident is declining gradually after 2004 year reached to 2433 cases in 2010 after 7200 cases in 2003. However, this declining balance the mining safety issue remains in a critical stage in China, comparing to the situation in U.S. which never exceeded proportion 50 death per year for the same mentioned period. This is a result of efforts which have been made by the US government to provide security and safety conditions for workers in mines, to work in an appropriate health environment free of hazards and accidents and taking into account the rights of workers by enacting regulations with the obligation the owner companies to follow them and develop occupational safety management systems.

Mine accidents are not evenly distributed in all Chinese provinces. The most provinces suffer from coal dust explosions risk are Shanxi, Henan, and Shandong (Wang et al., 2009). According to the statistics for over 60 years the total number of accidents have been accused in Shanxi was 32, and 29 in Henan, which that means the frequency of death is too high. Average mortality per year in Shanxi is 41 people, and in Henan is 34 people (Dai-ying and Bai-sheng, 2011).

#### 5.4.2.2 Coal Mine Gases and Evaluation of human health risks

"Health can be defined as a state of complete physical, mental and social well-being of an individual, and not merely the absence of disease and infirmity" (World Health Organisation, 2005). The objective of health risk assessment is to examine the potential health effects and determination the diseases caused by the occurrence and incidence of these risks and how to avoid them. Coal industry not only lead to people lose their natural livelihood and their safety, but they also suffer from significant health diseases due to air and water pollution.

Coal seams have a large number of contaminated and toxic gases would be found in the cracks and folded zones and between the coal layers, the gasses such as **Methane** (CH<sub>4</sub>), **Carbon dioxide** (CO<sub>2</sub>), and **Carbon monoxide** (CO) could be released during the mining operation making mixture with the air and stabilizes within the respiratory system in the human body pose a threat to human health causing breathing problems and an endless number of different diseases in different scales. Chinese coal resources are so rich in CH<sub>4</sub>

amounts, which approximately estimated by 12.5% of the world's total over than 34 trillion cubic meters for the coal seams with a depth of 2000 meters. Regrettably, the richest coal mine methane resource are located in the most vital regions related to coal mines for China, located in Shanxi-Shaanxi and Inner Mongolia province. Geologically, the coal deposit has been formed mainly in Carboniferous Permian and Middle-Lower Jurassic formations.

### 1. Methane (CH<sub>4</sub>)

It is explosive and flammable not toxic gas, normally is found near to ceiling of mine opening and working face, originally formed in unbroken parts in coal bed and is released after exploration. The concentration of the gas increase with the seam depth that's why the risk increases in underground mines. Methane is responsible for the mine explosions if its percentage exceeds the range between 5 to 15 percent in the air. With high concentration of gas and lowering the fresh air, methane can cause asphyxiation. Methane concentration raises more in the collapse areas and gob where the mined area is located.

### 2. Carbon monoxide (CO)

Carbon monoxide is a poison gas, when the human breaths too much amount the body replaces the oxygen in your red blood cells with carbon monoxide, and human no longer has the capacity to carry oxygen. Carbon monoxide is found during mine fires and after explosions or detonations of explosives. Table (4) shows the Symptoms of CO exposure function in the co concentration in (ppm).

<b>CO Concentration (ppm)</b>	<b>Symptoms of CO exposure</b>
50	No adverse effect with 8 hours of exposure.
200	Mild headache after 2-3 of exposure.
400	Headache and nausea after 1-2 hours of exposure.
800	Headache, nausea and dizziness after 45 minutes of exposure; collapse and unconsciousness after 2 hours of exposure.
1,000	Loss of consciousness after one hour of exposure.
1,600	Headache, nausea and dizziness after 20 minutes of exposure.
3,200	Headache, nausea and dizziness after 5-10 minutes of exposure; collapse and unconsciousness after 30 minutes of exposure.
6,400	Headache, nausea and dizziness after 1-2 minutes of exposure; unconsciousness and danger of death after 10-15 minutes of exposure.
12,800	Immediate physiological effects; unconsciousness and danger of death after 1-3 minutes of exposure.

**Table 4: Symptoms of CO exposure function in the concentration in (ppm)**

**Source: Walker S., 2011. CREIA**

### ***Mercury (Heavy metal)***

Coal burning in thermal power plant is considered one of the main sources of mercury emissions flow to the air, mercury is emitted from fly coal ash which contributes in proportion 60% of the total emissions, these exposures affect both of miners and inhabitants surrounding the processing station. Mercury is existing in coal in tiny amounts (0.01– 0.5 mg/kg), but during the burning processing mercury toxic vapor can be released and exposure mixing with air and enter the blood cycle in human body causes mischievous effects on the nervous, digestive and immune systems, lungs and kidneys, maybe leads to death. Mercury enters to water system and lack reaching to fish and phytoplankton (Gibb and O’Leary, 2014) and (Wang et al., 2010). Mercury contaminates the water sources, lakes and food which easily enter many cells in the body. The range of airborne mercury exposure at coal mining operations in China is 0.038~0.32mg/kg.

#### *5.4.2.3 Coal miners’ Social life vulnerability under economic fluctuations*

Generally, labors’ livelihood vulnerability depends on the range of assets and occupational activities to pursue their livelihoods. Mining industry is a large sector set up and relative sectors offer a lot of job opportunities including coal mine construction, coal mine exploitation, products distribution, education, scientific research, and equipment manufacturer, according to the chinese statistical data in 2017, the total number of employed person in mining sector is 4,909,000 persons divided into 446,000 persons in state-owned units, 94,000 persons in Urban collective-owned units, and 4,369,000 persons in other type of ownerships. Mining contains several operations and processing, in addition to that the mining projects have long-life term with huge amount of investments, thus coal mining follows the same concept. The level of vulnerability of the worker is determined by how weak or strong their livelihoods are, what the sustainability and stability of their occupational activities is, and the support of the policy and government's strategy to help workers to find alternative means to earn an income opportunities.

In context of coal mining, as a result of the profound amendment in the global economy, and considerable fluctuations in global energy prices in addition to coal price instability in the energy market, many economic problems would face coal miners in cities that rely mainly on coal industry as a source of income and livelihood. Furthermore, Coal miners' livelihood have become an important social issue worthy of investigation, “from the time

dimension perspective" and miss flexibility and stability the miners will get more suffer in term of finding other source of livelihood, principally the western and northeast regions of China (Wang et al., 2018). In recent decades, where the coal's side effect prevails its benefits and exposures to may fluctuations, a great external risk has been a barrier on workers, this sector in China absorbs a significant share of labor nearly 7 million people in the coal mining and washing coal industry. This enormous number of miners should face a challenge to adapt with economic fluctuation conditions and overcome the vulnerability context to secure a sustainable livelihood.

With the permit the Chinese government of the new policies on overcoming the surplus production of coal by shutdown of humble and illegal mines that lack professional safety and the use of advanced technology, which are usually found in villages and small areas where the people are characterized by poverty, and suffer from limited projects and capital assets, the reduction of the labor's income would be applied, that is going to have a negative impact of on his living life and his ability to provide essentials protests. In other hand, the government should encourage the investment in other more sustainable economic activities which would not be influenced by the nature of the market volatility and financial shock.

Coal mining industry does not have not only a direct impact on miners' livelihood, but also has indirect impact of the surrounding's livelihood. The deterioration of environment and natural resource such as water resources, soil effect mainly on the output capacity of the basic human activates for example agriculture and biomass energy, thus, effect on the households' income and livelihood (Fan et al., 2011).

#### 5.4.3 Economic vulnerability

The coal energy resource is so sensitive to economic fluctuations and easily influenced by this fluctuations compared with other industries. The economic fluctuations including "(Energy price fluctuations, market demand fluctuations, and economic policy fluctuations)" in addition to the mining cost itself. The economic vulnerability index is proposed to depends on economic sensitivity and response capacity

$$V_i = S_i / R_i \dots\dots\dots \text{Equation 5}$$

Where:  $V_i$ : is the economic vulnerability degree of year i,  $S_i$ : is the economic sensitivity index of year i, and  $R_i$ : is the economic response capacity index of year i. (He Li, et al., 2009).

**Demand Instability and fluctuations.** The global demand side is unstable for long term, especially if there are other alternatives that could achieve the same aim. The current states of supply is moving towards the low-carbon energy and low environmental footprint resource. The idea is, the global demand is sensitive to the price and supply. The impact price sensitivity of a demand leads to the higher demand will shift towards the other resources could be offered in lower price than coal. Energy sector is more reactive to price volatility.

**Price-Setting.** The price commodity in perfect market has been provided depends on the financial informations of all producers. This price is driven by the operating cost plus profit margin, in market the supply price should meet the anticipated demand purchasing ability. The producers can supply until the price higher than the operation cost. The thermal coal type price is declining. However, the operation cost remain the same or even getting higher due to obligations costs such as taxes, environment reform and washing, and other indirect cost, in this case the producers reduce their profit till the minimum. The technology which is needed in the coal industry caused also over-cost. So, in the perfect market case the price should set according to the direct and indirect cost to achieve the profit for the producers. Indeed, the price obligates to other indicators mainly the demand, for this reasons, China exposed to coal over-supply on the market. In the supply-demand curve principles, if the demand decrease (demand curve shifted to the left in the CSC) and the quantity of commodity increase, the price tend to fall as a result. The economic sensitivity for coal industry in China could be confined to overexploitation, depletion of regional coal resources with low global demand could lead to growth rate fluctuation of GDP. With existing an alternative resource in better way and a cheaper price the demand shifted for a long time not for a short time, that's making critical distribution on the coal mining investment and coal projects' capital.

**Impact of environmental policies.** The market are affected not only but by supply, demand and price volatility, but also by the policies which enacted by stakeholders such as government and policymaker which changes the value of the material. The policy change in the behaviour of producers and suppliers. Policy imposes strong limitations on the suppliers to modify the production system to mitigate the risks associated with indiscriminate production and mitigating its effects accounting for environmental damages by forcing producers to reduce production to the minimum required for the current time. The coal



mining in China put high pressure as I explained before which lead to increase the cost curve of operations. Some of policies and regulations increase in the marginal cost. The treatment costs of water and air and the carbon taxes lead to a raise in the cost curve. Hence increase the additional cost per each unit of production. The lack efficiency in the extraction and processing of the coals in small-scale mines has led to a surplus of production that is not necessarily with low coal-quality and has led to environmental degradation. The climate change impact will significantly increase the burden on populations already vulnerable to the extreme climate and bear the effects of projected and increasing changes as a result of climate change. The role of local politics is to control the performance of producers and to impose taxes and the role of global politics to compel states and governments to adhere to the general standards of environmental conservation.

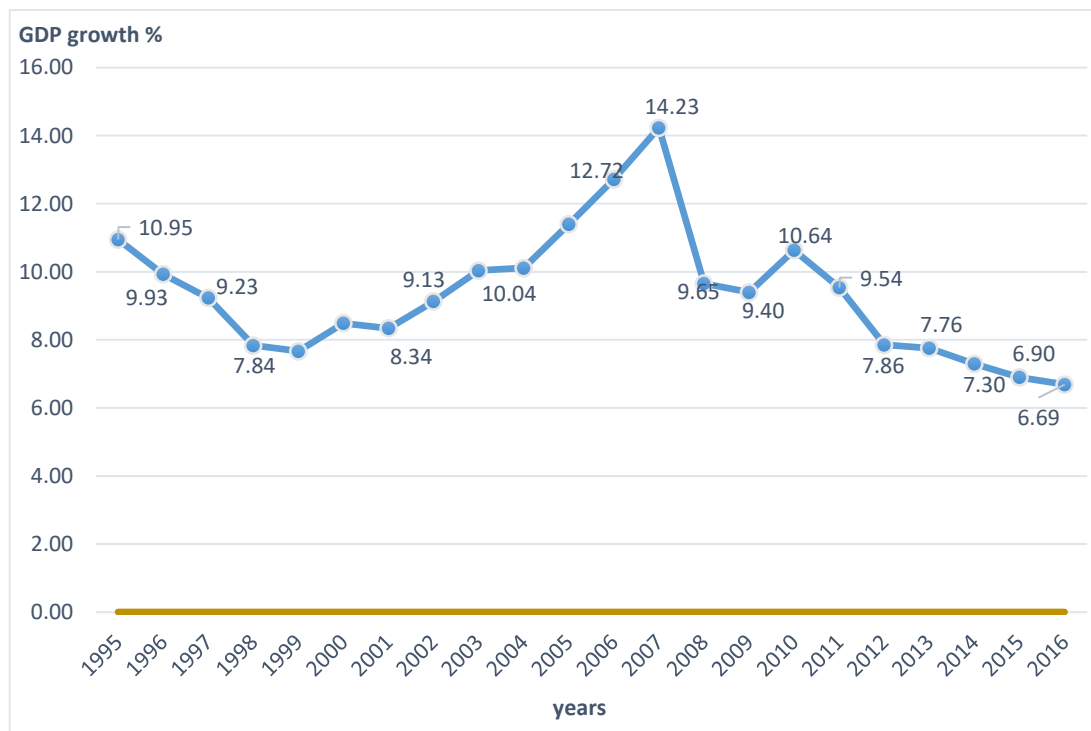
The general result of Economic Vulnerability will be impact on domestic economy of china and influence on the GDP growth rate. And increase the cost burden of operation to fix the impact and treat the environmental damage annex (E) show the formal data provided from National Bureau of Statistics of China, 2011. Energy Statistical Yearbook 2011 about the total investments for treatment the environmental.

#### *5.4.2.1 GDP*

During 1990s, China hit economic crisis was known as The Asian economic crisis which broke out in Thailand then spread to the major of Asia's countries acquired a burden of financial crisis and a significant impact on the Asian economy, in addition to increasing the rate of unemployment. China has been able to escape from the financial shock and only suffered from the secondary economic consequences from the financial crisis due to its strict financial policies then. As a result, that Influenced of Chinese economic and the growth of the country and the exports began to slow down.

The OECD in 1997 estimated that the average annual growth rate for China, including Hong Kong, will be 5.6% over the period 1995 to 2020 which means by 2020, China's GDP slightly less than half of that of the OECD combined (OECD Paris, 1997). According to World Bank data, GDP (in current US\$) in 2016 for China was around 11.119 trillion and for OECD countries 75.875 trillion. Figure (19) shows the development of China's GDP over past 30 years with the growth rate percentage. In the past, greater pressure and responsibility have been placed on the government to improve the economy. China has begun to practice economy reform plan using the energy economy as a key factor, with an

approval from the coal to play the main role in this reform plan and reinforce the domestic economy of China. It must be recognized that, the conflicts between environmental issues and economic growth resulting from using coal should be limited, with no loss of any of them, by restoring relations between economic growth and environmental protection. That explain the new responsibility of China’s government to keep the balance between its economic growth and the negative impact on environment. As a result, economic growth rate has slowed down in last few years, as it is shown in figure 7 the GDP growth percentage is 2008 was 9.65% after it was 14.23% in the previous year.

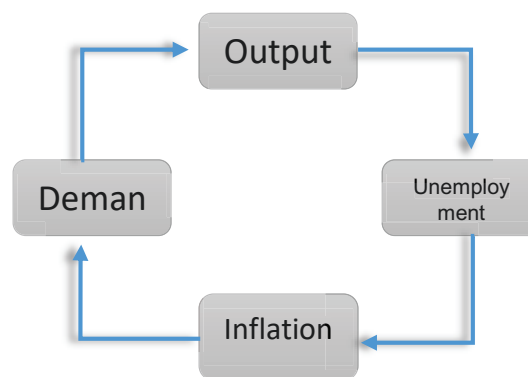


**Figure 18: GDP of China annual growth %**  
**Source: World Bank Data**

#### 5.4.2.2 Coal Market

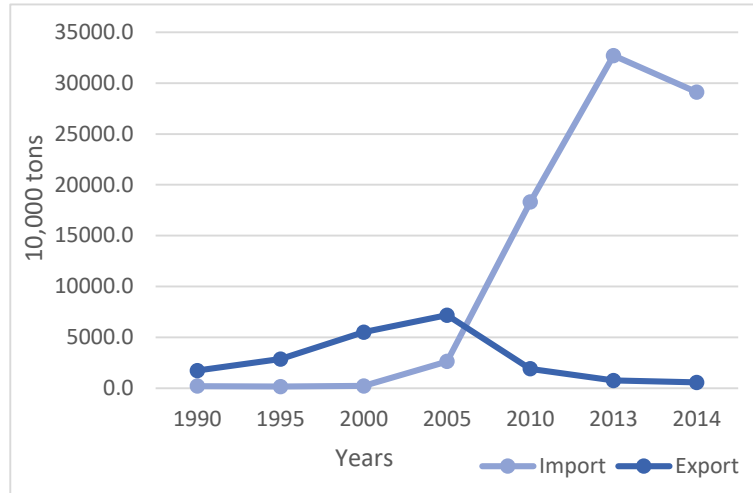
The lower global coal demand has led to over-supply in Chinese coal market and prices fell, according to *supply-demand curve* in case of decreasing the demand the lowering in price will be the inevitable result. This affects the existing investments in the coal industry and leads to shut down some of the coal mines that produce unwanted quantities which cause an increase in the total project cost. The main reason behind the lack of global demand for coal is the commitment of some countries to what have been submitted in environmental policies.

**Linkage between Aggregate Demand and Inflation in coal market.** As illustrated in in chapter (3) the relationship between supply market and demand for a commodity. There is a growing shortage of aggregate demand for coal due to technological changes and new regulations, leading to a shortage of coal production in China and closure a number of coal mines, both of state-owned and private mines. Aiming to reduce the over-production and reach to equilibrium point between global demand and domestic production of coal, which is determined by the requirements of the global market. The increase in the unemployment rate due to the inevitable closure of some mines and shrinking coal industry, a number of companies have fired some of its workers. The falling exports rate and increasing the unemployment rate would be caused economic inflation. Figure (20) shows the whole cycle of aggregate demand and inflation.



**Figure 19: Aggregate Demand and Inflation in coal market**

**Exports and imports.** Despite declining coal in Europe and will keep decline, coal exports will also decline significantly owing to a drop in its market. In the end, exports and imports subject to market controls in supply and demand operations. Chinese coal exports amounts sharply declines from 7173.1 (10,000 tonne) in 2003 and completely fell down reached to 1910.6 (10,000 tons) in 2010. Recently the coal exports reached to 574.2 (10,000 tons) in 2014. In Asian economic such as China and India, coal exports play a major role to keep the balance reform in their economic, China was the greatest exporter for coal in the market and that has helped it to reform the economy.



**Figure 20: Coal Export and Import in China coal market**  
*Source: Data taken from Energy Statistical Yearbook for china, 2016*

**Coal-electricity price linkage mechanism.** Electricity market is always changing and have lots of regulation problem, the market is controlled by a main factor which is decreasing the electricity price. The changing in electricity market and its supply is affected by the installation of wind turbine and photovoltaic cells. So, looking on all of this it's not cost wise to operate the power plants by fossils. So in an electricity market that has an alternatives than coal it becomes clear that the demand of this market to coal is controlling the coal price and this is due to the unbalanced market of coal industry and thermal coal generation industry. The asymmetry of Chinese electricity and thermal coal pricing reforms have led to serious conflict between electricity generation enterprises and coal supplying enterprises for a long time. The price of thermal coal has always been the focus of the debate between coal mining industry and electric power industry. Electricity market has a stronger market force than the coal mining enterprises. Being in a monopoly status, the electricity enterprises force the coal mining enterprises to lower the coal price, which has resulted in serious distortion of the coal price in China. Facing the phenomenon of coal price distortion in China. Artificially low price of the coal mining had caused serious losses of coal mining enterprises, which also caused shortages of coal supplies. This mean the only way to increase the coal price is by increasing the electricity price and this is too difficult.

## 5.5 Models and Methodology

Various kinds of analytical models have been proposed to explain the causes of vulnerability, the most important models of vulnerability presented were *Risk-Hazard (RH)* model and *Pressure and Release (PAR)* model which developed by Blaikie et al. (1994). RH model shows the impact of natural disaster as a function of two principles of vulnerability exposure and sensitivity, to assets the environmental impact and change is the application of this model, however, this model failed to deal with the causes of vulnerability, neither does it address the role of political economy in forming differential exposure and results.

*Hazard impact = function (exposure X sensitivity) ..... Equation 6*

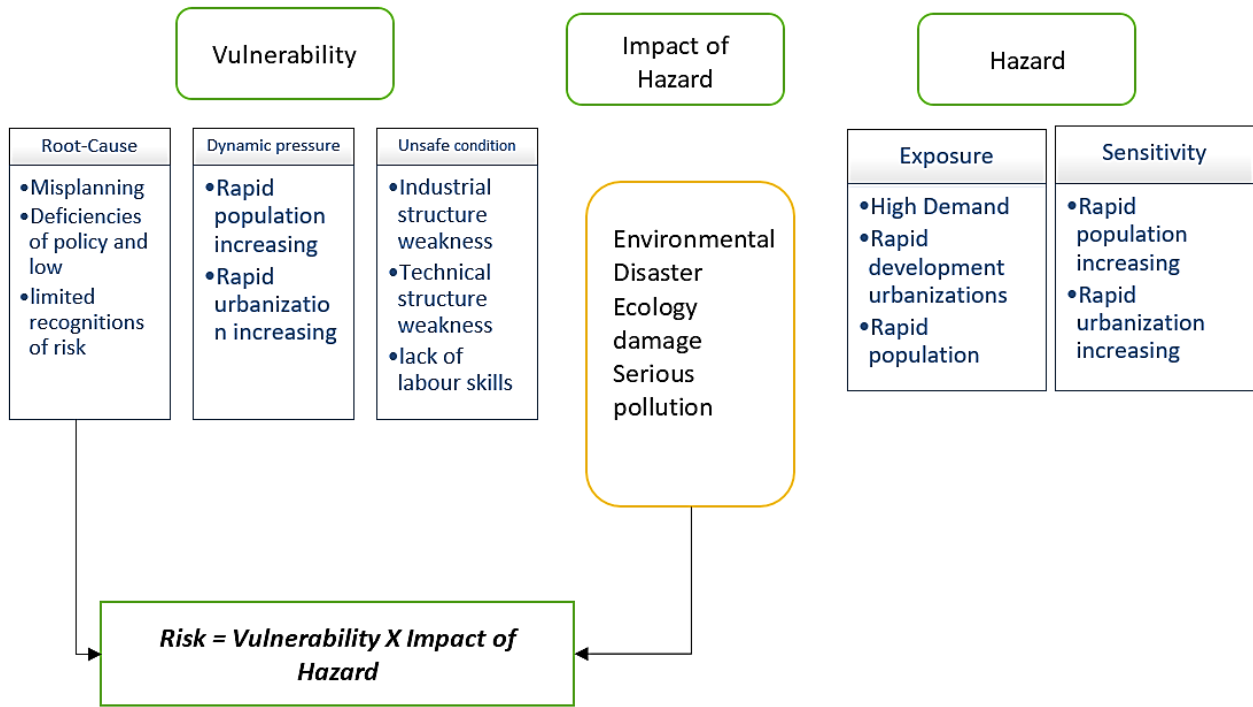
*PAR* model examines the relationship between socio-economic pressure and physical exposure. The model operates at different spatial (place, region, world), functional and temporal scales and takes into account the interaction of the multiple perturbations and stressor/stresses (Wisner et al., 2004). The model defines the risk as a function of natural hazard which represent natural side and progression of vulnerability which distinguishes between three elements represent the social side: root causes, dynamic pressures and unsafe conditions. According to Blaikie's explanations for those three elements, principal Root causes include economic, demographic and political processes, which affect the allocation and distribution of resources. Dynamic Pressures translate economic and political processes in local circumstances. Unsafe conditions are the specific forms in which vulnerability is expressed in time and space, such as those induced by the physical environment, local economy or social relations (Blaikie et al., 1994).

*Risk = progression of vulnerability X natural hazard ..... Equation 7*

In UNISDR Terminology on Disaster Risk Reduction, Risk is defined "the combination of the probability of an event and its negative consequences". Hazard is "dangerous, loss of livelihoods, social and economic disruption, or environmental damage".

There are modern models has been proposed in recent years such as, PSR model (Wolfslehner and Vacik, 2008) the objective of those models simply is to recognize the relationships among pressure, state, and response in terms of the causal relationship and the ESA model.

Therefore, I combine RH model and *PAR* model to assess the frameworks of Vulnerability for coal mining area, the combined model as shown in figure (21). To summarize the impact by two methods in case of China.



**Figure 21: combination between RH model and PAR model**

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## Chapter 6

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### Conclusion

Materials become critical when they are exposed to price fluctuations in the market, or when supplies are not matched with demand or when they have a significant tangible impact on the environmental. In the energy market scale, fossil fuel materials can be considered critical material because they are not settled in the market and are affected by the current external events. Market disturbances, and political events can significantly affect the nature of energy supplies, as has happened with the oil in the year 1970s and natural gas supplies to Europe due to the conflicts between Russia and Ukraine and the civil war in the Libya, this indicators reflect on the supply-demand balance. The problem is not explicitly the lack of energy materials supplies directly, but rather about what these materials offer. The demand of energy, electricity, transport fuel and heavy industries are the main motive of demand of the energy materials. The risk of supply energy materials translated into risk of energy supply, the majority of energy came from the fossil fuels. Energy is a vital commodity for any country for sustainability of economy growth and industry development. The nation use this development of energy to reform and growth their economy, there is a positive relationship between fossil fuel energy (energy consumption) and economic growth (GDP). Many energy efficiency indicators were developed and applied for explain differences in energy performance between countries, and the environmental and economic impact assessing came at the top of these indicators. Energy security and suitability are considered as main indicator to measure the energy performance.

This paper focus on the coal energy resources in China and investigate the coal industry ecosystem vulnerability. China broadly is the largest country of coal production and coal consumption in the world, coal was and still remain playing a dominant and role in domestic energy resource. Furthermore, China is the most country are suffering from the coal industry's impact and its relative sectors.

High percentage of energy in China depends on coal, as a tool to reform the economy. This dependency requires sustainable energy solutions. Which that means China's energy sector needs to massive investments, technological and management improvements. Despite technological advances, policies toward sustainable development and renewable energy China domestic energy sector itself faces the growth and development challenges that require technological innovations, capital investment, large-scale social and environmental policies and improvements in management. If China follow the same plan of energy they can't meet the energy demand in the future. China government needs to change the policies concerning the environmental and social issue. The energy policy are needed to reform the market failure, the sustainability and energy price balance lean on the perfect energy policy. The technological solutions could minimize coal's impact on the environment.

Energy minerals Nations seek to stabilize the market to ensure stability in investment not only nations that are keen on this fortitude, but also investors, stockholders and consumers. It's widely noted, the producer countries for energy minerals have stable economy with high independence and increasing in the export of both of crude minerals and energy, for instance China in the last decades has got self-sufficiency in energy, and the reason for coal production is staggering



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# Annexes

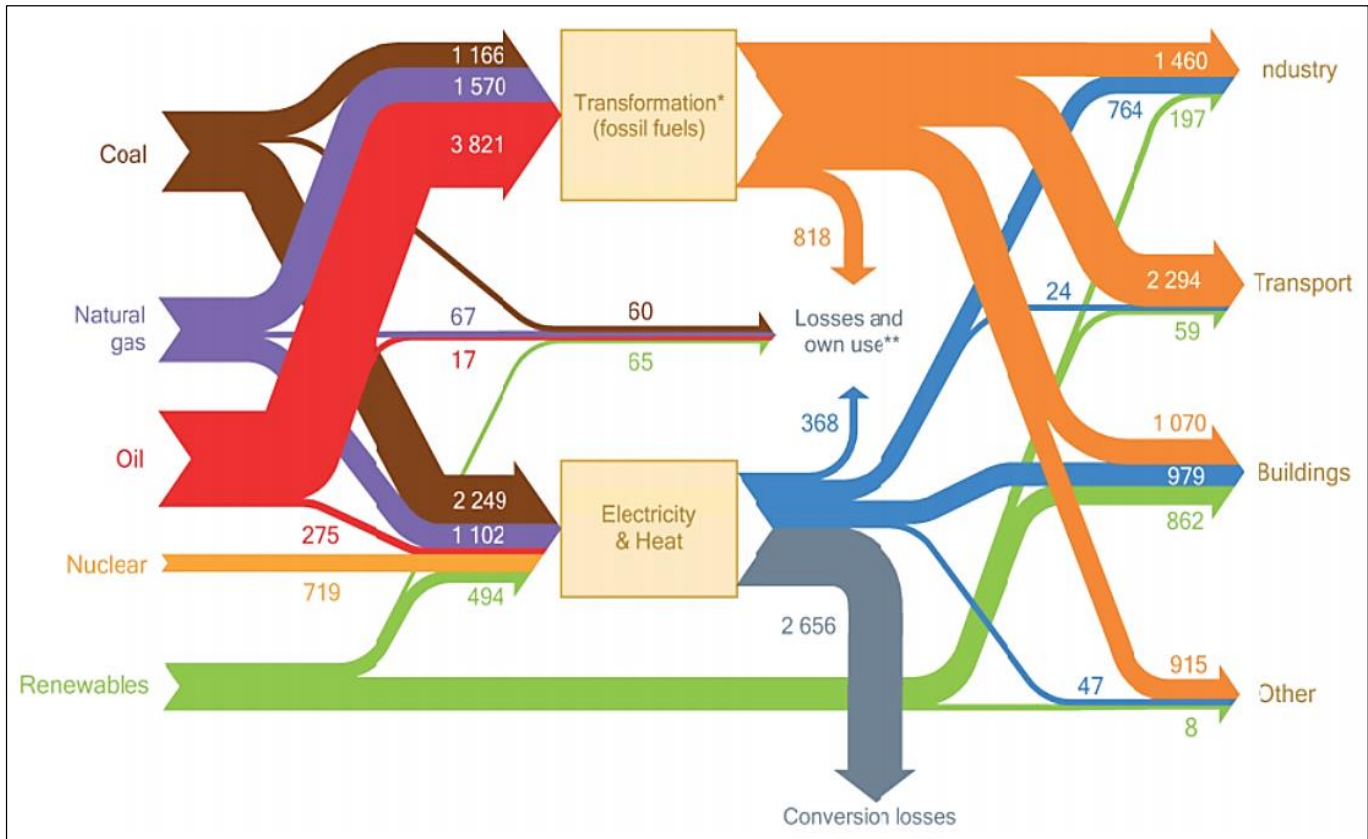
## Annex (A) Coal production over the world and the growth rate per year in million tonnes in 2016

1	Coal: Production*																					Growth rate per annum			Share		
2																						2016	2005-15	2016			
3	Million tonnes	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2016	2005-15	2016	
4	US	937.1	965.1	988.8	1013.8	998.3	974.0	1023.0	992.7	972.3	1008.9	1026.5	1054.8	1040.2	1063.0	975.2	983.7	993.9	922.1	893.4	907.2	813.7	<b>660.6</b>	-19.0%	-2.3%	8.9%	
5	Canada	75.0	75.9	78.8	75.3	72.4	69.1	70.5	67.0	62.6	66.2	68.4	67.4	69.0	68.4	64.6	68.0	67.5	67.3	68.4	67.3	61.2	<b>60.3</b>	-1.8%	-1.1%	0.8%	
6	Mexico	8.9	9.7	9.4	10.1	10.3	11.3	8.9	7.1	9.2	12.2	12.7	14.1	15.2	14.4	12.7	15.3	16.6	15.2	14.6	14.9	12.3	<b>8.0</b>	-34.8%	-0.3%	0.1%	
7	<b>Total North America</b>	<b>1021.0</b>	<b>1050.7</b>	<b>1077.0</b>	<b>1099.2</b>	<b>1081.0</b>	<b>1054.4</b>	<b>1102.4</b>	<b>1066.8</b>	<b>1044.1</b>	<b>1087.3</b>	<b>1107.6</b>	<b>1136.3</b>	<b>1124.4</b>	<b>1145.9</b>	<b>1052.5</b>	<b>1067.0</b>	<b>1081.0</b>	<b>1004.6</b>	<b>976.5</b>	<b>989.5</b>	<b>887.2</b>	<b>728.9</b>	<b>-18.1%</b>	<b>-2.2%</b>	<b>9.8%</b>	
8	Brazil	5.2	4.8	5.6	5.5	5.7	6.8	5.7	5.1	4.6	5.4	6.3	5.9	6.0	6.6	5.1	5.4	5.5	6.6	8.6	7.9	8.0	<b>8.1</b>	-	2.5%	0.1%	
9	Colombia	25.7	29.6	32.7	33.6	32.8	38.2	43.9	39.5	50.0	53.9	59.7	66.2	69.9	73.5	72.8	74.4	85.8	89.2	85.5	88.6	85.5	<b>90.5</b>	5.5%	3.7%	12%	
10	Venezuela	4.4	4.2	5.3	6.5	6.6	7.9	7.7	8.1	7.0	8.1	7.2	7.2	6.9	5.1	3.3	2.6	2.6	1.9	1.2	0.8	0.8	<b>0.3</b>	-66.4%	-19.7%	♦	
11	Other S. & Cent. America	1.8	1.8	1.7	0.5	0.9	0.8	0.8	0.6	0.5	0.3	0.8	0.9	0.5	0.8	0.9	0.8	0.9	1.0	3.2	4.5	3.4	<b>2.8</b>	-18.7%	16.7%	♦	
12	<b>Total S. &amp; Cent. America</b>	<b>37.1</b>	<b>40.3</b>	<b>45.4</b>	<b>46.1</b>	<b>45.9</b>	<b>53.7</b>	<b>58.0</b>	<b>53.3</b>	<b>62.2</b>	<b>67.7</b>	<b>73.9</b>	<b>80.1</b>	<b>83.2</b>	<b>86.0</b>	<b>82.0</b>	<b>83.2</b>	<b>94.8</b>	<b>98.7</b>	<b>98.5</b>	<b>101.0</b>	<b>97.8</b>	<b>101.6</b>	<b>3.6%</b>	<b>2.8%</b>	<b>1.4%</b>	
13	Bulgaria	30.8	31.3	29.7	30.1	25.3	26.4	26.3	25.7	27.2	26.4	24.6	25.5	28.3	28.8	27.2	29.3	37.1	33.4	28.6	31.3	35.9	<b>31.5</b>	-12.5%	3.8%	0.4%	
14	Czech Republic	74.3	76.2	73.5	67.5	59.1	65.2	66.1	63.4	63.9	61.8	62.0	62.9	62.6	60.2	56.4	55.2	57.9	55.0	49.0	46.9	46.4	<b>46.0</b>	-1.2%	-2.9%	0.6%	
15	Germany	246.7	235.8	223.6	207.3	201.1	201.6	203.0	208.4	205.2	208.0	203.1	197.4	201.9	192.5	183.6	182.3	188.6	196.2	190.6	185.8	184.3	<b>176.1</b>	-4.7%	-1.0%	2.4%	
16	Greece	57.7	59.8	59.8	60.9	62.1	63.9	66.3	70.5	69.3	70.0	69.4	64.8	66.3	65.7	64.9	56.5	58.7	63.0	53.9	50.8	46.2	<b>33.1</b>	-28.7%	-4.0%	0.4%	
17	Hungary	12.2	15.1	15.6	14.5	14.6	14.0	13.9	13.0	13.3	11.5	9.6	10.0	9.8	9.4	9.0	9.1	9.6	9.3	9.6	9.6	9.3	<b>9.3</b>	0.6%	-0.3%	0.1%	
18	Kazakhstan	83.3	76.8	72.6	69.8	58.4	74.9	79.1	73.7	84.9	86.9	86.6	96.2	97.8	111.1	100.9	110.9	116.4	120.5	119.6	114.0	107.3	<b>102.4</b>	-4.9%	2.2%	14%	
19	Poland	200.7	201.7	200.9	178.6	172.7	162.8	163.5	161.9	163.8	161.3	159.5	156.1	145.9	144.0	135.2	133.2	133.3	133.3	144.1	142.9	137.1	135.8	<b>131.1</b>	-3.8%	-1.6%	1.8%
20	Romania	41.1	41.9	33.8	26.2	22.9	29.3	33.3	30.4	33.1	31.8	31.1	34.9	35.8	35.9	34.0	31.1	35.5	33.9	24.7	23.6	25.5	<b>23.2</b>	-9.2%	-2.0%	0.3%	
21	Russian Federation	269.6	262.1	250.6	235.4	255.1	262.1	274.0	258.9	278.7	284.4	300.0	311.4	315.6	330.2	302.4	322.9	337.4	358.3	355.2	357.4	372.7	<b>385.4</b>	3.1%	2.2%	5.2%	
22	Serbia	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	37.7	39.2	38.8	37.9	40.8	38.2	40.3	29.8	<b>38.4</b>	1.4%	n/a	0.5%	
23	Spain	28.5	27.4	26.5	26.1	24.3	23.5	22.7	22.0	20.5	20.5	19.4	18.4	17.2	10.2	9.4	8.4	6.6	6.2	4.4	3.9	3.1	<b>1.7</b>	-43.5%	-16.8%	♦	
24	Turkey	55.1	56.4	59.9	67.4	67.0	63.3	62.1	54.0	48.6	46.4	60.8	64.3	75.4	79.4	79.5	73.4	76.0	71.5	60.4	65.2	58.4	<b>70.6</b>	20.5%	-0.4%	0.9%	
25	Ukraine	85.4	71.5	77.7	77.9	82.4	81.5	84.3	83.2	80.9	82.0	79.6	80.8	77.2	79.9	74.4	77.3	85.2	87.3	84.8	64.0	38.5	<b>41.8</b>	8.2%	-7.0%	0.6%	
26	United Kingdom	53.0	50.2	48.5	41.2	37.1	31.2	31.9	30.0	28.3	25.1	20.5	18.5	17.0	18.1	17.9	18.3	18.6	17.0	12.8	11.6	8.6	<b>4.2</b>	-51.5%	-8.3%	0.1%	
27	USSR	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	<b>n/a</b>	n/a	n/a	n/a	
28	Uzbekistan	3.1	2.8	2.9	3.0	3.0	2.5	2.7	2.7	1.9	2.8	3.2	2.8	3.4	3.3	3.7	3.3	3.8	4.0	4.1	4.4	4.0	<b>3.9</b>	-2.2%	2.2%	0.1%	
29	Other Europe & Eurasia	102.3	99.1	106.2	97.2	92.4	92.7	94.1	97.5	103.5	95.5	100.4	106.2	63.4	67.1	68.9	71.6	74.2	67.4	76.3	71.9	66.3	<b>63.4</b>	-4.6%	-4.1%	0.9%	
30	<b>Total Europe &amp; Eurasia</b>	<b>1343.8</b>	<b>1308.0</b>	<b>1280.9</b>	<b>1202.9</b>	<b>1177.3</b>	<b>1194.7</b>	<b>1223.4</b>	<b>1195.4</b>	<b>1222.2</b>	<b>1214.4</b>	<b>1229.7</b>	<b>1250.1</b>	<b>1255.3</b>	<b>1274.8</b>	<b>1206.1</b>	<b>1220.8</b>	<b>1285.5</b>	<b>1305.2</b>	<b>1257.0</b>	<b>1207.4</b>	<b>1180.0</b>	<b>1162.0</b>	<b>-1.8%</b>	<b>-0.4%</b>	<b>15.6%</b>	
37	<b>Total Africa</b>	<b>214.0</b>	<b>213.5</b>	<b>227.2</b>	<b>230.7</b>	<b>230.6</b>	<b>230.5</b>	<b>230.0</b>	<b>226.3</b>	<b>243.5</b>	<b>248.5</b>	<b>250.0</b>	<b>248.5</b>	<b>251.1</b>	<b>255.1</b>	<b>250.7</b>	<b>259.0</b>	<b>257.3</b>	<b>267.3</b>	<b>267.6</b>	<b>276.3</b>	<b>266.1</b>	<b>264.2</b>	<b>-1.0%</b>	<b>0.6%</b>	<b>3.5%</b>	
38	Australia	248.1	257.0	281.0	290.7	305.8	313.9	335.5	343.2	351.1	363.2	378.8	386.7	396.4	408.4	422.2	434.4	423.2	448.2	472.8	504.2	505.4	<b>492.8</b>	-2.8%	2.9%	6.6%	
39	China	1360.7	1396.7	1387.5	1332.0	1364.0	1384.2	1471.5	1550.4	1634.9	2122.6	2365.1	2569.7	2759.9	2903.4	3115.4	3428.4	3764.4	3945.1	3974.3	3873.9	3746.5	<b>3411.0</b>	-9.2%	4.7%	45.7%	
40	India	289.0	311.0	319.4	320.9	314.4	334.8	341.9	358.1	375.4	408.0	429.0	449.7	479.1	515.4	556.8	572.3	553.8	605.6	608.5	646.2	674.2	<b>692.4</b>	2.4%	4.6%	9.3%	
41	Indonesia	41.8	50.4	54.8	62.2	73.7	77.0	92.5	103.3	114.3	132.4	152.7	193.8	216.9	240.2	256.2	275.2	353.3	385.9	474.6	458.1	461.6	<b>434.0</b>	-6.2%	11.7%	5.8%	
42	Japan	6.3	6.5	4.3	3.7	3.9	3.1	3.2	1.4	1.3	1.3	1.1	1.4	1.4	1.2	1.3	0.9	1.3	1.3	1.2	1.3	1.2	<b>1.3</b>	14.2%	0.5%	♦	
43	Mongolia	5.0	5.1	4.9	5.1	5.0	5.2	5.1	5.5	5.7	6.9	7.5	8.1	9.2	10.1	14.4	25.2	32.0	29.9	30.1	25.3	24.2	<b>38.1</b>	57.0%	12.4%	0.5%	
44	New Zealand	3.6	3.6	3.6	3.1	3.5	3.5	3.9	4.5	5.2	5.2	5.3	5.7	4.8	4.8	4.6	5.3	4.9	4.9	4.6	4.0	3.4	<b>2.9</b>	-15.1%	-4.3%	♦	
45	Pakistan	3.2	3.5	3.1	3.3	3.3	3.2	3.3	3.5	3.3	3.4	3.5	4.0	3.7	4.0	3.5	3.4	3.2	3.0	3.0	3.4	<b>3.0</b>	<b>3.0</b>	<b>19.3%</b>	50.5%	0.1%	
46	South Korea	5.7	5.0	4.5	4.4	4.2	4.2	3.8	3.3	3.3	3.2	2.8	2.8	2.9	2.8	2.5	2.1	2.1	2.1	1.8	1.7	1.8	<b>1.7</b>	-2.4%	-4.5%	♦	

### Annex A: the global coal production in 2016

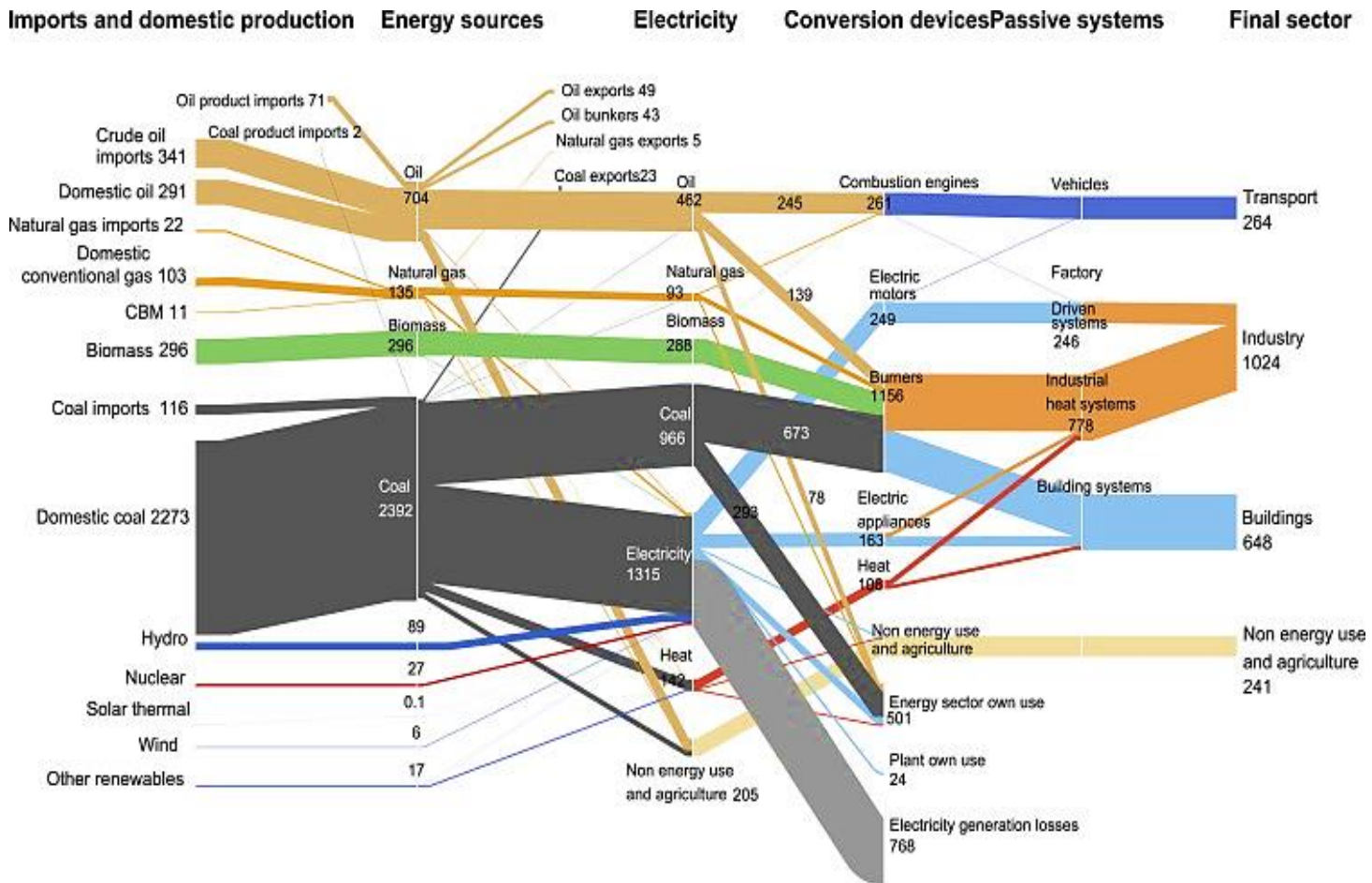
Source: bp statistical review of world energy 2017, excel format

Annex (B) a Sankey diagram of the global energy flows 2010



**Annex B: Sankey diagram of the global energy flows 2010. Units are given in Mtoe.**  
 Source: <http://www.sankey-diagrams.com/world-energy-flows-2012/>  
 From the 'World Energy Outlook 2012' by OECD/IEA

Annex (C) a Sankey diagram of the Chinese energy flows 2010



**Annex C: The flow of energy from initial source to final service in China in 2010. Units are given in Mtce.**  
 Source: Qin et al., 2015

Annex (D) Impacts from coal affect land, water and air



***Annex D-1: Steam and smoke from waste coal and stone rises after being dumped next to an unauthorized steel factory on November 3, 2016 in Inner Mongolia, China  
Source: Sherwin, 2016. Foreign policy magazine website  
<http://foreignpolicy.com/2016/12/07/china-is-outsourcing-its-pollution/>***



***Annex D-2: A coal ash dam owned by the Shentou No 2 Power Plant in Shuimotou village, Shuozhou, Shanxi province***

***Jin Zhu (China Daily), Updated: 2010-09-16***

***[http://www.chinadaily.com.cn/china/2010-09/16/content\\_11309441.htm](http://www.chinadaily.com.cn/china/2010-09/16/content_11309441.htm)***

Annex (E) the total investment in the treatment of Environmental pollution in China

Item	2011	2012	2013	2014	2015
<b>Total Investment in the Treatment of Environmental Pollution</b> (100 million yuan)	<b>7114.0</b>	<b>8253.5</b>	<b>9037.2</b>	<b>9575.5</b>	<b>8806.3</b>
Investment in Urban Environmental Infrastructure	4557.2	5062.7	5223.0	5463.9	4946.8
Gas Supply	444.1	551.8	607.9	574.0	463.1
Centralized Heating	593.3	798.1	819.5	763.0	687.8
Drainage Works	971.6	934.1	1055.0	1196.1	1248.5
Gardening and Greening	1991.9	2380.0	2234.9	2338.5	2075.4
Environmental Sanitation	556.2	398.6	505.7	592.2	472.0
Investment in the Treatment of Industrial Pollution	444.4	500.5	849.7	997.7	773.7
Environmental Investment of Project of Environmental Protection Acceptance Completed This Year	2112.4	2690.4	2964.5	3113.9	3085.8
<b>Total Investment in the Treatment of Environmental Pollution as Percent of GDP</b> (%)	<b>1.45</b>	<b>1.53</b>	<b>1.52</b>	<b>1.49</b>	<b>1.28</b>

***Annex E-1: the total investment in the treatment of Environmental pollution in China  
National Bureau of Statistics of China, 2011. Energy Statistical Yearbook 2011***

(10 000 yuan)



Year Region	Investment					
	Completed in the Treatment of Industrial Pollution	Treatment of Waste Water	Treatment of Waste Gas	Treatment of Solid Waste	Treatment of Noise Pollution	Treatment of Other Pollution
2000	2347895	1095897	909242	114673	13692	214390
2005	4581909	1337147	2129571	274181	30613	810396
2006	4839485	1511165	2332697	182631	30145	782848
2007	5523909	1960722	2752642	182532	18279	606838
2008	5426404	1945977	2656987	196851	28383	598206
2009	4426207	1494606	2324616	218536	14100	374349
2010	3969768	1295519	1881883	142692	14193	620021
2011	4443610	1577471	2116811	313875	21623	413831
2012	5004573	1403448	2577139	247499	11627	764860
2013	8496647	1248822	6409109	140480	17628	680608
2014	9976511	1152473	7893935	150504	10950	768649
2015	7736822	1184138	5218073	161468	27892	1145251

**Annex E-2: the total investment in the treatment of waste water, waste gas and waste soild in China  
National Bureau of Statistics of China, 2011. Energy Statistical Yearbook 2011**

## Thesis Grade

Thesis: Assessing Economic and Environmental in the coal mining area under economic fluctuations and volatility energy market

Author: Sara Mohamed

Supervisor	<u>Wang Jia Chen</u>	Grade	98	signature	
Co-supervisor	<u>Nikolaus A. Sifferlinger</u>	Grade	93	signature	 11.6.18



## Thesis Grade

Thesis: Assessing Economic and Environmental in the coal mining area under economic fluctuations and volatility energy market

Author: Sara Mohamed

Review Expert Li Yang

Grade 97

signature 