LAPPEENRANTA UNIVERSITY OF TECHNOLOGY

LUT School of Energy Technology

Electricity Market and Power Systems

Zhanjun Tan

# Fossil Fuel Subsidies in Northeast Asia and Nuclear Liability Insurance

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# ABSTRACT

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In this thesis, the main discussion focuses on fossil fuels subsidies in Northeast Asia and nuclear liability insurance. In fossil fuel subsidies, it includes direct and indirect subsidies. Reviewing the estimations from different organizations, such as, IMF, IEA, OECD, and IISD/GSI, estimating the hidden cost and effects to human health and environment from burning fossil fuels, and shortly analyzing nuclear liability insurance are the central issues.

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# Abbreviations

ANS—American Nuclear Society

COP—Conference of Parties

CSE—Consumer Support Estimate

ECB—European Central Bank

EDGAR—Emission Database for Global Atmospheric Research

EEA—European Environment Agency

EU ETS—European Union Emission Trading System

GBD—Global Burden of Diseases

GDP—Gross Domestic Product

GHG—Green House Gas

GSI—Global Subsidies Initiative

GSSE—General Services Support Estimate

GST—Goods and Service Tax

ICCT—International Council on Clean Transportation

IEA—International Energy Agency

IHME—Institute for Health Metrics and Evaluation

IISD—International Institute for Sustainable Development

IMF—International Monetary Fund

IPCC—Intergovernmental Panel on Climate Change

NEA—Nuclear Energy Agency

OECD—Organization for Economic Co-operation and Development

PM—Particulate Matter

PSE—Producer Support Estimate

R&D—Research & Development

TEPCO—Tokyo Electric Power Company

TSE—Total Support Estimate

U.S.EIA—U.S. Energy Information Administration

U.S.EPA—United States Environmental Protection Agency

UNEP—United Nations Environment Programme

VAT—Value-added Tax

WNA—World Nuclear Association

WHO—World Health Organization

WTO—World Trade Organization

# 1 Introduction

Due to the fact that climate change and global warming problems attract more and more countries' attentions, then people begin to think about the reasons of the consequences. At the Paris climate conference (COP21), 195 countries agreed the first universal climate deal in December 2015. "The agreement sets out a global action plan to put the world on track to avoid dangerous climate change by limiting global warming to well below 2°C. The agreement is due to enter into force in 2020 [19]."In this case, electricity and heating generation from burning fossil fuels comes to our sights. What are the fossil fuels? In generally speaking, it mainly includes coal, oil and natural gas. In Asia, China and Indian make a huge contribution to consume fossil fuels and electricity as emerging countries and economy. For example, China's fossil fuels consumption accounts for around 80% of total electricity production from 1990 to 2013. Under the huge consumption of fossil fuels generated electricity, the real cost of energy became a notable discussion topic in recent years. The central focus is on energy subsidies, which includes not only direct subsidies—direct cash payment, but also indirect subsidies—also called "externalities", which need to take emissions cost ($CO_2$, $SO_2$, NOx and $PM_{2.5}$ emissions), health cost and environment damage into account. Due to control the direct and indirect subsidies, in the meantime, the renewable energy solutions, such as solar panels, wind energy and hydro power, became much more cost competitive than conventional fossil fuels sources electricity generation without considering subsidies within 10 years, 100% renewable energy system could accomplish this goal in the future.

On the aspect of nuclear energy, it does not produce $CO_2$ emissions to warm up the planet, but the much more serious problems are how to deal with the nuclear radiation and waste. How safe it is? What kind of liability the nuclear power companies and the States should fulfill? Moreover, three severe nuclear accidents happened in recent 50 years' history, The Three Mile Island Accident (U.S.) in 1979, The Chernobyl Accident (Soviet Union) in 1986, The Fukushima Daiichi (Japan) in 2011 [47, 49, 51].Those three catastrophes force public to pay much more attentions on nuclear power plants, for example, after the Fukushima Daiichi accident happened in March 2011, Germany shut down 8 nuclear power plants immediately as of May 2011, it also plans to shut down all nuclear power plants with total capacity of 20,339 MWe until 2022, by now almost half of the capacity was already shut down as of June 2015 [50].

# 2 Definition of Subsidy

The widely used definition of subsidy is mainly based on WTO (World Trade Organization), in this thesis mainly talking about the definition of subsidy in IEA (International Energy Agency), IMF (International Monetary Fund), OECD (Organization for Economic Co-operation and Development) and IPCC (Intergovernmental Panel on Climate Change).

WTO provides a general definition of subsidy in the WTO (1994) Agreement on subsidies and countervailing measures:"

*Article 1*

*Definition of a Subsidy*

1.1 For the purpose of this Agreement, a subsidy shall be deemed to exist if:

(a)(1) there is a financial contribution by a government or any public body within the territory of a Member(referred to in this Agreement as “government”), i.e., where:

(i) a government practice involves a direct transfer of funds (e.g., grants, loans, and equity infusion, potential direct transfers of funds or liabilities (e.g., loan guarantees);

(ii) government revenue that is otherwise due is foregone or not collected (e.g., fiscal incentives such as tax credits)[1];

(iii) a government provides goods or services other than general infrastructure, or purchases goods;

(iv) a government makes payments to a funding mechanism, or entrusts or directs a private body to carry out one or more of the type of functions illustrated in (i) to (iii) above which would normally be vested in the government and the practice, in no real sense, differs from practices normally followed by governments;

or

(a)(2) there is any form of income or price support in the sense of Article XVI of GATT 1994;

and

(b) a benefit is thereby conferred." [58]

**IEA**

[1] In accordance with the provisions of Article XVI of GATT 1994 (Note to Article XVI) and the provisions of Annexes I through III of this Agreement, the exemption of an exported product from duties or taxes borne by the like product when destined for domestic consumption, or the remission of such duties or taxes in amounts not in excess of those which have accrued, shall not be deemed to be a subsidy.

The broadly used definition of energy subsidies in IEA is any governmental action which decreases the expense of energy production, increases the price of energy producers or decreases the price of energy consumers in primary energy sector [23].

**IMF**

Under the definition of IMF, subsidies are current payments from government to enterprises for their production activities or services they produce, such as sell, export, or import. To be specific, subsidies are the payment only for producers, not final consumers, and are only current transfers, not capital transfers [29].

**OECD**

OECD provides a different perspective to define the subsidy which is on the basis of agricultural issues. Even though it is notified as agricultural, it still could apply to other sectors. It consists of four parts, Producer Support Estimate (PSE), General Services Support Estimate (GSSE), Consumer Support Estimate (CSE), and Total Support Estimate (TSE).

Producer Support Estimate (PSE): the annual monetary value of gross transfers from consumers and taxpayers to agricultural producers.

General Services Support Estimate (GSSE): the annual monetary value of gross transfers to general services provided to agricultural producers collectively. Any transfers to individual producers are not included.

Consumer Support Estimate (CSE): the annual monetary value of gross transfers from (to) consumers of agricultural commodities.

Total Support Estimate (TSE): the annual monetary value of all gross transfers from taxpayers and consumers [11].

**IPCC**

In IPCC Report 2001 Mitigation, the definition of subsidy is a direct payment from the government to an entity, or a tax reduction to that entity, for implementing a practice the government wishes to encourage [32].

## 2.1 Types of Fossil Fuels Subsidies

### 2.1.1 Direct Subsidies

In OECD definition of direct subsidy is government action that benefits consumers or producers to compensate their income or lower their expense [39]. There are two main forms of energy subsidies: first, which intended to reduce the cost of consuming fossil fuels; second, which focused on supporting domestic fossil-fuel production [6]. Under the support of some producer subsidies, consumers can benefits from lower fossil-fuel prices indirectly.

Consumers' subsidies plays an important role of price controls in non-OECD, former eastern bloc countries and developing countries [26]. In general, it retains lower fossil-fuel prices to stimulate certain economic sectors or moderate poverty via expanding the access to energy for locals [36,45].

Producers' subsidies generally decrease the production costs or increase revenues, in order to maintain the business for marginal producers [36]. To reduce import dependency, subsidies are still the critical factor [15]. With regard to subsidies, it includes direct cash transfers to producers or consumers, and unobvious support mechanisms. For fossil-fuel subsidies, the price controls, market access limits and trade restrictions are usually the key factors. The OECD [35] and the UNEP [46] distinguish from the typical support to the production and consumption of fossil-fuels by governments in following aspects: direct financial transfers, preferential tax treatment, trade restrictions, direct energy-related services provided by government, and regulation of the energy sector.

Another similar category of energy subsidies is expressed in the 2010 Joint Report of the IEA, the OECD, and the World Bank in following seven common types: trade instruments, regulations, tax breaks for consumers or producers of fossil-fuels, credit to fossil-fuel producers, direct financial transfer to lower end user prices or to reduce the costs of producers, risk transfer, and energy-related services provided by the government [27].

### 2.1.2 Indirect Subsidies

Indirect subsidies are also known as "externalities". It includes following aspects: burdens, effects and impacts, damages. For instance, environment damage, heavy metal emissions, health cost and emissions cost ($CO_2$, $SO_2$, NOx, $PM_{2.5}$).From the quantity perspective, indirect subsidies are far more amount than direct subsidies. It will result vital effect in decision making and in welfare reducing of society's members [10]. In IMF's definition, post-tax subsidies consist of two parts, pre-tax subsidies and externalities, the major part of post-tax subsidies is considered as "externalities", such as, the impact on global warming, on public health, on road damage, on traffic congestion and accidents, and on foregone consumption tax revenue (foregone VAT) [31]. It is much larger than pretax subsidies, estimation conducted by amounting to US$5.3 trillion in 2015— about 6.5 percent of global GDP (Gross Domestic Product). It is comprised of the major share over 50% on local pollution, global warming, prices below international supply costs, and other local factors [3, 30].

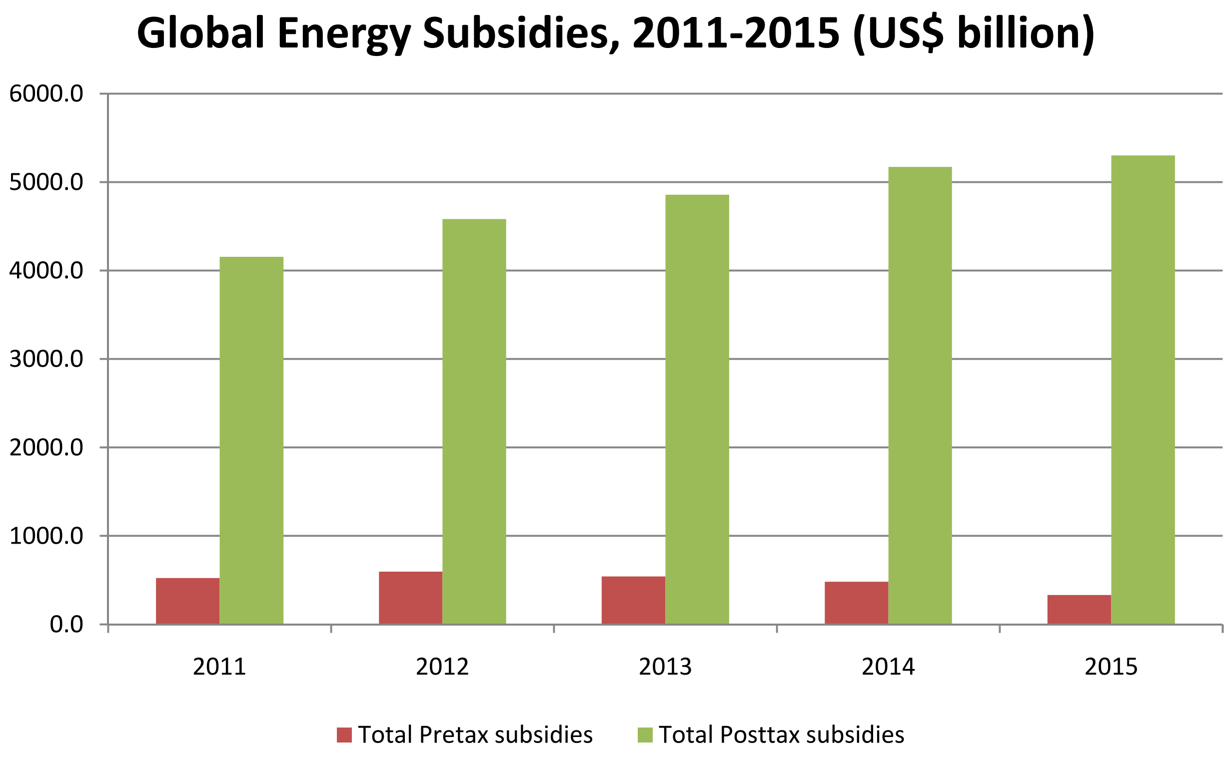


*Figure 45 Global Energy Subsidies, 2011-2015 (US$ billion)*

*Source: IMF (2015)*

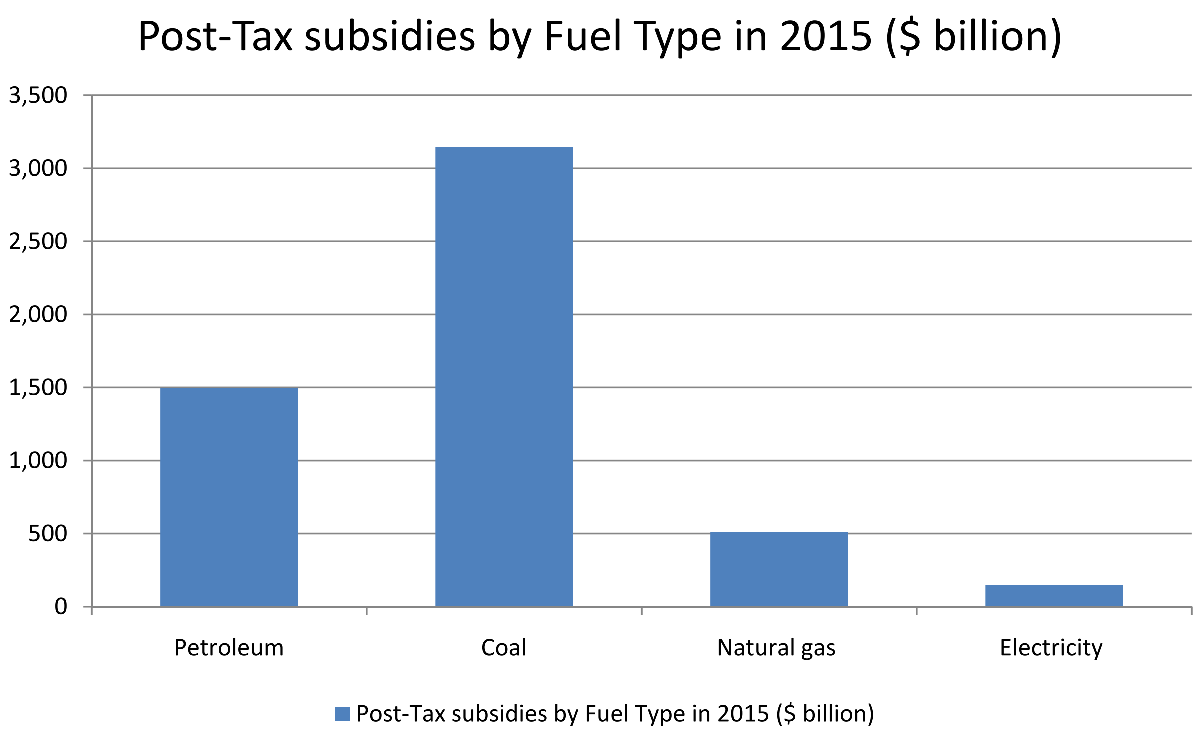

*Figure 46 Post-tax subsidies by fuel type in 2015 (US$ billion)*

*Source: IMF (2015)*

**Classification of Post-Tax subsidies by Fuel Types and Externalities (US$ billion)**

| | 2011 | 2013 | 2015 |
|---|---|---|---|
| **Petroleum** | | | |
| post-tax subsidies | **1,366** | **1,613** | **1,497** |
| pre-tax subsidies | 241 | 267 | 135 |
| externalities (net of any fuel taxes) | 942 | 1,121 | 1,162 |
| global warming | 166 | 202 | 209 |
| local air pollution | 266 | 291 | 299 |
| congestion | 271 | 335 | 359 |
| accidents | 219 | 271 | 271 |
| road damage | 19 | 23 | 24 |
| foregone consumption tax revenue | 183 | 224 | 200 |
| **Coal** | | | |
| post-tax subsidies | **2,124** | **2,530** | **3,147** |
| pre-tax subsidies | 7 | 5 | 5 |
| externalities (net of any fuel taxes) | 2,098 | 2,506 | 3,123 |
| global warming | 531 | 617 | 750 |
| local air pollution | 1,567 | 1,889 | 2,372 |
| foregone consumption tax revenue | 18 | 19 | 20 |
| **Natural gas** | | | |
| post-tax subsidies | **436** | **482** | **510** |
| pre-tax subsidies | 111 | 112 | 93 |
| externalities (net of any fuel taxes) | 282 | 322 | 371 |
| global warming | 232 | 267 | 308 |
| local air pollution | 50 | 56 | 62 |
| foregone consumption tax revenue | 42 | 48 | 46 |
| **Electricity** | | | |
| post-tax subsidies | **231** | **233** | **148** |
| pre-tax subsidies | 163 | 156 | 99 |
| foregone consumption tax revenue | 68 | 76 | 49 |
| **Total** | | | |
| post-tax subsidies | **4,157** | **4,858** | **5,302** |
| pre-tax subsidies | 523 | 541 | 333 |
| externalities (net of any fuel taxes) | 3,323 | 3,950 | 4,655 |
| global warming | 929 | 1,086 | 1,268 |
| local pollution | 1,884 | 2,235 | 2,734 |
| congestion | 271 | 335 | 359 |
| accidents | 219 | 271 | 271 |
| road damage | 19 | 23 | 24 |
| foregone consumption tax revenue | 311 | 367 | 313 |

*Table 2 Classification of Post-Tax subsidies by Fuel Types and Externalities (US$ billion)*

*Source: IMF (2015)*

# 3 Methodology

Two worldwide accepted approaches are applied in estimating fossil-fuel subsidies: the Inventory Approach and the Price-gap Approach.

## 3.1 The Inventory Approach

The approach of OECD creates a list of government support policies which effects the production and consumption of fossil-fuels. It is depicted by the PSE-CSE model which applies to agriculture as well. The model estimates transfers of which distinguishes the differences from internal prices and international reference prices. In most OECD countries, the prices of fossil-fuels are similar as an international reference price, therefore, the estimations of market transfers are not included in the Inventory (details in "The Price-gap Approach" below). For instance, budgetary transfers and tax expenditures are so far included in the OECD Inventory. There is a method established for measuring risk transfers, and the subsidy supplement for state-owned enterprises. According to the data from the respective government units, the estimation of OECD's approach is derived. Consumers can benefit in tax expenditures from the reduction or exemption of VAT and fuel excise taxes [28].

## 3.2 The Price-gap Approach

The so called "price-gap" approach is estimating the gap between domestic fuel prices and reference prices. The consumption subsidy will appear while the domestic price declines. Hence, the IEA and IMF employ this approach within their studies and apply international fuel prices as reference price. According to the expense of electricity production, transmission and distribution in individual countries, the reference prices for electricity is calculated. For fossil-fuel exporting countries, this approach can be applied as well. The merits of applying price-gap approach is that enables to compare the main support from administrative pricing or export restrictions amongst countries. The shortage, for instance, is the producer subsidies are not revealed in price-gap analysis [28].

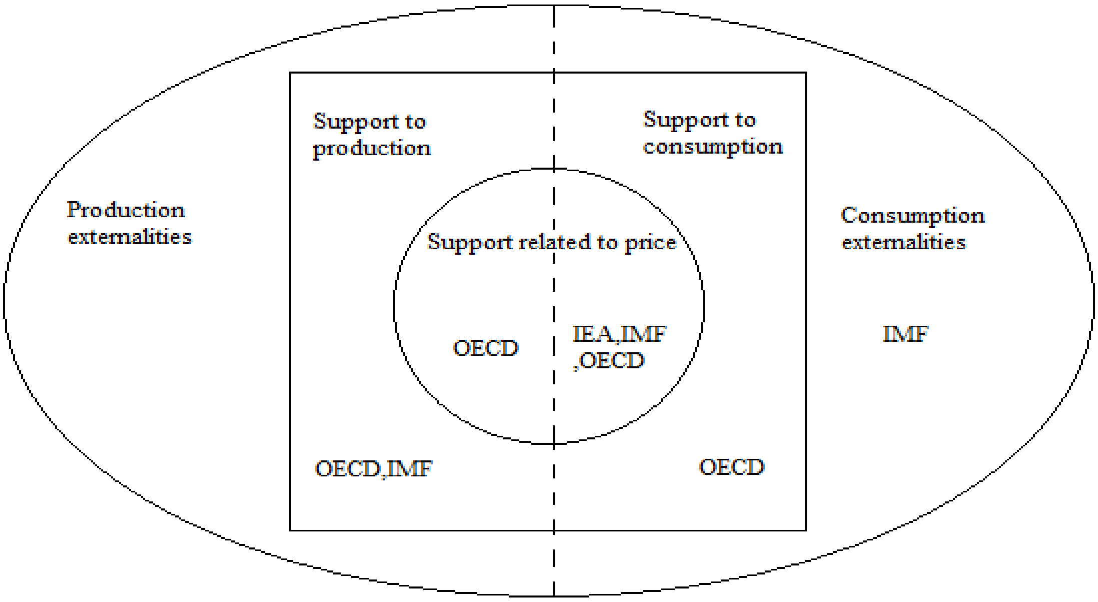


*Figure 47 Comparison of subsidy or support estimation*

*Source: International Institute for Sustainable Development (IISD) and Global Subsidies Initiative (GSI)(2013)*

# 4 Estimation of Fossil Fuels Subsidies by Organizations

Based on the methods mentioned above, four international organizations (IEA, IMF, OECD, and GSI/IISD) provide some useful data of fossil-fuel subsidies as follows.

**IEA**

In IEA's estimation, it measures consumer fossil-fuel subsidies of 40 developing countries annually. The reference price and the end user price are compared in this approach. When the difference is positive, this particular type of fossil-fuel source is subsidized. To be specific, the reference price is equivalent to the import parity price for importers, same as the export parity price for exporters [24]. The following figures indicate the estimation in China and Korea, Rep. from 2011 to 2014 by IEA.

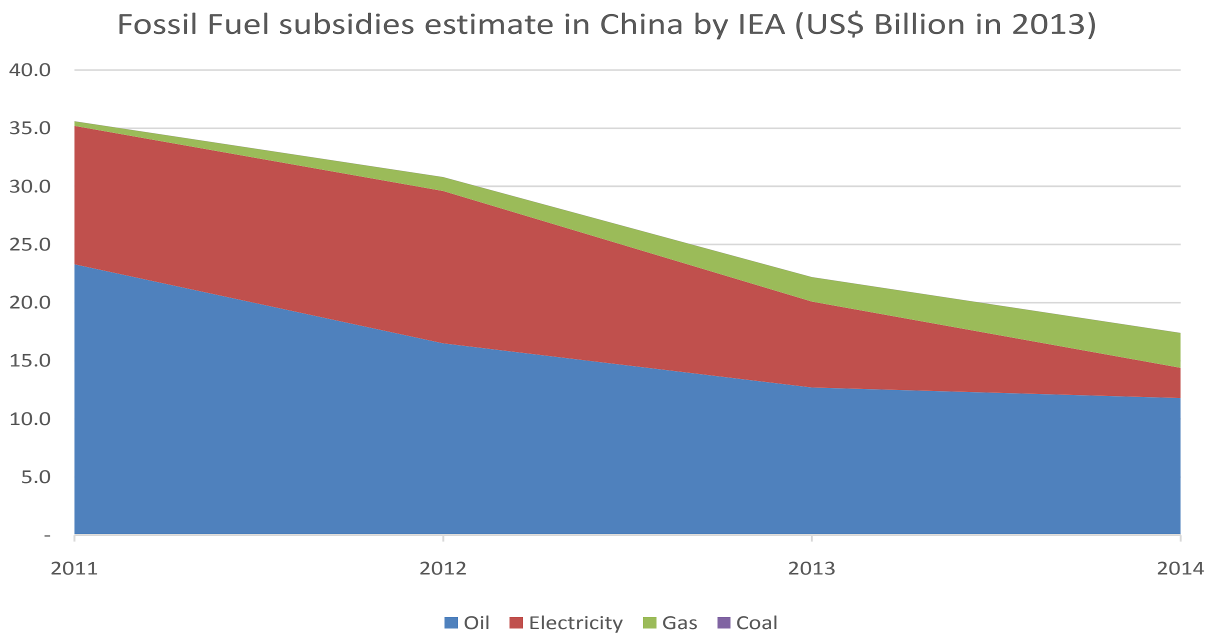


*Figure 48  Fossil Fuel subsidies estimate in China by IEA (US$ Billion in 2013)*

*Source: IEA fossil-fuel subsidies database (2015)*

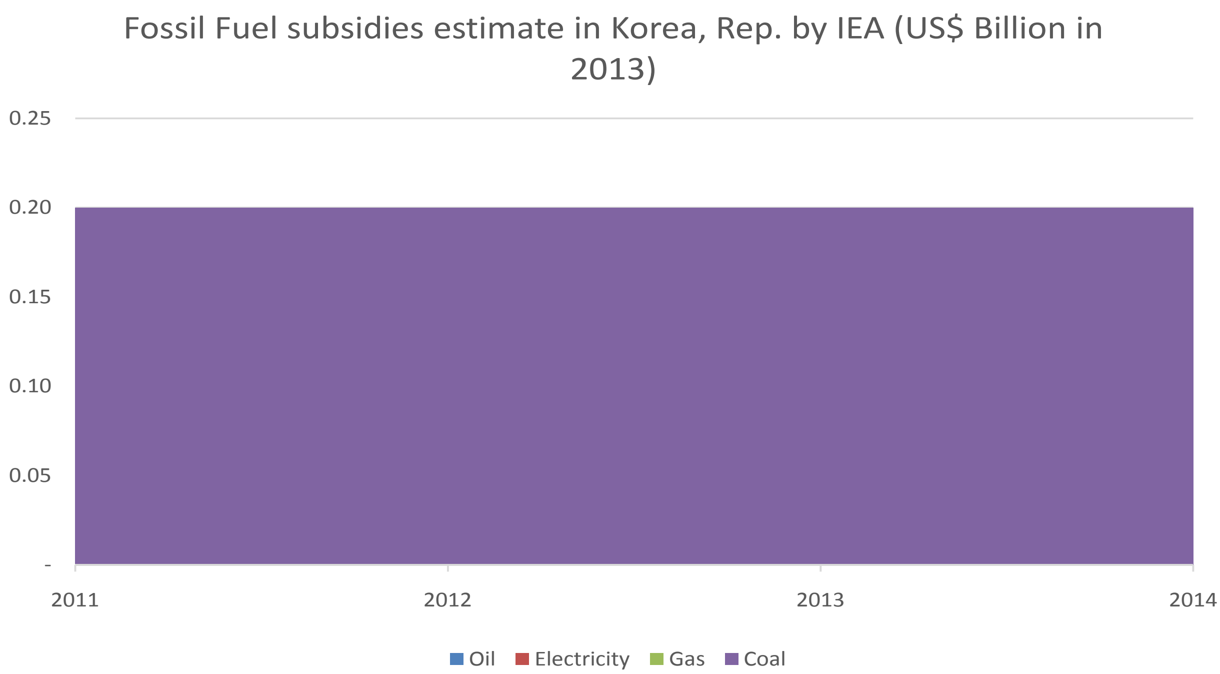


*Figure 49 Fossil Fuel subsidies estimate in Korea, Rep. by IEA (US$ Billion in 2013)*

*Source: IEA fossil-fuel subsidies database (2015)*

**IMF**

In IMF's estimation, the energy subsidies of producer and consumer are separated. When the consumers prices are under supply costs, it results in arising of consumer subsidies. In the other hand, producers subsidies go up when prices beyond supply costs. In this case, the international market price are considered as the benchmark price [9].

Besides the separation on energy subsidies from producer and consumer, IMF also divides the fossil-fuel consumption into pre-tax subsidies and tax subsidies. The definition of pre-tax subsidies are similar as IEA's approach. The tax subsidy takes the taxation differences between the efficient level and the actual level into account by different fuel types. First of all, the efficient level implies issues -like pollution and health impact of it, environmental costs, congestion, which affects the welfare of fossil-fuel users- are not considered in the tax controls of externalities. By assessing post-tax subsidies for coal in this approach, the negative externalities result in the usage of coal is the largest and the most polluting fuel source. Second, fossil-fuels are taxed as other consumer products beneath efficient taxation. Obviously, the post-tax subsidy is the sum of pre-tax and tax subsidies in different fossil-fuel sources. Even though the pre-tax subsidies are almost eliminated in the developed countries, they are extensively provided in developing countries. Unsurprisingly, tax subsidies appear in both developed and developing countries [9].

The tables below indicate the IMF fossil fuels subsidies estimation by sources in Northeast Asia from 2003 to 2015 [3].

Fossil Fuels Subsidies Estimate in China by Sources (US$ Billion)

| | Petroleum | | Natural Gas | | Coal | | Electricity | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Pre-tax | Post-tax | Pre-tax | Post-tax | Pre-tax | Post-tax | Pre-tax | Post-tax | Pre-tax | Post-tax |
| 2003 | - | 0.00 | - | 2.13 | - | 279.84 | - | - | - | 281.97 |
| 2004 | - | 60.64 | - | 2.51 | - | 322.11 | - | - | - | 385.26 |
| 2005 | - | 0.00 | - | 3.15 | - | 389.35 | - | - | - | 392.50 |
| 2006 | - | 63.97 | - | 4.05 | - | 468.71 | - | - | - | 536.73 |
| 2007 | - | 0.00 | 0.00 | 4.96 | 0.11 | 500.55 | - | 9.66 | 0.11 | 515.17 |
| 2008 | - | 10.97 | 3.62 | 9.38 | 2.31 | 531.45 | - | 11.63 | 5.93 | 563.43 |
| 2009 | - | 0.00 | 0.00 | 6.46 | 2.87 | 648.45 | - | 11.84 | 2.87 | 666.75 |
| 2010 | - | 84.25 | 0.00 | 8.65 | 1.52 | 807.51 | - | 42.59 | 1.52 | 943.00 |
| 2011 | - | 100.30 | 0.00 | 11.49 | 1.00 | 926.48 | - | 16.65 | 1.00 | 1054.92 |
| 2012 | - | 104.91 | 0.00 | 14.98 | 2.57 | 1130.71 | - | 20.81 | 2.57 | 1271.42 |
| 2013 | - | 125.99 | 0.00 | 16.12 | 0.00 | 1227.89 | - | 18.73 | - | 1388.74 |
| 2014 | - | 130.39 | - | 18.01 | - | 1409.88 | - | - | - | 1558.28 |
| 2015 | - | 100.71 | - | 23.80 | - | 1923.33 | - | - | - | 2047.84 |

*Table 2 Fossil Fuels Subsidies Estimate in China by Sources (US$ Billion)*

*Source: IMF Energy Subsidies Template 2015*

*Note: "-" represents no data.*

Fossil Fuels Subsidies Estimate in Japan by Sources (US$ Billion)

| Year | Petroleum | | Natural Gas | | Coal | | Electricity | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Pre-tax | Post-tax | Pre-tax | Post-tax | Pre-tax | Post-tax | Pre-tax | Post-tax | Pre-tax | Post-tax |
| 2003 | - | 0.00 | - | 8.21 | - | 17.70 | - | - | - | 25.92 |
| 2004 | - | 50.30 | - | 7.61 | - | 18.21 | - | - | - | 76.13 |
| 2005 | 0.00 | 52.62 | 0.00 | 7.74 | 0.00 | 17.86 | 0.00 | - | 0.00 | 78.22 |
| 2006 | 0.00 | 55.63 | 0.00 | 8.74 | 0.00 | 18.50 | 0.00 | - | 0.00 | 82.87 |
| 2007 | 0.10 | 53.26 | 0.01 | 8.93 | 0.00 | 18.28 | 0.00 | - | 0.11 | 80.47 |
| 2008 | 0.00 | 47.97 | 0.00 | 8.70 | 0.00 | 17.23 | - | - | - | 73.90 |
| 2009 | 0.12 | 41.44 | 0.01 | 8.65 | 0.00 | 15.97 | - | - | 0.12 | 66.06 |
| 2010 | 0.11 | 55.27 | 0.00 | 10.02 | 0.00 | 19.69 | - | - | 0.11 | 84.98 |
| 2011 | 0.11 | 49.63 | 0.01 | 12.04 | 0.00 | 18.32 | - | - | 0.12 | 79.99 |
| 2012 | 0.12 | 56.30 | 0.01 | 14.39 | 0.00 | 21.67 | - | - | 0.12 | 92.36 |
| 2013 | 0.10 | 68.93 | 0.00 | 14.53 | 0.00 | 23.37 | - | - | 0.10 | 106.82 |
| 2014 | 0.10 | 72.84 | 0.00 | 15.14 | 0.00 | 24.46 | - | - | 0.10 | 112.44 |
| 2015 | 0.12 | 92.01 | 0.00 | 18.89 | 0.00 | 30.70 | - | - | 0.12 | 141.60 |

*Table 3 Fossil Fuels Subsidies Estimate in Japan by Sources (US$ Billion)*

*Source: IMF Energy Subsidies Template 2015*

*Note: "-" represents no data.*

Fossil Fuels Subsidies Estimate in Korea, Rep. by Sources (US$ Billion)

| Year | Petroleum | | Natural Gas | | Coal | | Electricity | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Pre-tax | Post-tax | Pre-tax | Post-tax | Pre-tax | Post-tax | Pre-tax | Post-tax | Pre-tax | Post-tax |
| 2003 | - | 0.00 | - | 2.02 | - | 10.89 | - | - | - | 12.90 |
| 2004 | - | 7.78 | - | 2.27 | - | 10.69 | - | - | - | 20.73 |
| 2005 | 0.00 | 6.04 | 0.00 | 2.57 | 0.00 | 11.02 | 0.00 | - | - | 19.63 |
| 2006 | 0.00 | 4.95 | 0.00 | 2.84 | 0.00 | 12.19 | 0.00 | - | - | 19.98 |
| 2007 | 0.00 | 4.69 | 0.00 | 2.95 | 0.00 | 12.46 | - | 0.00 | - | 20.10 |
| 2008 | 0.00 | 9.77 | 0.00 | 2.98 | 0.14 | 13.80 | - | 0.00 | 0.14 | 26.56 |
| 2009 | 0.00 | 11.37 | 0.00 | 2.92 | 0.13 | 15.05 | - | 1.82 | 0.13 | 31.16 |
| 2010 | 0.00 | 15.43 | 0.00 | 4.04 | 0.14 | 18.68 | - | 0.00 | 0.14 | 38.15 |
| 2011 | 0.00 | 15.15 | 0.00 | 4.57 | 0.14 | 20.51 | - | 0.00 | 0.14 | 40.23 |
| 2012 | 0.00 | 17.51 | 0.00 | 5.62 | 0.16 | 22.26 | - | 0.00 | 0.16 | 45.40 |
| 2013 | 0.00 | 18.08 | 0.00 | 5.89 | 0.14 | 22.44 | - | 0.00 | 0.14 | 46.41 |
| 2014 | 0.00 | 19.25 | 0.00 | 6.35 | 0.14 | 24.32 | - | - | 0.14 | 49.92 |
| 2015 | 0.00 | 26.15 | 0.00 | 8.17 | 0.00 | 31.44 | - | - | - | 65.76 |

*Table 4 Fossil Fuels Subsidies Estimate in Korea, Rep. by Sources (US$ Billion)*

*Source: IMF Energy Subsidies Template 2015*

*Note: "-" represents no data.*

Fossil Fuels Subsidies Estimate in Mongolia by Sources (US$ Billion)

| Year | Petroleum | | Natural Gas | | Coal | | Electricity | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Pre-tax | Post-tax | Pre-tax | Post-tax | Pre-tax | Post-tax | Pre-tax | Post-tax | Pre-tax | Post-tax |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 2003 | - | 0.00 | - | - | - | 0.35 | - | - | - | 0.35 |
| 2004 | - | 0.13 | - | - | - | 0.35 | - | - | - | 0.48 |
| 2005 | - | 0.00 | - | - | - | 0.37 | - | - | - | 0.37 |
| 2006 | - | 0.07 | - | - | - | 0.43 | - | - | - | 0.50 |
| 2007 | - | 0.00 | - | - | - | 0.42 | - | - | - | 0.42 |
| 2008 | - | 0.00 | - | - | - | 0.41 | - | - | - | 0.41 |
| 2009 | - | 0.00 | - | - | - | 0.46 | - | - | - | 0.46 |
| 2010 | - | 0.17 | - | - | - | 0.57 | - | - | - | 0.74 |
| 2011 | - | 0.22 | - | - | - | 0.60 | - | - | - | 0.82 |
| 2012 | - | 0.29 | - | - | - | 0.76 | - | - | - | 1.05 |
| 2013 | - | 0.45 | - | - | - | 0.83 | - | - | - | 1.28 |
| 2014 | - | 0.72 | - | - | - | 0.95 | - | - | - | 1.67 |
| 2015 | - | 1.02 | - | - | - | 1.29 | - | - | - | 2.31 |

*Table 5 Fossil Fuels Subsidies Estimate in Mongolia by Sources (US$ Billion)*

*Source: IMF Energy Subsidies Template 2015*

*Note: "-" represents no data.*

The following figures depict the estimation of fossil fuels corrective tax by emissions and by fuel sources and the death per ton of mortality causes by coal and natural gas in Northeast Asia countries in 2010 [25].

IMF Fossil Fuels Corrective Tax Estimation by Emissions in 2010

| € per ton | CO2 | SO2 | | NOx | | PM2.5 | |
|---|---|---|---|---|---|---|---|
| | | Coal | Natural Gas | Coal | Natural Gas | Coal | Natural Gas |
| China | 26 | 16663 | 19334 | 11739 | 12552 | 20869 | 24368 |
| Japan | 26 | 27806 | 5327 | 18315 | 4892 | 33548 | 9914 |
| Korea, Rep. | 26 | 26629 | 26221 | 19229 | 19181 | 34812 | 34398 |
| Mongolia | 26 | 2372 | #N/A | 2068 | #N/A | 2644 | #N/A |

*Table 6 IMF Fossil Fuels Corrective Tax Estimation by Emissions in 2010*

*Source: Data Base for Getting Energy Price Right (2010)*

IMF Fossil Fuels Corrective tax Estimation by Coal and Natural Gas in 2010

| € per GJ | Coal | Natural Gas in power generation | Natural Gas in domestic heating |
|---|---|---|---|
| | average across all sources | average across all sources | total |
| China | 11 | 2.4 | 1.9 |
| Japan | 4 | 1.7 | 1.9 |

| | | | |
|---|---|---|---|
| Korea, Rep. | 6 | 3.1 | 1.7 |
| Mongolia | 6 | #N/A | #N/A |

*Table 7 IMF Fossil Fuels Corrective tax Estimation by Coal and Natural Gas in 2010*

*Source: Data Base for Getting Energy Price Right (2010)*

IMF Fossil Fuels Corrective Tax Estimation by Gasoline and Diesel in 2010

| € per liter | Gasoline | Diesel |
|---|---|---|
| | total | total |
| China | 0.42 | 0.39 |
| Japan | 0.85 | 1.09 |
| Korea, Rep. | 0.74 | 0.91 |
| Mongolia | 0.36 | 0.41 |

*Table 8 IMF Fossil Fuels Corrective Tax Estimation by Gasoline and Diesel in 2010*

*Source: Data Base for Getting Energy Price Right (2010)*

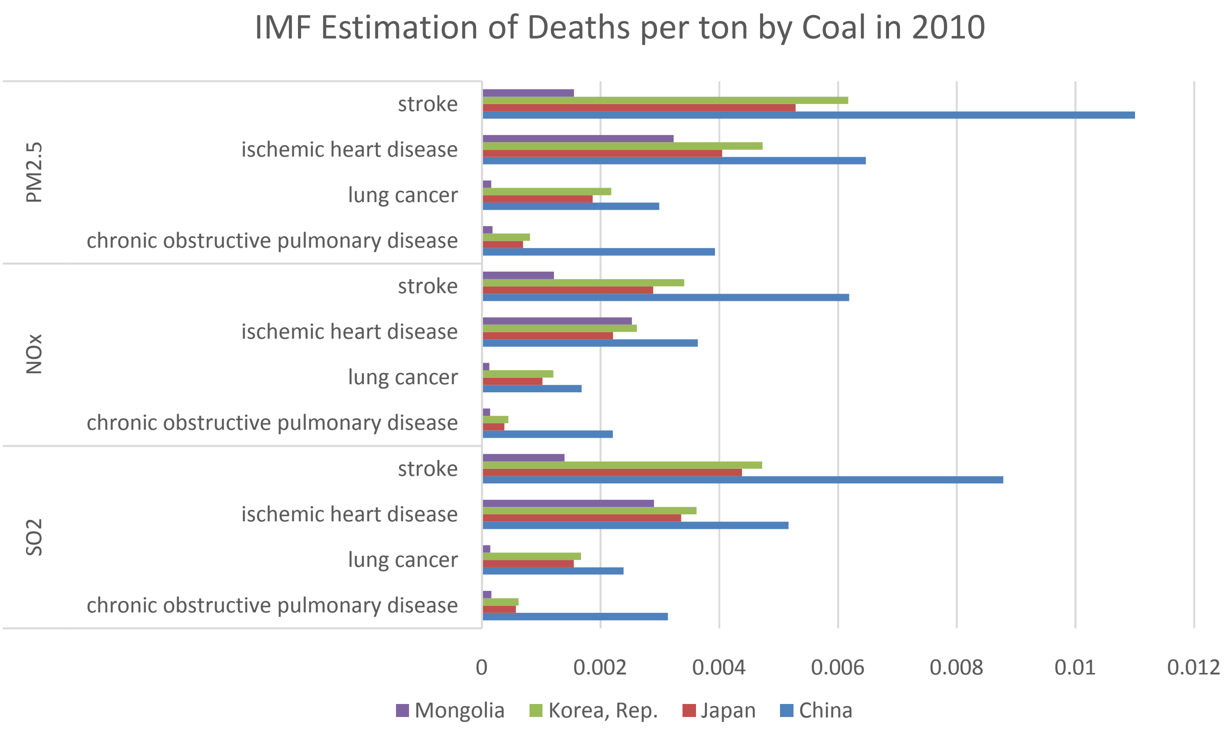


*Figure 50 IMF Estimation of Deaths per ton by Coal in 2010*

*Source: Data Base for Getting Energy Price Right (2010)*

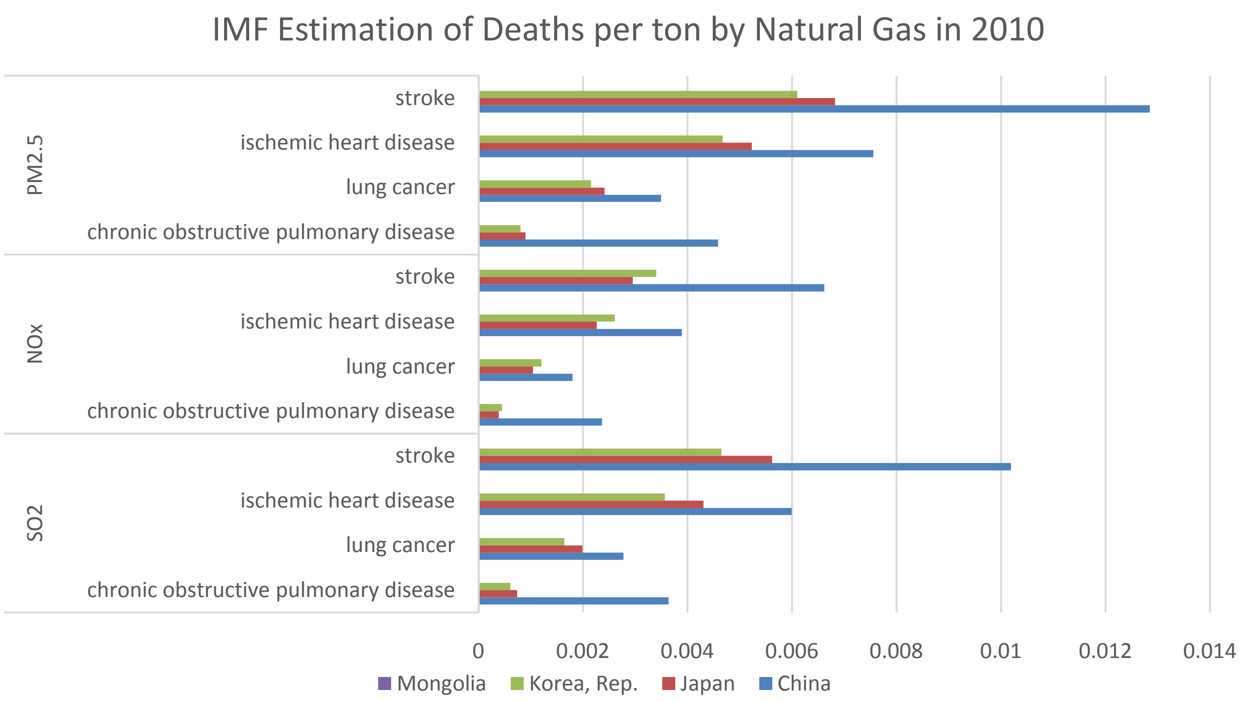


*Figure 51 IMF Estimation of Deaths per ton by Natural Gas in 2010*

*Source: Data Base for Getting Energy Price Right (2010)*

## OECD

The direct budgetary transfers and tax expenditures which benefit fossil-fuel production or consumption are employed by OECD to measure production and consumption subsidies [1]. Therefore, the main focus of OECD is to estimate all fossil-fuel subsidies which obviously comprise in the general government budget. The figure below shows the budgetary transfer on fossil fuel support, this could consider as direct cash payment.

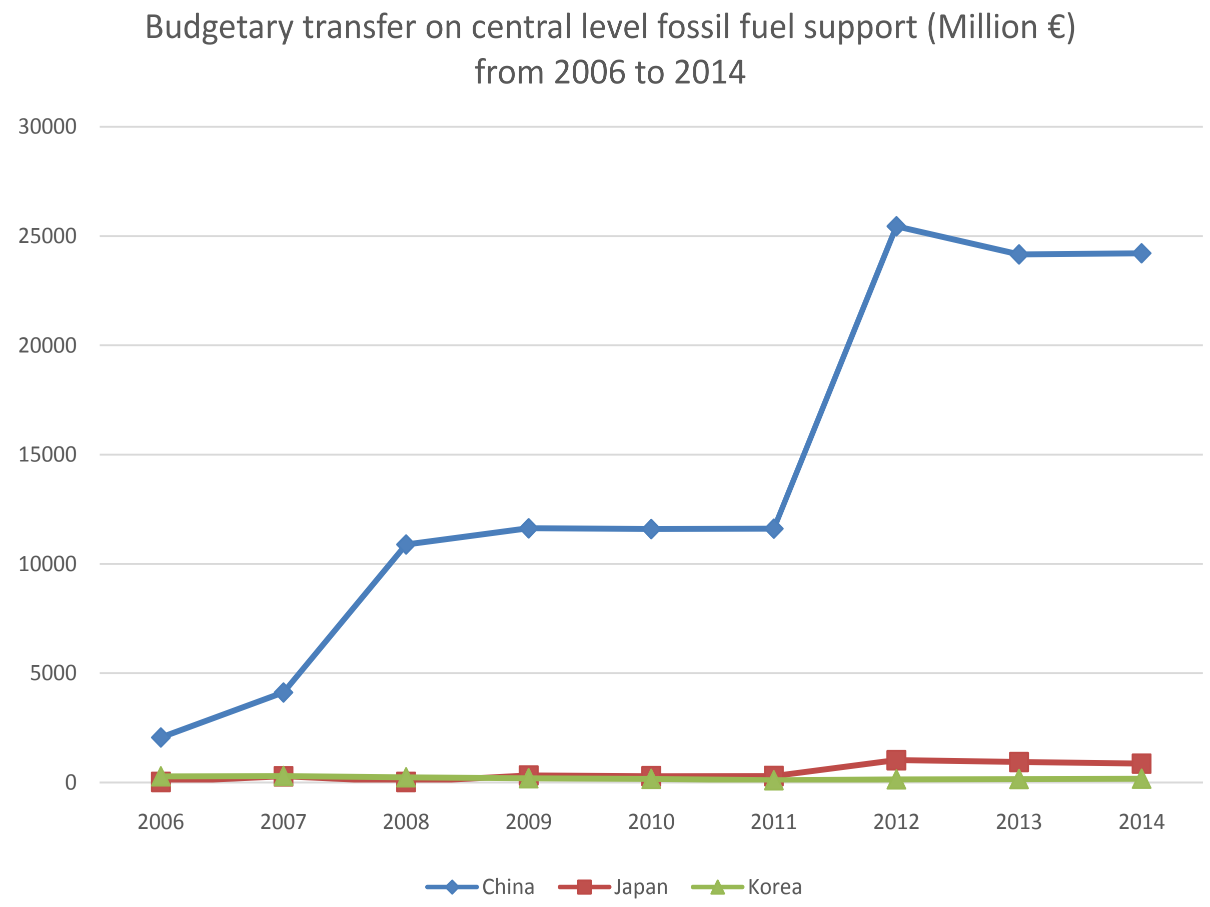


*Figure 52 Budgetary transfer on central level fossil fuel support (Million €) from 2006 to 2014*

*Source: OECD statistics database (2016)*

**GSI/IISD**

GSI/IISD research uses PSE-CSE models with Price-gap assessments to estimate fossil-fuel subsidies, but the shortcoming is only a few coal producers contain in PSE models by IEA [38].

# 5 Emissions Costs and Effects

As mentioned before in the beginning, the emissions costs account for critical proportion of energy subsidies. The main emissions costs are caused by $CO_2$, $SO_2$, NOx, and $PM_{2.5}$ emissions. With different emissions, it causes several types of consequences, for instance, global warming, acid rain, lung tissue damage and respiratory diseases, respectively. In terms of diseases category, the focus is on stroke, ischemic heart disease, chronic obstructive pulmonary disease, and lung cancer.

## 5.1 $CO_2$ Emissions

$CO_2$ emissions are the primary greenhouse gas emitted through human activities. In IEA's estimation of target countries, the main source of $CO_2$ emission is from fossil-fuels combustion, such as coal, oil, and natural gas. In 1971, the $CO_2$ emissions from fuel combustion were similar between China and Japan, but started from 1975, the values increased constantly, until 2002 it increased extremely fast and reached 9000 million tones level in China. In 2015, $CO_2$ emissions from fuel combustion emitted five times more than 1971 in Northeast Asia countries, and reached up to 10.83 billion tones in 2015. China accounts for over 80% of total emitted $CO_2$ emissions in 2015 [25].

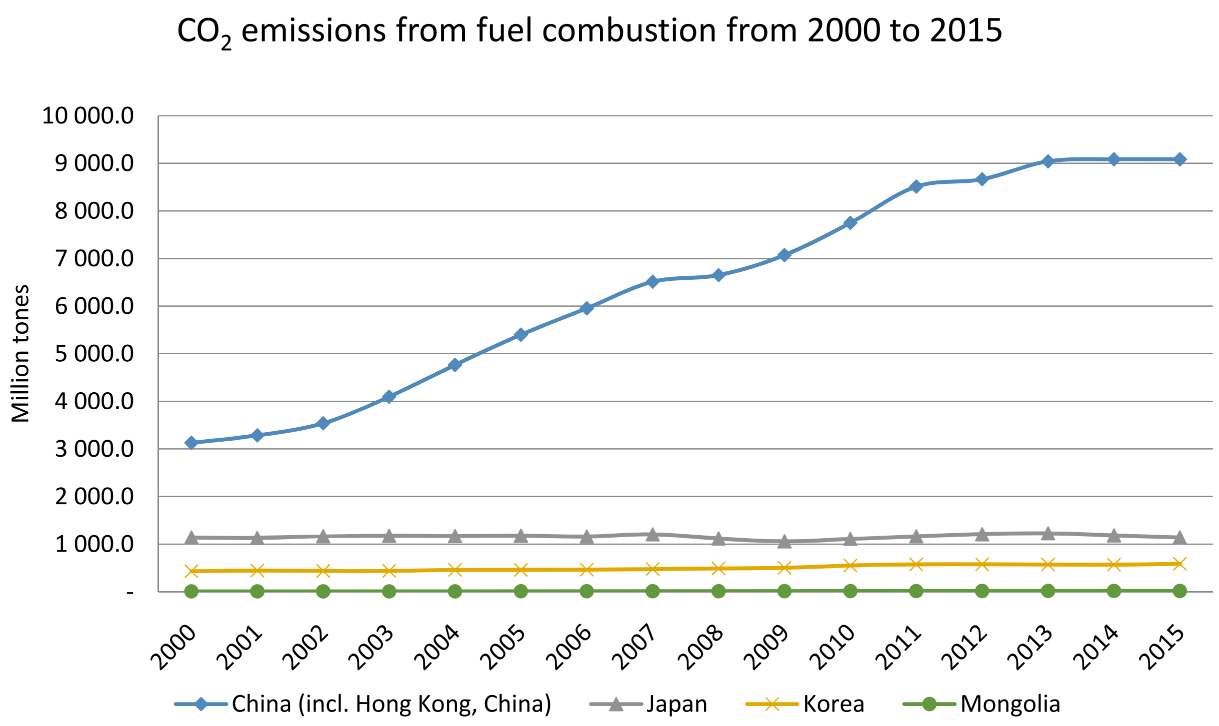


*Figure 53 $CO_2$ emissions from fuel combustion from 2000 to 2015*

*Source: IEA $CO_2$ Emissions from Fuel Combustion, Highlights, IEA, 2017.*

According to IPCC Climate Change 2014 synthesis report, GHG (Green House Gas) emissions reached 49 gigatonnes globally by human activities in 2010. It is almost doubled the amount of GHG emissions with 27 gigatonnes in 1970. $CO_2$ emissions from fossil-fuels combustion accounted for 65% of total annual emissions in 2010. The main sources of anthropogenic GHG emissions are from fossil-fuels combustion, deforestation, and agriculture [33].

With regard to $CO_2$ emissions per kWh of electricity, the following figure shows the emissions in World level, Europe level, OECD Asia Oceania level, and China (incl. Hong Kong, China) from 1990 to 2015 [25]. As the following figure shows, World level of $CO_2$ emissions per $kWh_{el}$ is quite stable and even declines a little bit towards 500 $gCO_2/kWh_{el}$ in 2015. Europe makes the transition gradually to almost 300 $gCO_2/kWh_{el}$ level at the same year. To be more specific, Australia, Israel, Japan, Korea, Rep., and New Zealand are included in OECD Asia Oceania. In contrast of Europe level, it even raises a few after steady state for 20 years. Another substantial reduction is made by China, it appears that the amount of $CO_2$ emissions per $kWh_{el}$ falls to 657 g from 909 g at the year of 2015 [25]. Moreover, China's coal consumption of power plants with capacity level 6000 kW or higher is 312 $g/kWh_{el}$ in 2010. In 2014, the number reduced 12 $g/kWh_{el}$ to 300 $g/kWh_{el}$ [8].

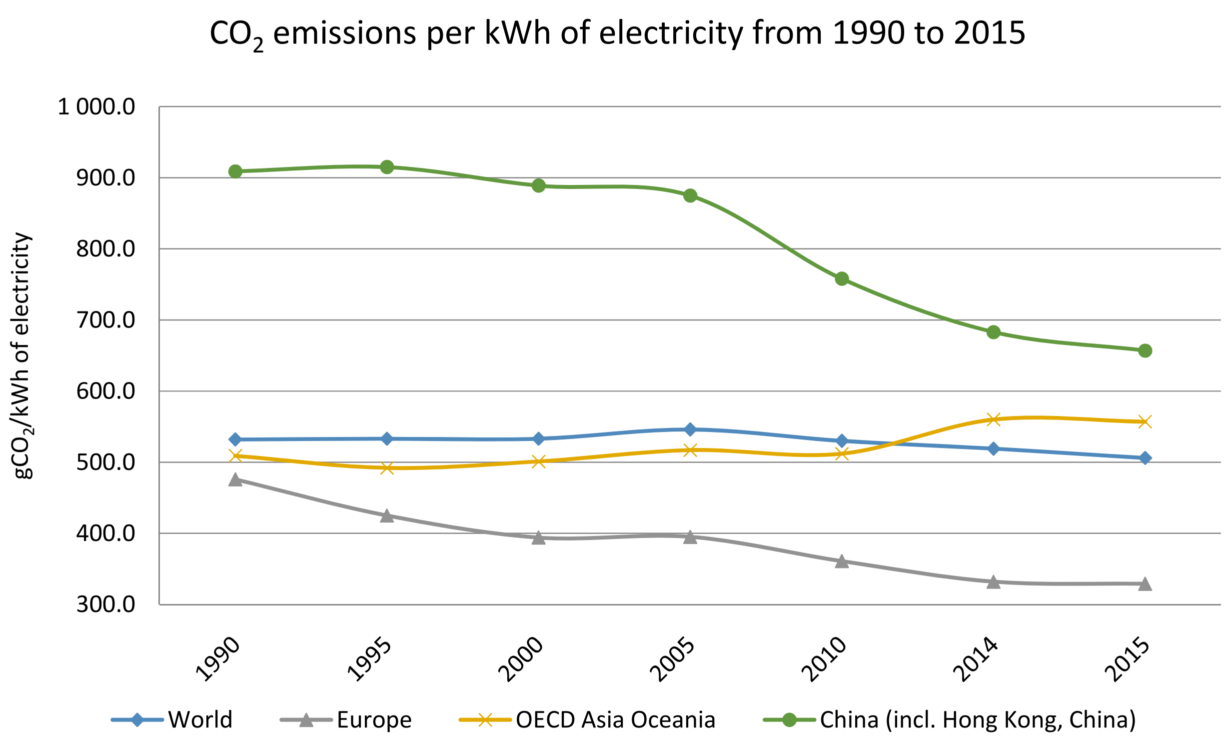


*Figure 54 $CO_2$ emissions per kWh of electricity from 1990 to 2015*

*Source: IEA $CO_2$ Emissions from Fuel Combustion, Highlights, IEA, 2017.*

The figure below depicts the $CO_2$ emissions per kWh of electricity per TPES (Total Primary Energy Supply) in target countries from 2000 to 2015. The leading country is Mongolia with over 310 $gCO_2/kWh_{el}$ in average. China is raising up to the peak with 267.5 $gCO_2/kWh_{el}$ in 2010 and drops to 261.5 $gCO_2/kWh_{el}$ in 2015. The situation of Japan seems stable till 2010, but jumps to 228.4

$gCO_2/kWh_{el}$ in 2015. The case in Korea, Rep. starts with a high value, but ends up with stabilized level around 190 $gCO_2/kWh_{el}$ [25].

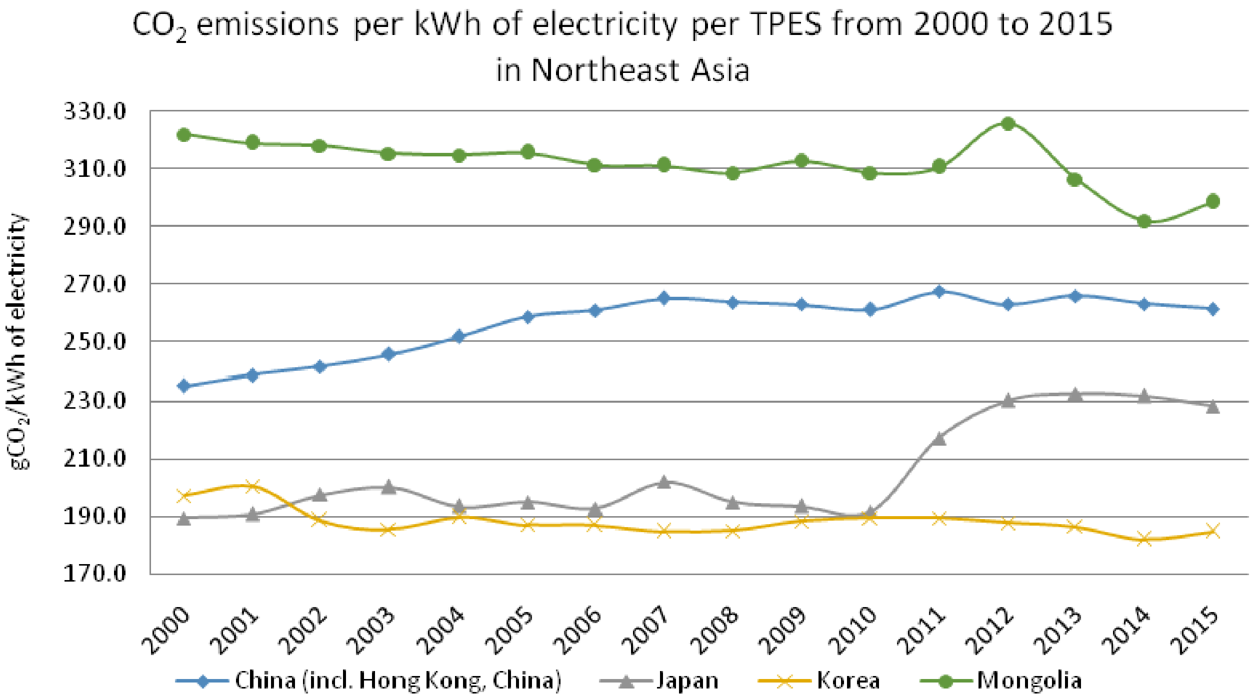


*Figure 55 $CO_2$ emissions per kWh of electricity per TPES from 2000 to 2015 in Northeast Asia*

*Source: IEA $CO_2$ Emissions from Fuel Combustion, Highlights, IEA, 2017.*

The following series figures show the $CO_2$ emissions from coal, oil and natural gas combustion. As the Figure 12 explains, the $CO_2$ emissions of coal reached the peak with 7545 million tonnes in 2013 and decreased 1.8 % at the end of 2015. For the other three countries, the numbers look steady and arise slightly at the end of 2015. Figure 13 denotes the emissions by oil combustion in four Northeast Asia countries. The trend of China is growing up to 1295 million tonnes at the end of 2015. While Japan and Korea, Rep. have the falling trend down to 425 and 162 million tonnes, respectively. Meanwhile, Mongolia ends up to 3.5 million tonnes at the same year. Due to the fact that Mongolia only utilized coal and oil as the electricity generation fuel sources, hence, is no data for Mongolia in Figure 14. Japan and Korea, Rep. have similar trend of the whole time, whereas China has seven times of the amount than 2000, while Korea, Rep. has the similar level [33].

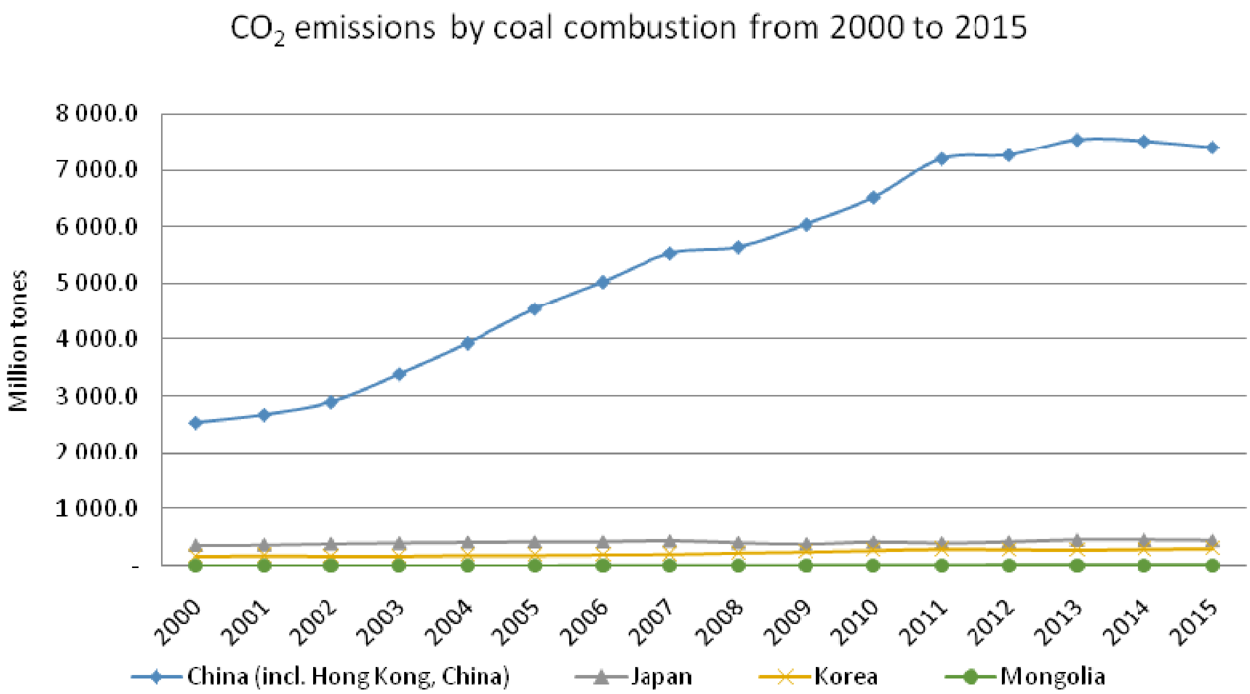


*Figure 56 CO2 emissions by coal combustion from 2000 to 2015*

*Source: $CO_2$ Emissions from Fuel Combustion Highlights (2017), IEA.*

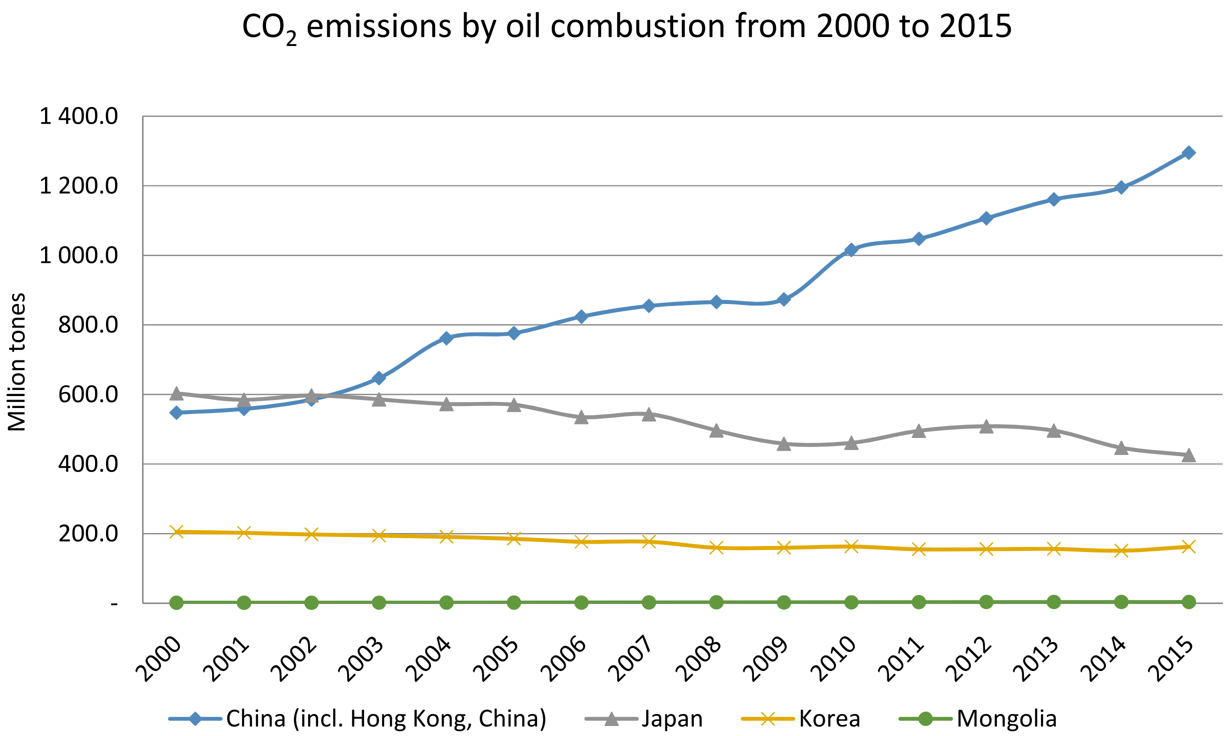


*Figure 57 $CO_2$ emissions by oil combustion from 2000 to 2015*

*Source: $CO_2$ Emissions from Fuel Combustion Highlights (2017), IEA.*

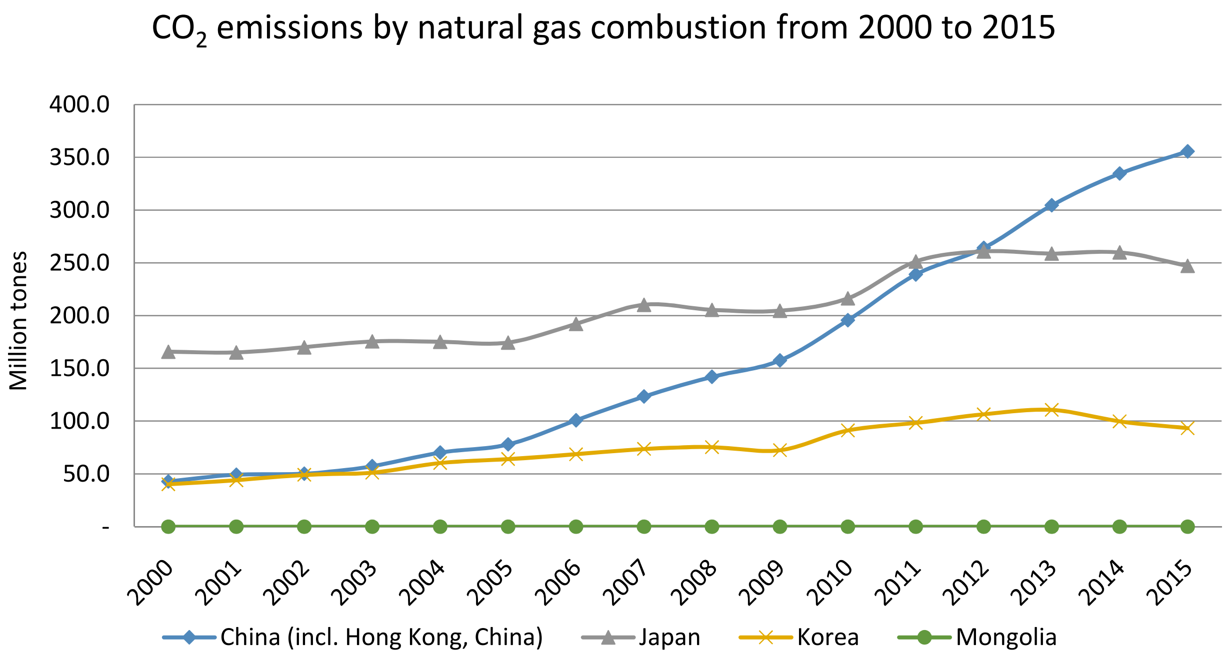


*Figure 58 $CO_2$ emissions by natural gas combustion from 2000 to 2015*

*Source: $CO_2$ Emissions from Fuel Combustion Highlights (2017), IEA.*

Under the regulation of European Union Emission Trading System (EU ETS), the carbon market was established in 2005. EU ETS was divided into three phases: First, a preliminary pilot period to attempt to fulfill the Kyoto Protocol emission targets they set up from 2005 to 2007; Second, this is a four-year period for all members who accepted the agreement in the first phase to meet the setting targets; Third, based on the operation experiences from the first and second phase, the following seven-year project is initiated. In order to function the project, certain changes have been made (details in reference) [18].

From Figure 15, the peak carbon spot price was € 30.79 which appeared in 2008 at the beginning of second phase, and the bottom price was € 3.07 in 2013 at the beginning of third phase. The trend of carbon price is dropping nevertheless. Based on the annually average carbon spot price in Figure 16, the cost of $CO_2$ emission can be calculated.

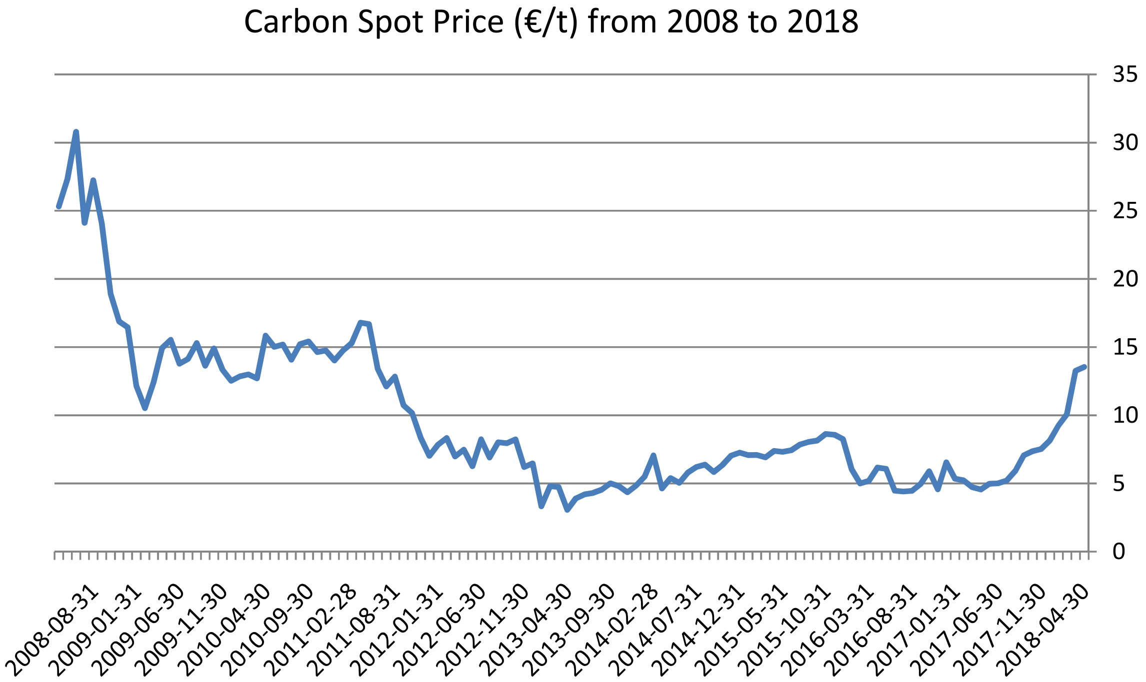


*Figure 59 Carbon Spot Price (€/t) from 2008 to 2018*

*Source: Quandl (2018), "ECX EUA Futures, Continuous Contract #1 (C1) (Front Month)", Quandl online database, available at:https://www.quandl.com/data/CHRIS/ICE_C1-ECX-EUA-Futures-Continuous-Contract-1-C1-Front-Month?utm_medium=graph&utm_source=quandl(Accessed on 19.05.2018)*

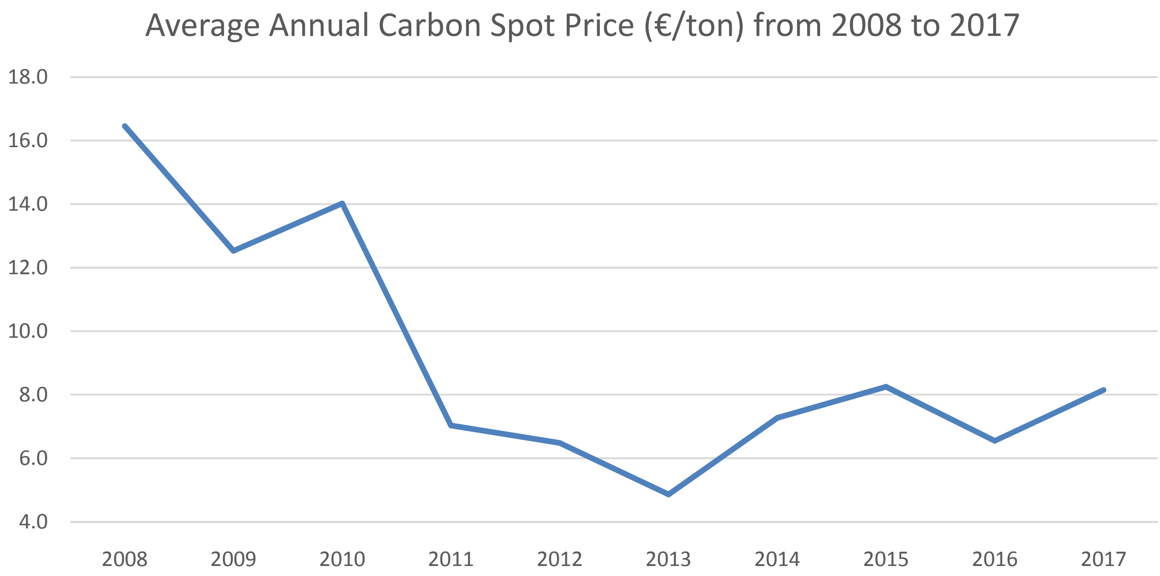


*Figure 60 Average Annual Carbon Spot Price (€/t) from 2008 to 2017*

*Source: Quandl (2017), "ECX EUA Futures, Continuous Contract #1 (C1) (Front Month)", Quandl online database, available at:https://www.quandl.com/data/CHRIS/ICE_C1-ECX-EUA-Futures-Continuous-Contract-1-C1-Front-Month?utm_medium=graph&utm_source=quandl(Accessed on 19.05.2018).*

With regard to Northeast Asia region, the cost of $CO_2$ emissions from fuel combustion can be estimated based on the average carbon spot price. From the following figure, due to the dropping of carbon spot price, the amount of total cost should be dropped, but in 2010 and 2011, the total costs were increasing because of the rising amount of the emissions. China has to make more effort to reduce the heavy emissions in the future.

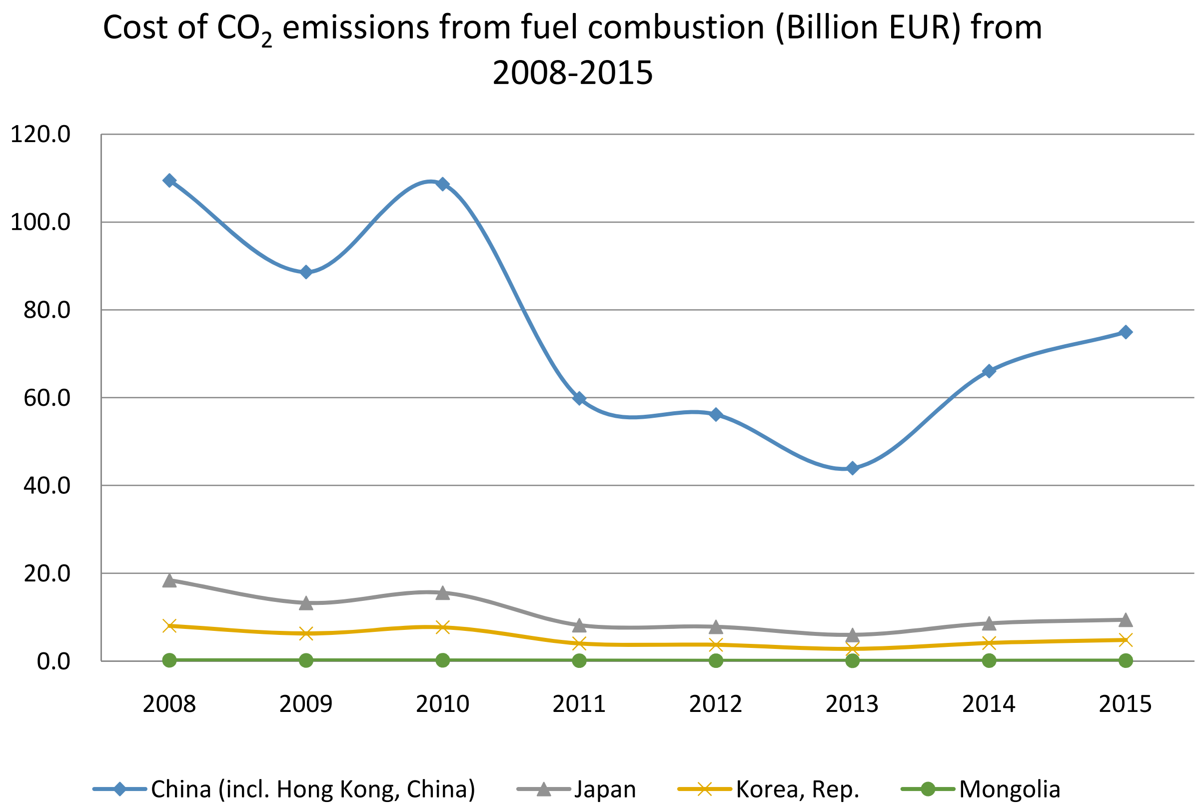


*Figure 61 Cost of $CO_2$ emissions from fuel combustion (Billion EUR) from 2008 to 2015*

*Source: Author's calculation, based on IEA $CO_2$ Emissions from Fuel Combustion data (2017) and Average Annual Carbon Spot Price*

According the figures showing below, the cost of $CO_2$ emissions from fuel combustion by coal, oil and natural gas is categorized individually. Compare with those three cases, the main source for China is considered to be coal, the quantity of the cost is huge enough. Thinking about the oil, these four countries are pure net import countries, therefore, the scale of using oil is really smaller than coal. Another reason to consume considerable coal might be because of the cheap coal market price. On natural gas sector, Japan's consumption is similar to China during these 6 years and Mongolia does not consider natural gas as fuel source.

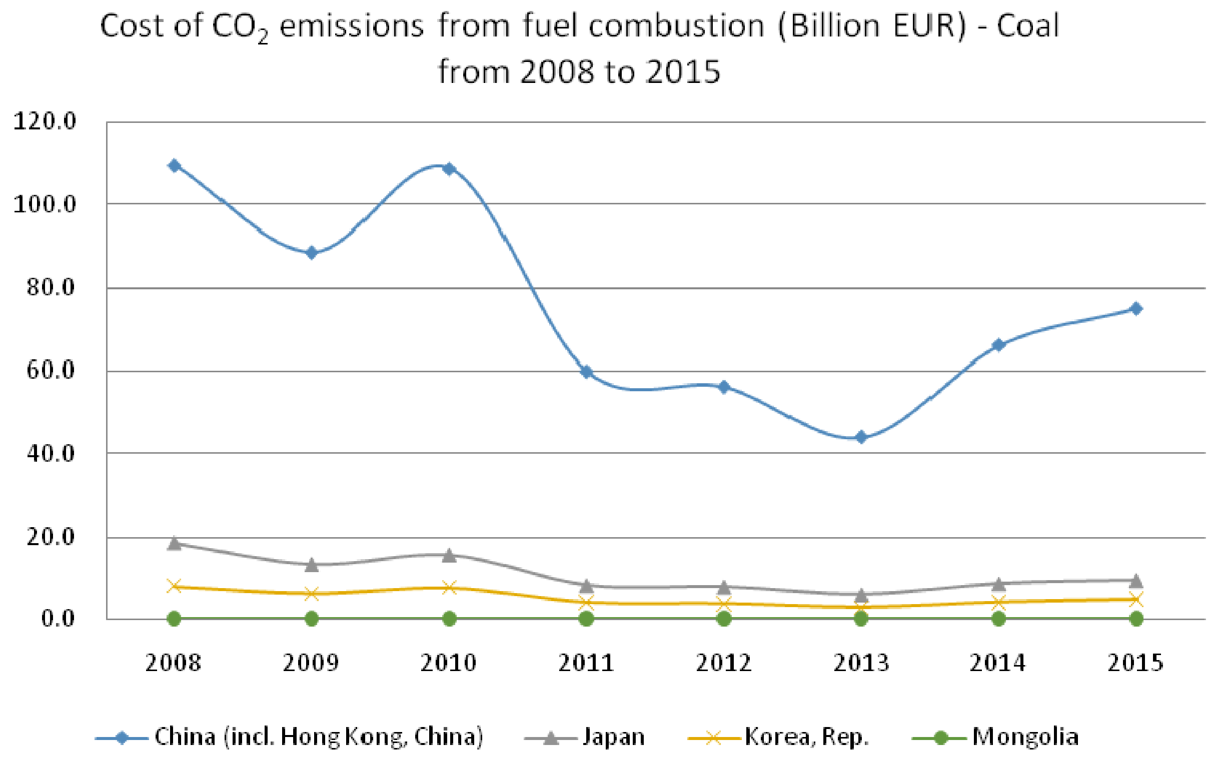


*Figure 62 Cost of $CO_2$ emissions from fuel combustion (Billion EUR) - Coal from 2008 to 2015*

*Source: Author's calculation, based on IEA $CO_2$ Emissions from Fuel Combustion data (2017) and Average Annual Carbon Spot Price*

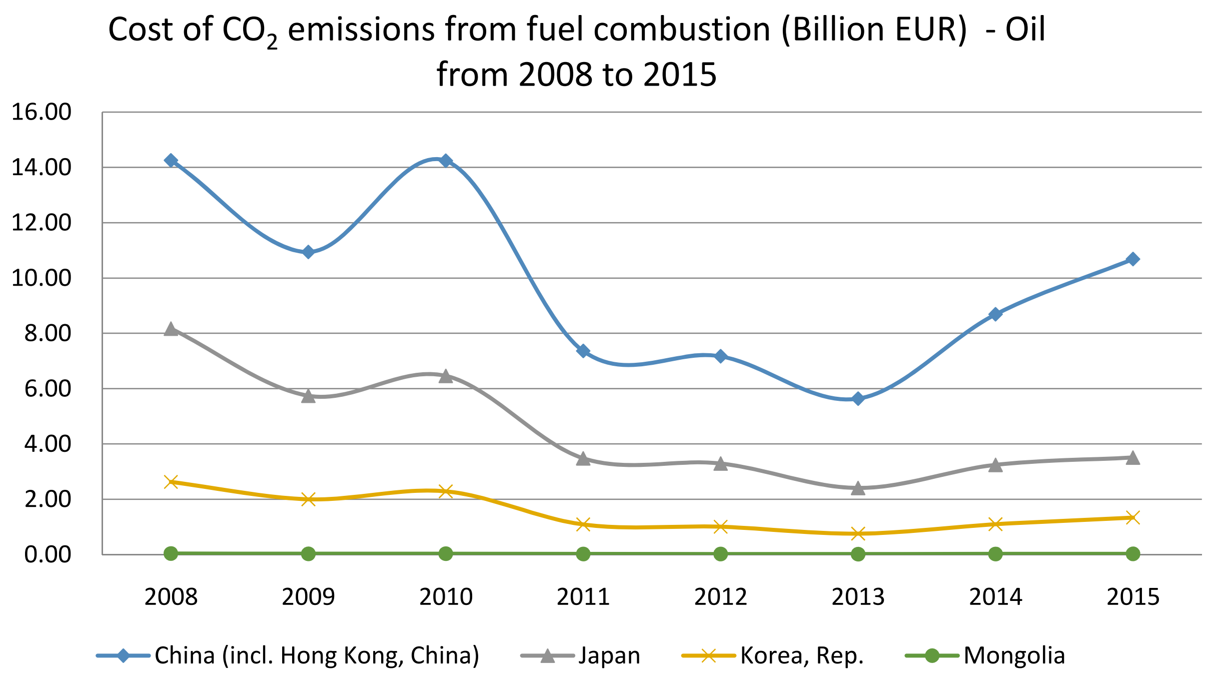


*Figure 63 Cost of CO2 emissions from fuel combustion (Billion EUR) - Oil from 2008 to 2015*

*Source: Author's calculation, based on IEA $CO_2$ Emissions from Fuel Combustion data (2017) and Average Annual Carbon Spot Price*

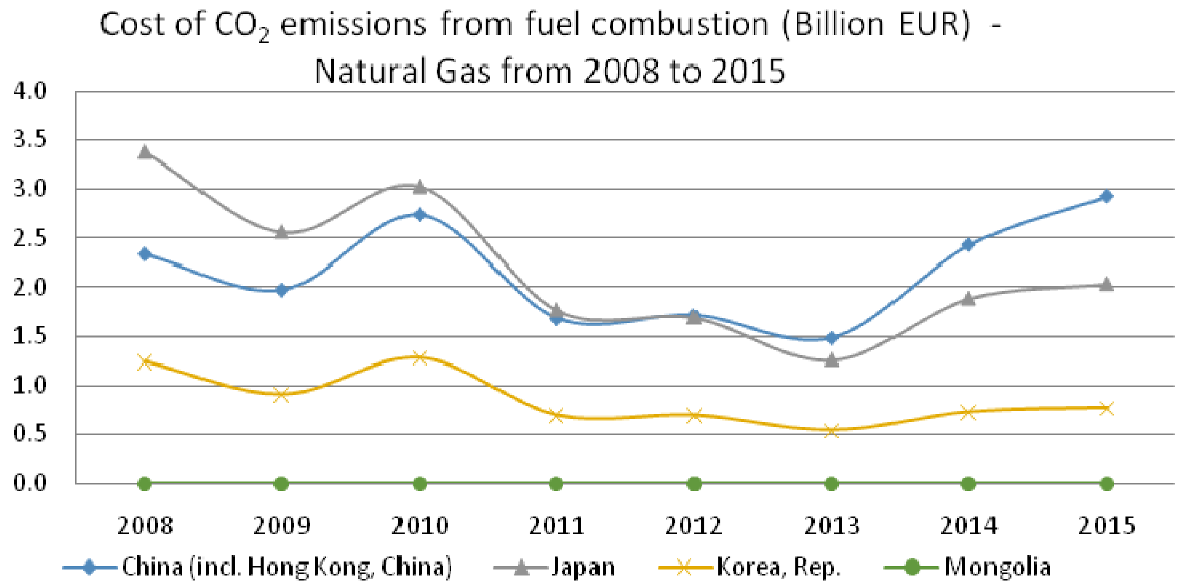


*Figure 64 Cost of CO2 emissions from fuel combustion (Billion EUR) - Natural Gas from 2008 to 2015*

*Source: Author's calculation, based on IEA $CO_2$ Emissions from Fuel Combustion data (2017) and Average Annual Carbon Spot Price*

## 5.2 $SO_2$ Emissions

$SO_2$ emissions from fossil fuels combustion might cause acid raining and smog and the formation of the fine particulate matter. That is the reason why people should be care about the $SO_2$ emissions environmental effects, such as, forest degradation, acidic soil and corrosion of buildings. The main Sulfur element from burning fossil fuels mostly comes from coal and oil. Due to the fact that coal and oil are the main source for China to generate electricity in power plant, as the figure below indicates that China's $SO_2$ emissions account for more than 80% in Northeast Asia in 2000 and maintain the increasing trend up to 92% in 2008. It is more than doubled of the emissions for China in 2008 compared with 2000 [14].

Each year, *the auction holds by* Environmental Protection Agency (EPA) for $SO_2$ emissions allowances *are allowed up to 125,000 tons under Phase II of Title IV of the Clean Air Act Amendments, multiple parties take part in this programme to* put *apart* in an Auction Allowance

Reserve [16].

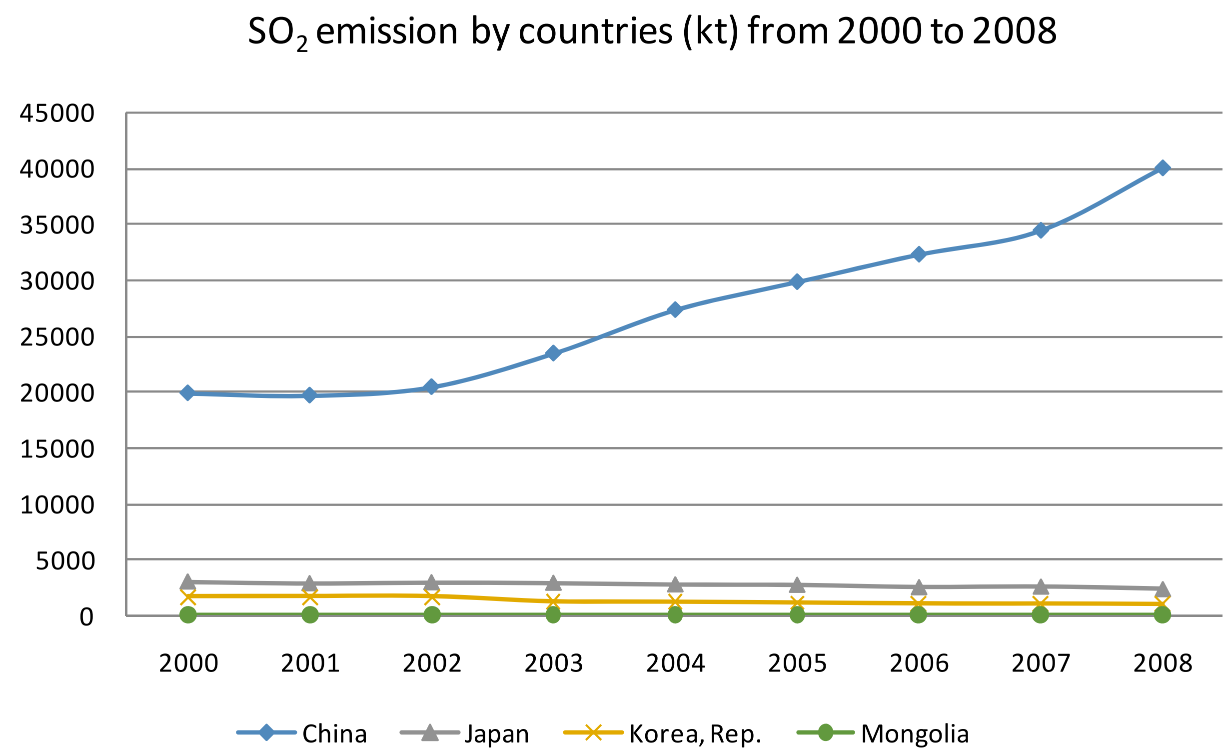


*Figure 65 $SO_2$ emission by countries (kt) from 2000 to 2008*

*Source: EDGAR Database (2012).*

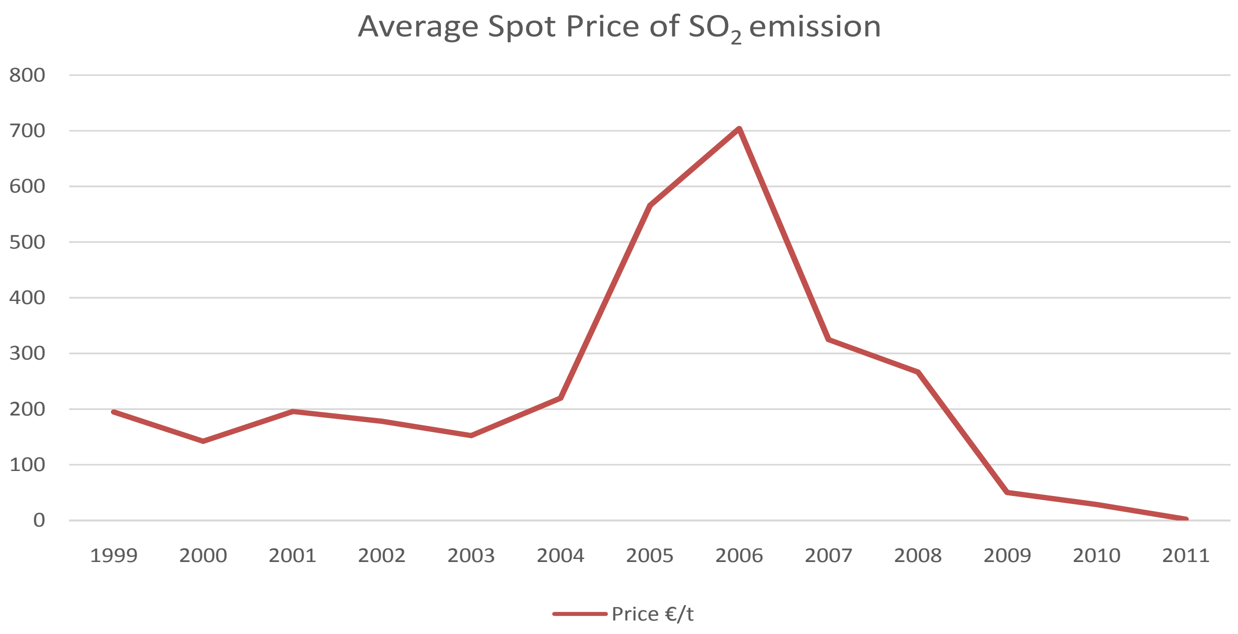


*Figure 66 Average Spot Price of $SO_2$ emission*

*Source: U.S. Energy Information Administration (EIA) (2011)*

According to the figure above, the $SO_2$ emissions price started to decline since 2006, it implies the demand of the market is shrinking for some reasons. In terms of the average $SO_2$ price data from EIA, the estimated cost of $SO_2$ emissions is illustrated below:

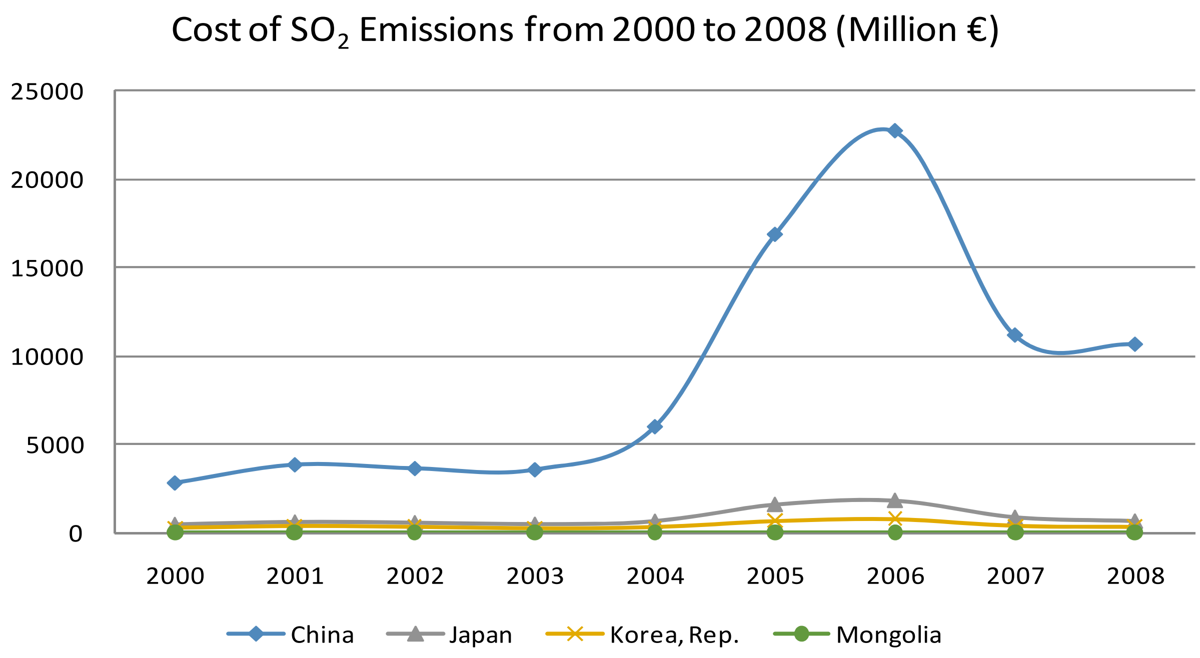


*Figure 67 Cost of $SO_2$ Emissions from 2000 to 2008 (Million €)*

*Source: Author's calculation, based on EDGAR database (2012) and EIA Sulfur Dioxide Average Spot Price (2011).*

The peak price appeared in 2006 with the price € 704/t, it is more than 7 times cost in 2000 around € 3.5 billion in total.

## 5.3 NOx Emissions

NOx emissions are another source to form acid rain, and small particles may cause premature death by penetrating into sensitive lung tissue. It may also lead to respiratory diseases somehow, for example, emphysema or bronchitis, or even worsen existing heart disease. In Mongolia, the emissions are around 50 kt in 2008 and it is similar to the beginning of 1970. Japan and Korea, Rep. has a downside than the beginning. For China, the situation is 6 times more in 2008 than 1970. Even there was a slight decline from 1999 to 2001, because of decreasing the use of fossil fuel to generate electricity by 2% [13].

In recent years, the prices of summer seasonal nitrogen oxides ($NO_X$) emissions allowances decline surprisingly from both the EPA's Clean Air Interstate Rule (CAIR) and the $NO_X$ Budget Trading Program (NBP). $NO_X$ prices fell from € 500/t in 2008 to € 10/t by 2011. Due to the D.C. Court of Appeals shut down CAIR, the price kept dropping to the end of 2011 [17].

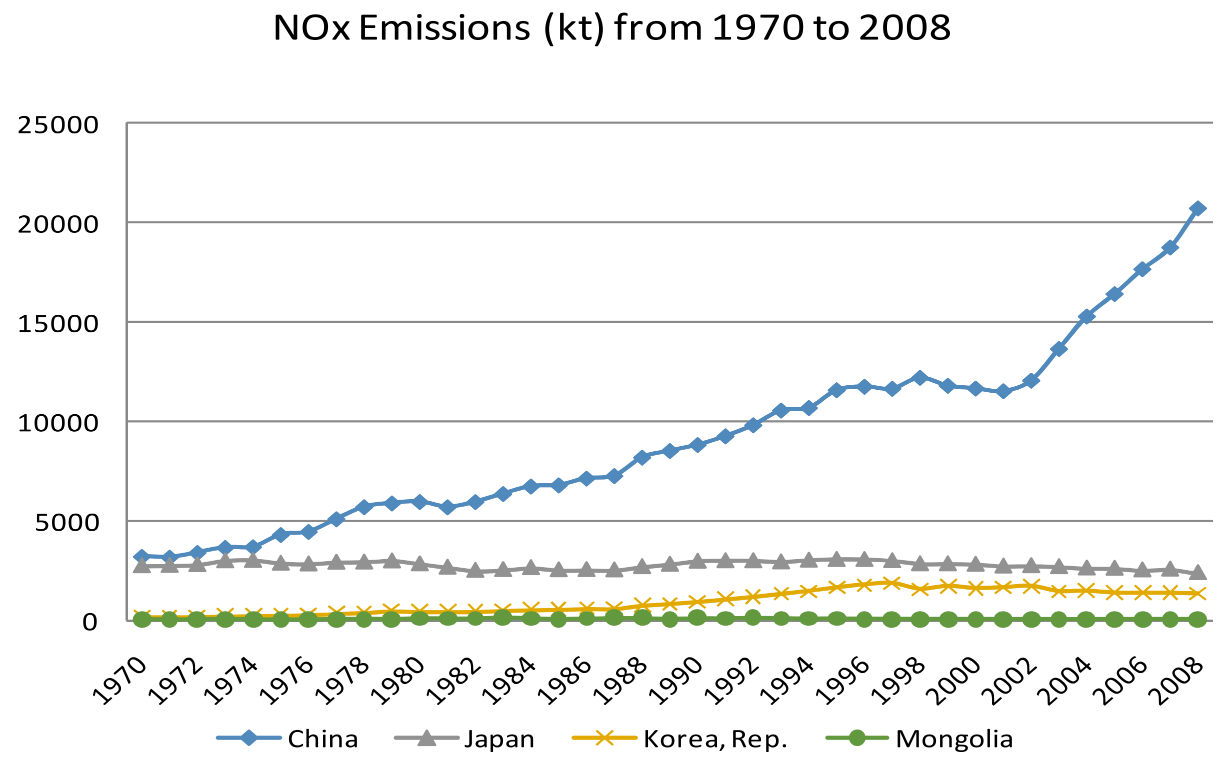


*Figure 68 NOx Emissions (kt) from 1970 to 2008*

*Source: EDGAR Database (2012).*

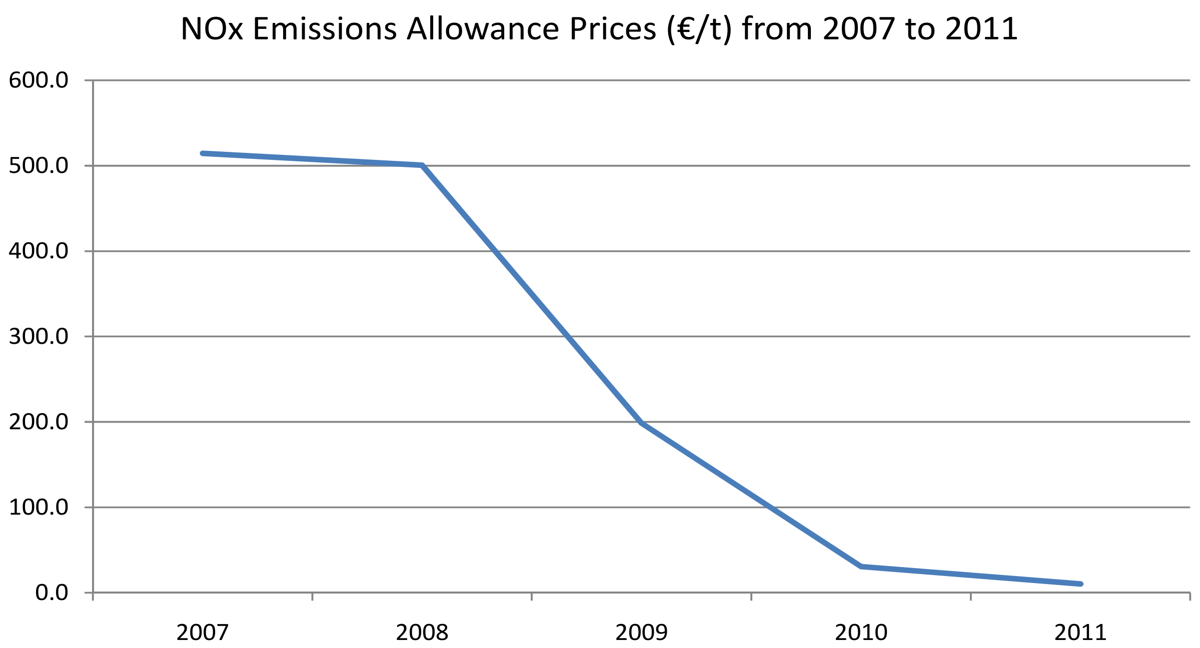


*Figure 25 NOx Emissions Allowance Prices (€/t) from 2007 to 2011*

*Source: U.S. Energy Information Administration (EIA) (2012)*

Based on the average allowance price of NOx emissions and annual NOx emissions from EDGAR database, the cost of emissions could be estimated in following figures:

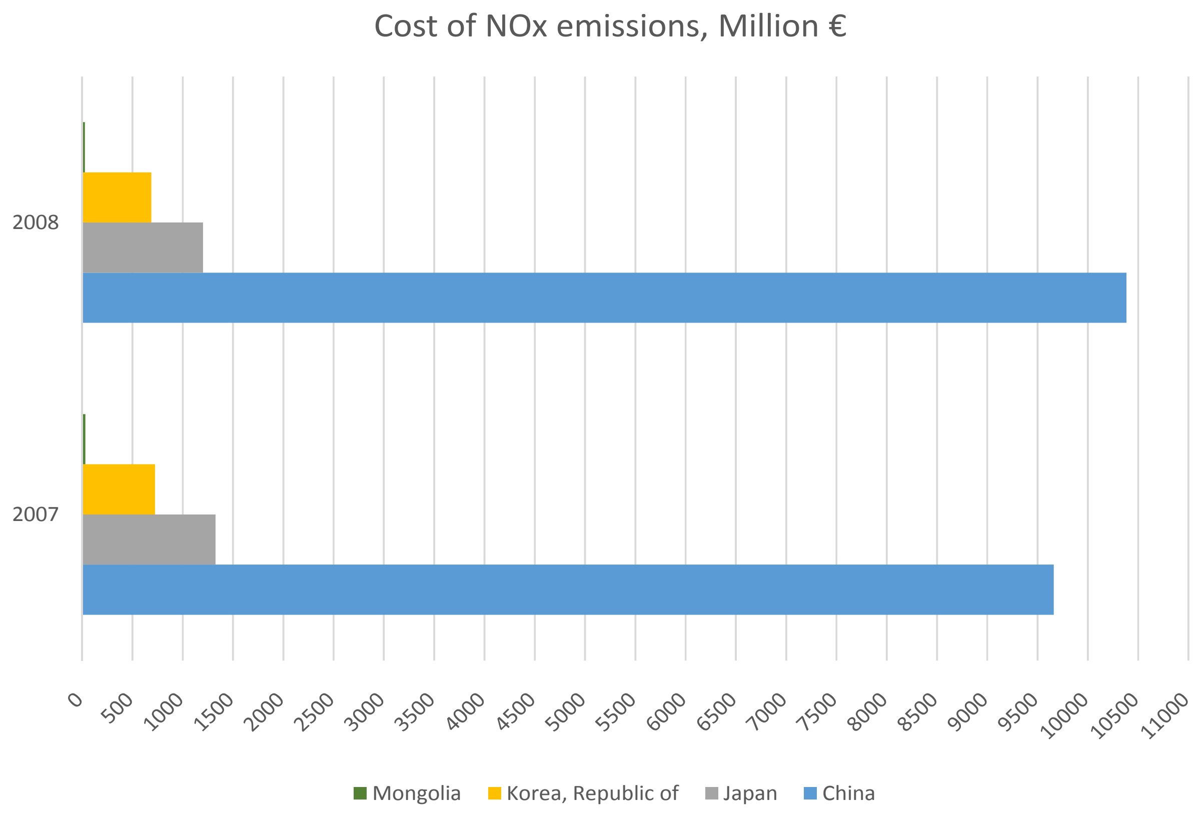


*Figure 69 Cost of NOx emissions, Million €*

*Source: Author's calculation, based on EDGAR database (2012) and EIA NOx Emissions Allowance Price (2012).*

Due to lack of emissions quantities data from 2009 to 2011, the figure only demonstrates the cost in 2007 and 2008. In figure above, even though the price is a little bit lower in 2008, the amount of emissions are still more than 2007, that is why the total cost is rising up even the price is lower. The pie charts below show that China is still account for more than 80% cost in Northeast Asia region in both study years.

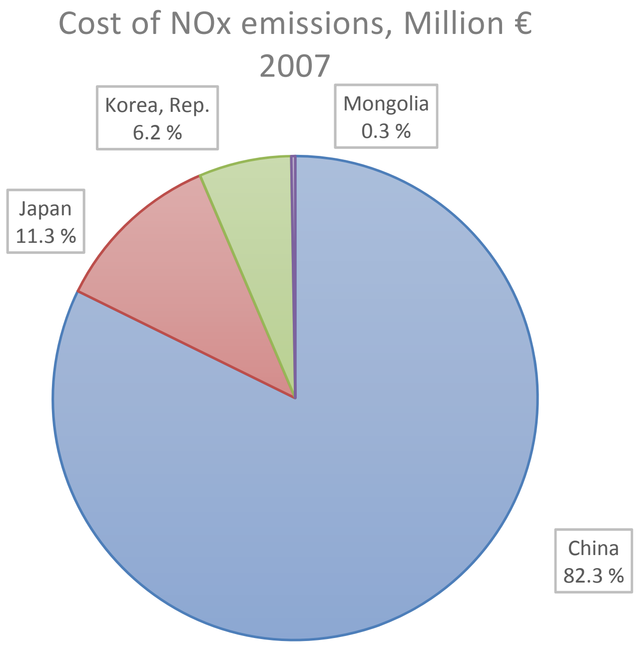


*Figure 70 Cost of NOx emissions, Million €,2007*

*Source: Author's calculation, based on EDGAR database (2012) and EIA NOx Emissions Allowance Price (2012).*

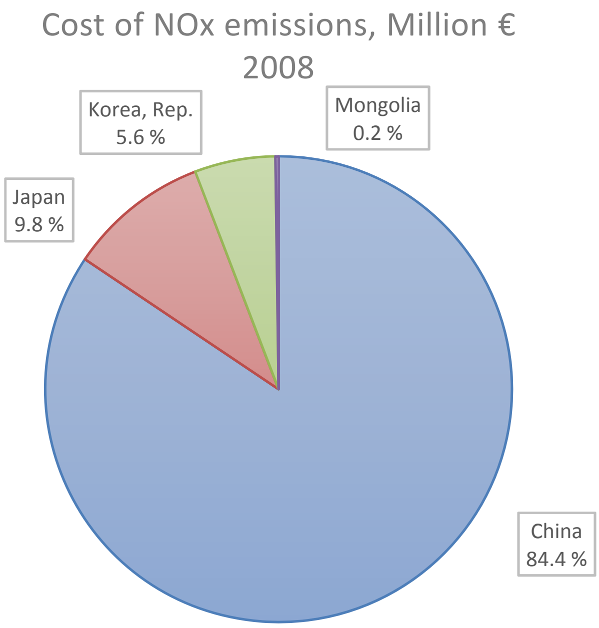


*Figure 71 Cost of NOx emissions, Million €,2008*

*Source: Author's calculation, based on EDGAR database (2012) and EIA NOx Emissions Allowance Price (2012).*

## 5.4 $PM_{2.5}$ Emissions

$PM_{2.5}$ emissions are also known as particulate matter (PM) with a diameter of 2.5 µm or less. For example, cilia and mucus can filter large particles in the nose and throat, but with the $PM_{10}$ can breathe through the bronchi, lungs, and lead to respiratory diseases, for instance, asthma, lung cancer, cardiovascular disease, and some extent of lifetime effects. The figure below shows that China was the only country which the $PM_{2.5}$ emissions were continuing increased in Northeast Asia from 1990 to 2015. The other three countries' concentrations were decreasing gradually [56].

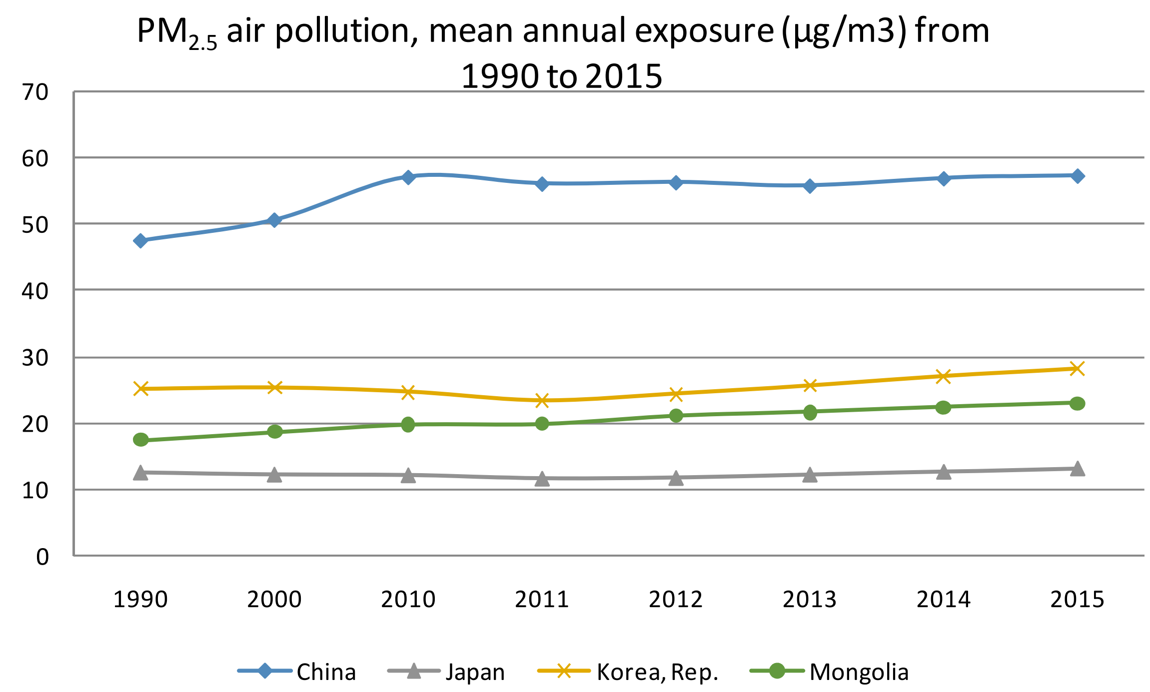


*Figure 72 $PM_{2.5}$ air pollution, mean annual exposure (µg/$m^3$) from 1990 to 2015*

*Source: World Bank (2016).*

Based on the IMF cost estimation of $PM_{2.5}$ emissions, the cost of emissions are shown in table below.

| Country | Mean annual exposure (µg/$m^3$) | Average price EUR/ton (mean value of coal and natural gas) | Cost of $PM_{2.5}$ emissions (EUR/$km^3$) |
|---|---|---|---|
| China | 57 | 22571.51 | 1286.58 |
| Japan | 12.1 | 38353.29 | 464.07 |
| Korea, Rep. | 24.7 | 34532.9 | 852.96 |

| | | | |
|---|---|---|---|
| Mongolia | 19.7 | 2638.39* | 51.98 |

*Note: due to the fuel sources in Mongolia are mainly coal and oil, the average price applies the coal price for Mongolia.

*Table 9 Cost of $PM_{2.5}$ emissions in 2010*

*Source: Author's calculation, based on the data from IMF report (2014).and World Bank (2016)*

## 5.5 Comparison of Emissions Costs in 2008

In 2008, the figures indicate that $CO_2$ emissions account for the largest portion of the cost in total. The second largest one is NOx emissions. $SO_2$ emissions comes the third. In terms of the calculation, China needs to consume at least € 170 billion which is more than 4 times in total of the other three countries in 2008. The results in following figures are based on the former calculations about $CO_2$ emission, $SO_2$ emission, and NOx emission.

Comparison of Emissions Costs (Million €) in 2008

| Country | $CO_2$ | $SO_2$ | NOx |
|---|---|---|---|
| China | 149679 | 10634 | 10383 |
| Japan | 26674 | 619 | 1201 |
| Korea, Rep. | 11463 | 280 | 688 |
| Mongolia | 302 | 22 | 26 |

*Table 10 Comparison of Emissions Costs (Million €) in 2008*

*Source: Author's calculation.*

# 6 Electricity Generation and Power Generation Capacity from Fossil Fuels

In China, the dramatically increasing of total electricity generation from fossil fuels are along with the constant significantly installing fossil fuels power generation capacities from 1990 to 2014. The total generation and installed capacity reached to 5145 TWh and 823.9 GW in China, respectively. The trend of total generation in Japan and Mongolia are quite stable since 1990. However, the electricity demand in Korea, Rep. increased 5 times in 2014 than 1990 [55].

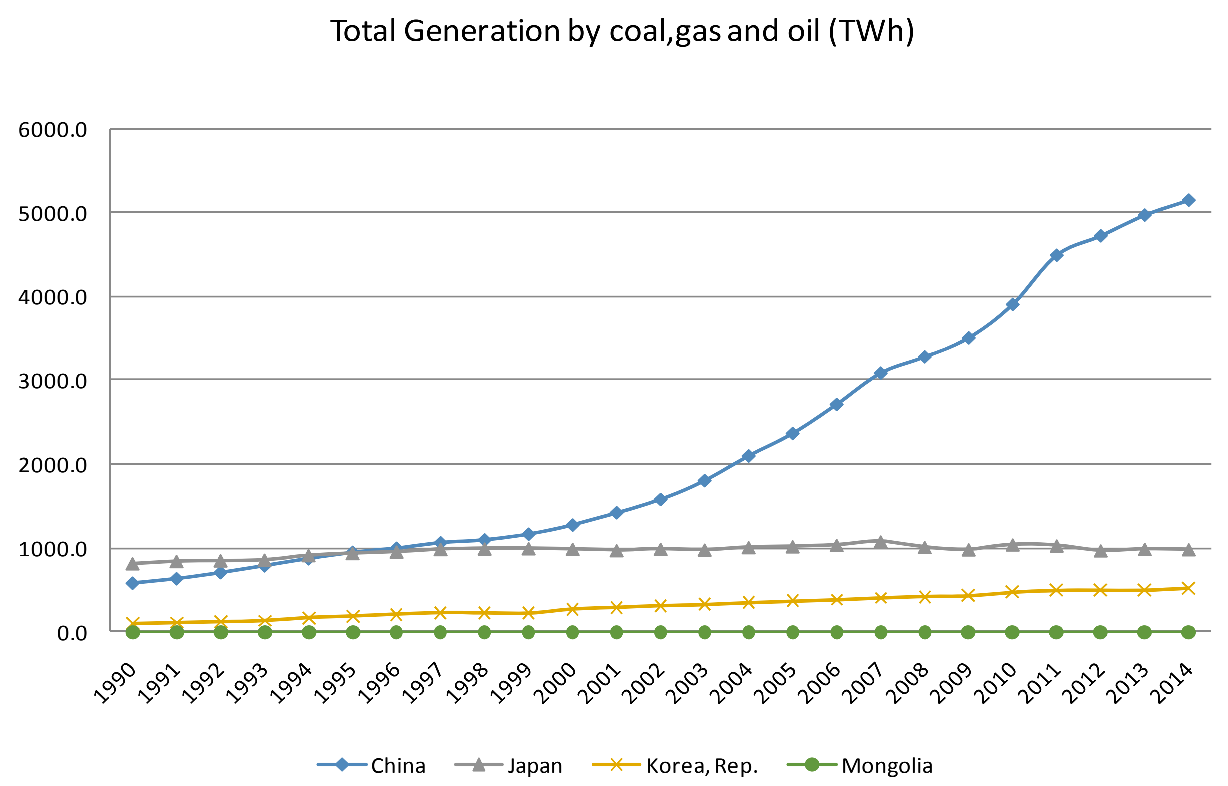


*Figure 73 Total Generation by coal, gas and oil sources (TWh)*

*Source: Sarah Toupet , The Shift Project Data Portal (Original data from World Bank) (2016).*

In Japan, the total incremental capacities during 25 years are 67 GW along with the 170 TWh electricity generation. In Korea, Rep., the situation is that with around 56 GW incremental installed capacities generate 418 TWh of electricity. It is more than doubled the electricity generation in Japan with less installed capacities.

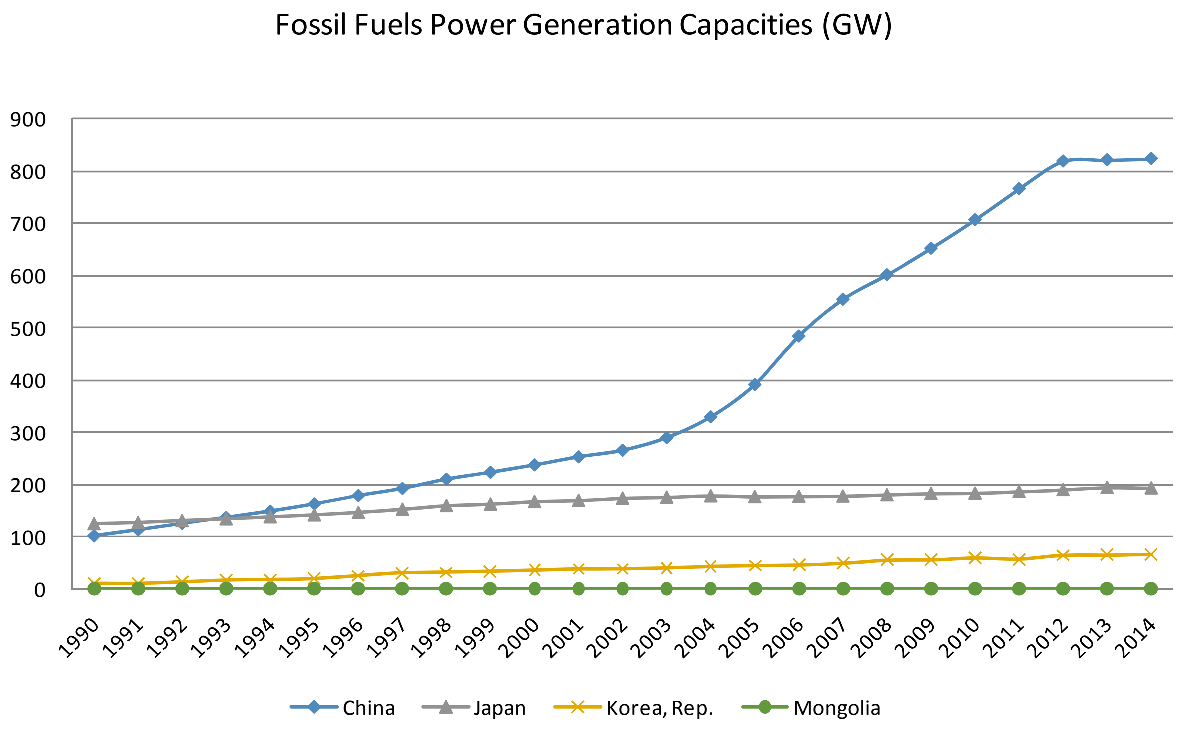


*Figure 74 Fossil Fuels Power Generation Capacities (GW)*

*Source: Sarah Toupet, The Shift Project Data Portal (Original data from US EIA Historical Statistics) (2016).*

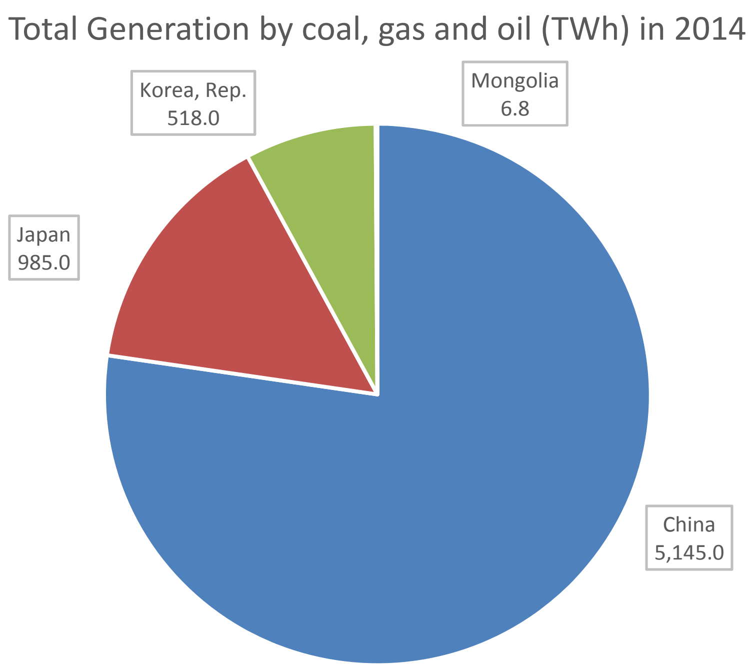


*Figure 75 Total Generation by coal, gas and oil (TWh) in 2014*

*Source: Sarah Toupet, The Shift Project Data Portal (Original data from World Bank) (2016).*

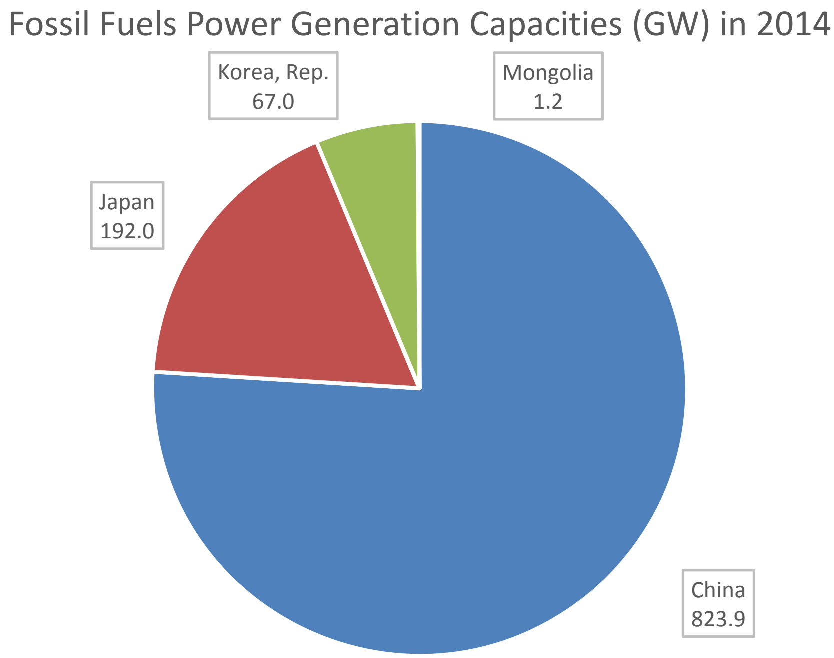


*Figure 76 Fossil Fuels Power Generation Capacities (GW) in 2014*

*Source: Sarah Toupet, The Shift Project Data Portal (Original data from US EIA Historical Statistics) (2016).*

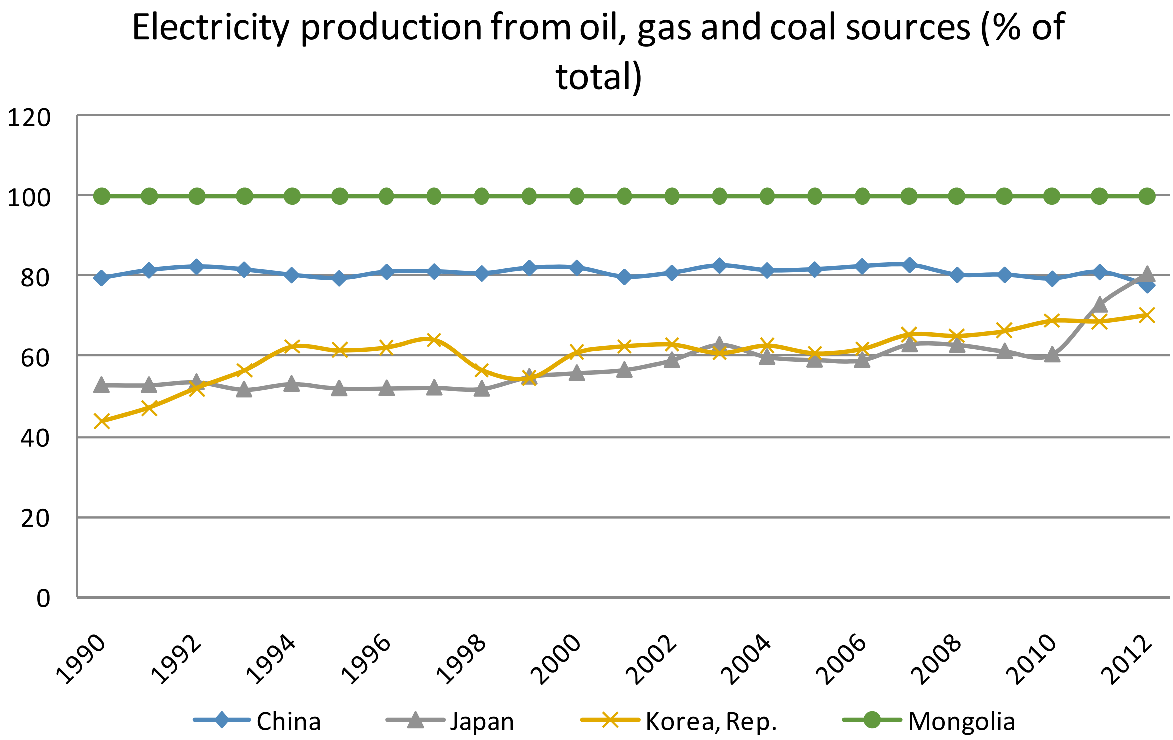


*Figure 77 Electricity production from coal, gas and oil sources (% of total)*

*Source: World Bank (2016), World Bank Database.*

According to the figure above, the percentage of fossil fuels to generate electricity in China, Japan, Korea, Rep. and Mongolia is around 80%, 60%, 60% and 100% in average from 1990 to 2012, individually. Based on this figure, it is easily to find out that China and Mongolia has really stable trend for using fossil fuels, for China, it is even started to decline, for Mongolia, due to the fact that electricity production was generated by coal and oil, therefore, the percentage value was 100% in this case, but the case for Japan and Korea, Rep. has the uptrend on fossil fuels utilization to produce electricity. For Japan, it is increased 20% electricity production from fossil fuels from 2010 to 2012.

# 7 Health Costs and Effects

## 7.1 Mortality by Causes

Due to the fact that electricity production from fossil fuels account for around 80% constantly in China since 1990, hence, the emissions from burning fossil fuels cause certain health effects on human beings, for instance, $PM_{2.5}$ and $PM_{10}$ emissions can cause heart disease, lung cancer and respiratory disease; $SO_2$ and NOx emissions can cause respiratory tract and lung tissue damage, further more respiratory failure.

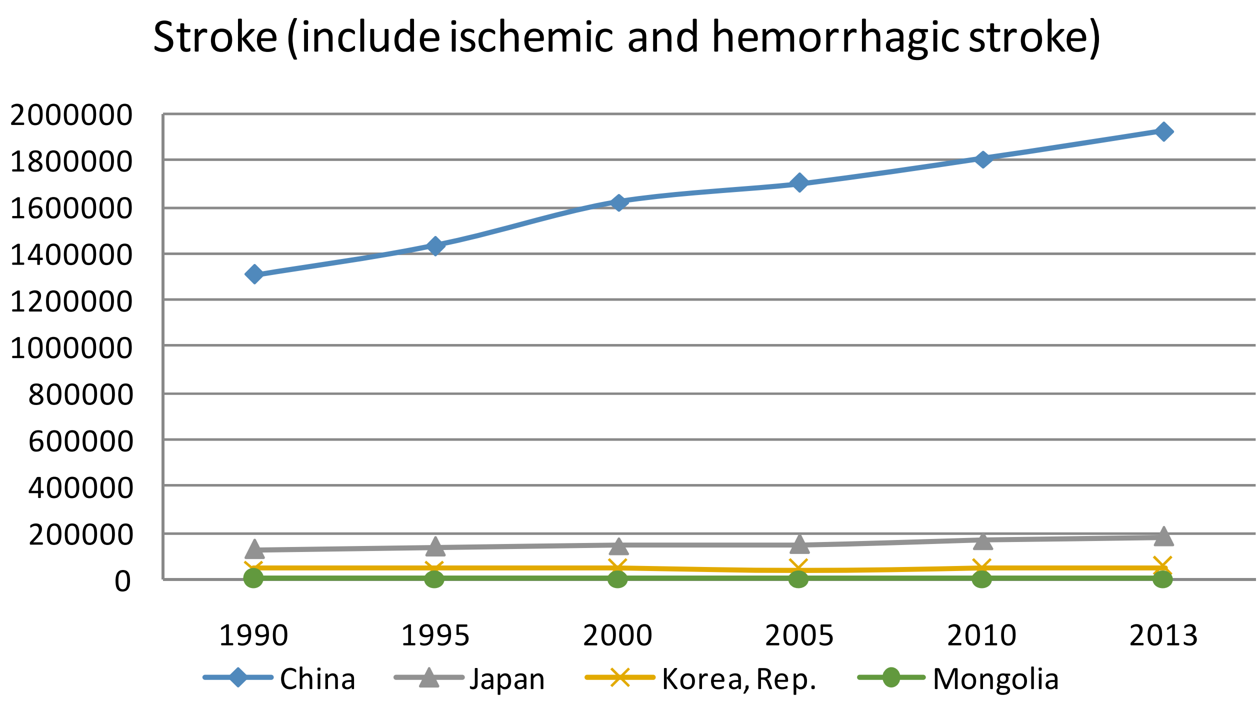


*Figure 78 Stroke (include ischemic and hemorrhagic stroke)*

*Source: Global Burden of Disease Program (2016)*

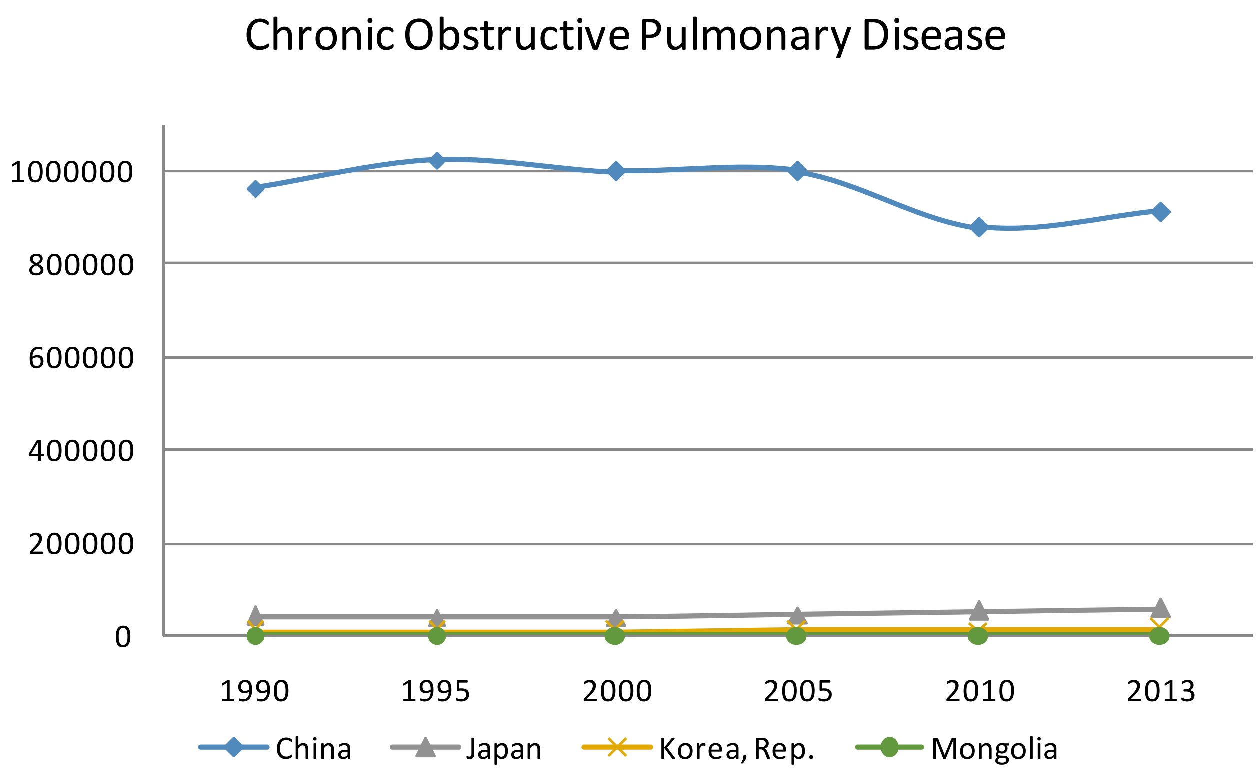


*Figure 79 Chronic Obstructive Pulmonary Disease*

*Source: Global Burden of Disease Program (2016)*

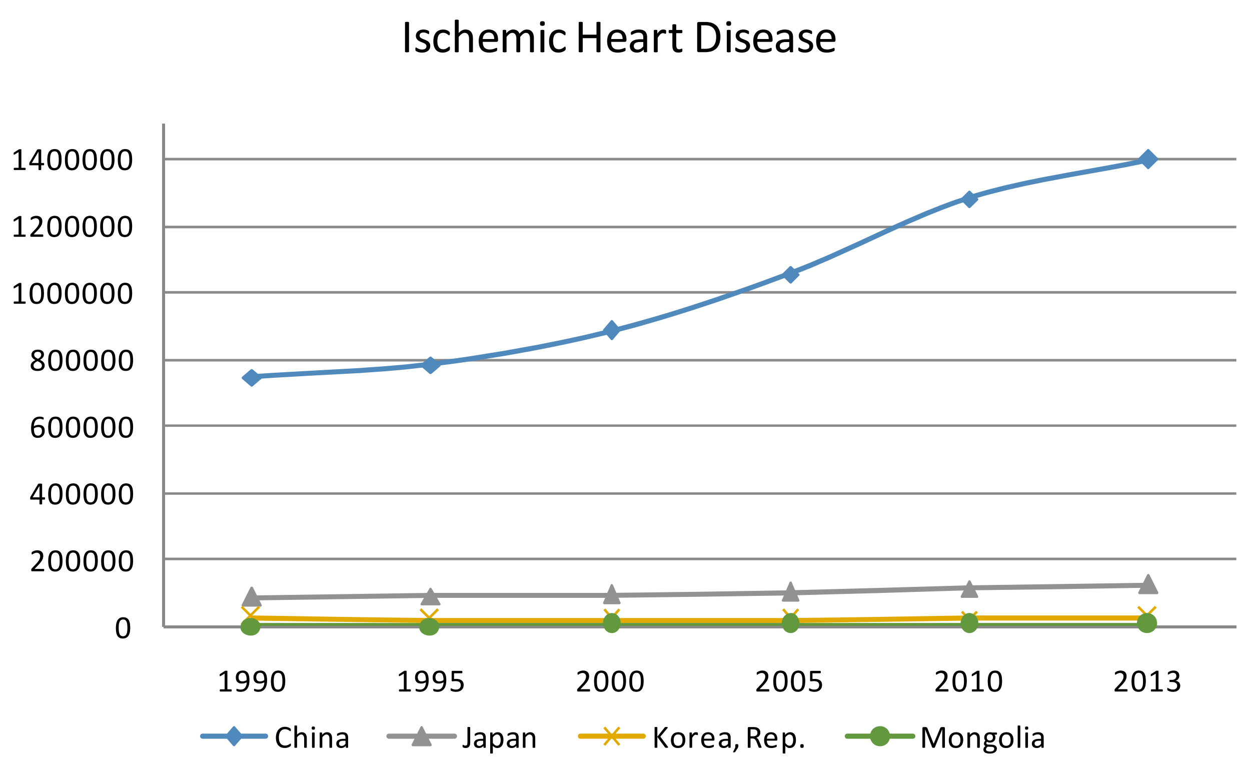


*Figure 80 Ischemic Heart Disease*

*Source: Global Burden of Disease Program (2016)*

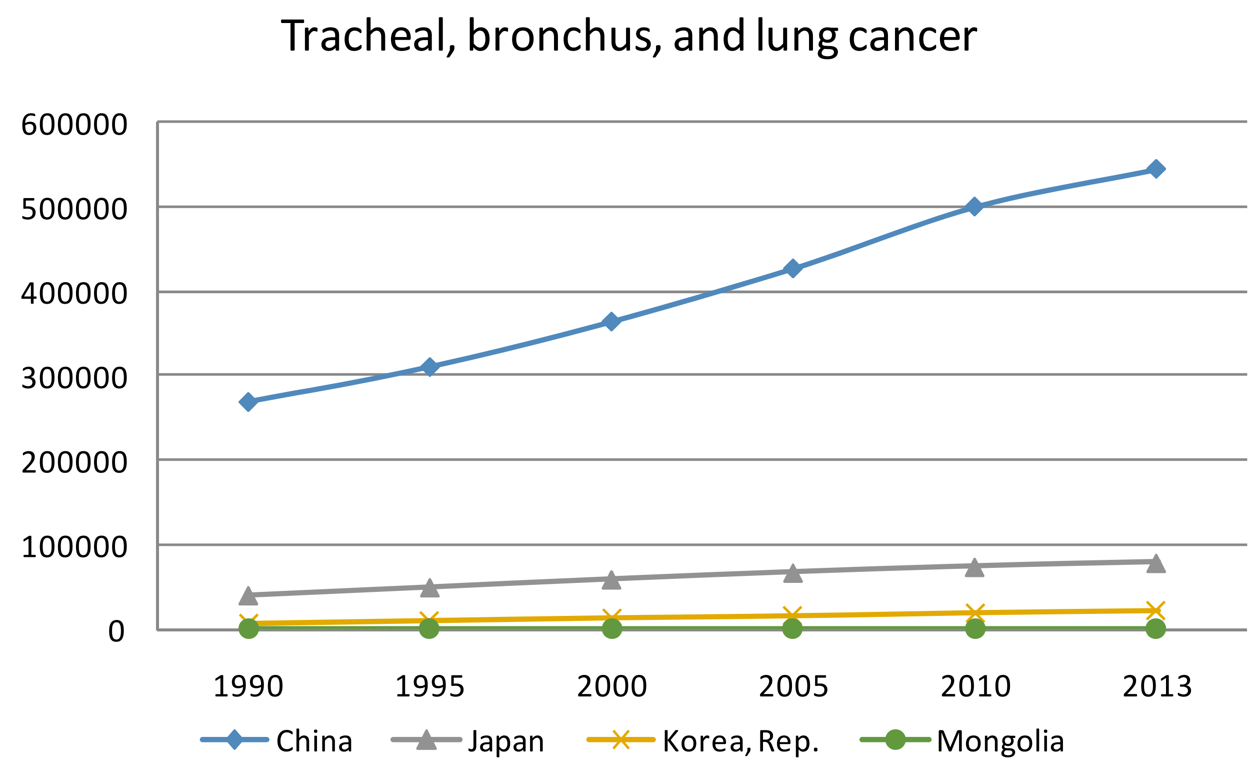


*Figure 81 Tracheal, bronchus, and lung cancer*

*Source: Global Burden of Disease Program (2016)*

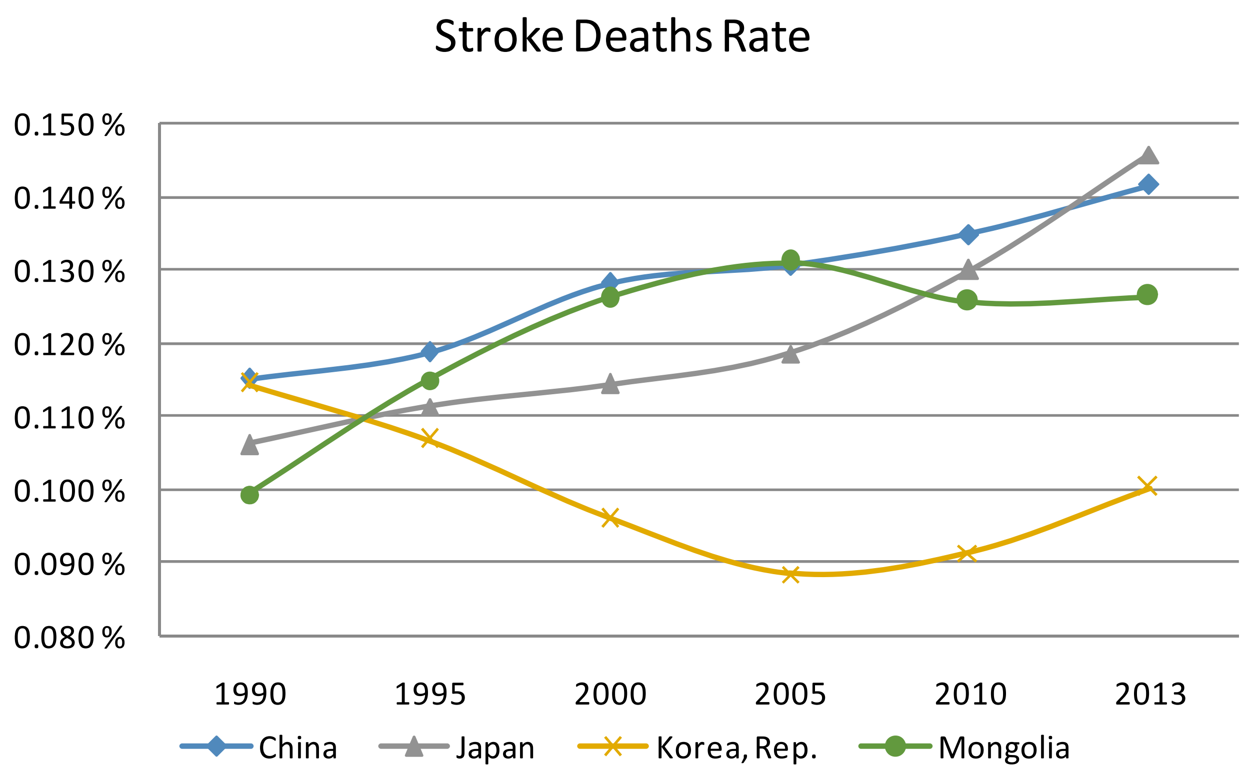


*Figure 82 Stroke Deaths Rate*

*Source: Author's calculation. (Based on Global Burden of Disease Program data and World Bank Population data) (2016)*

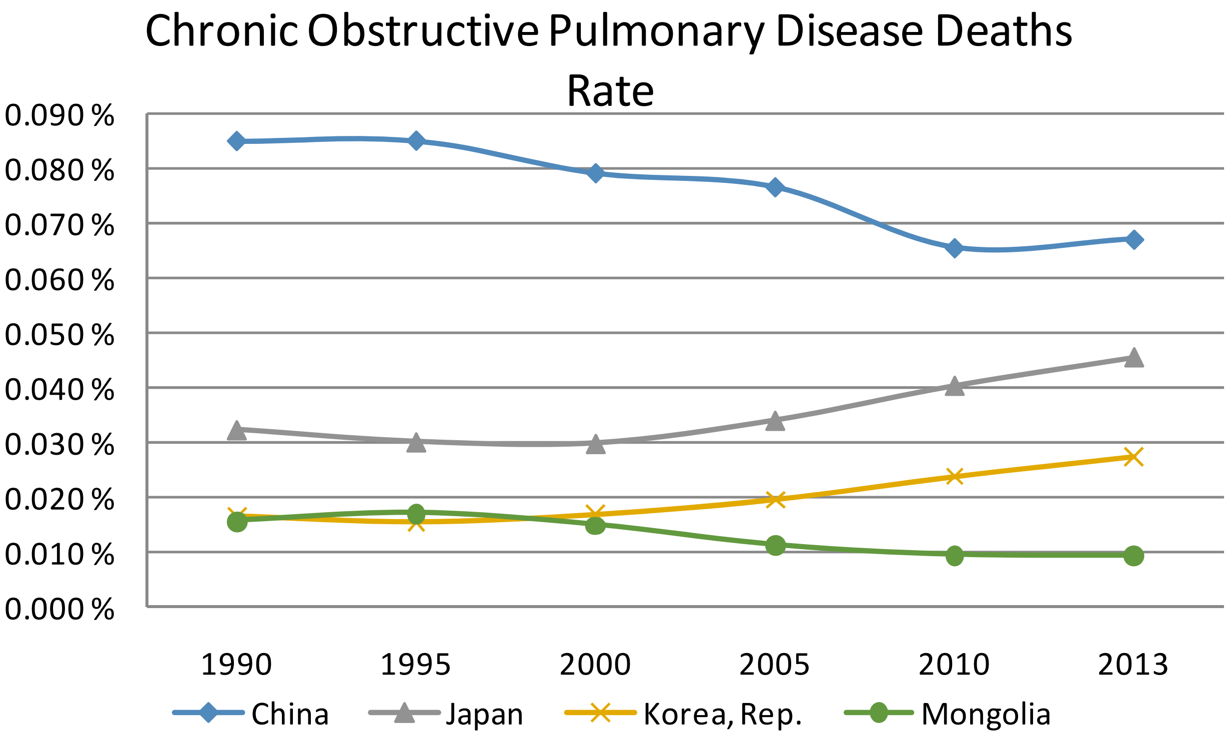


*Figure 83 Chronic Obstructive Pulmonary Disease Deaths Rate*

*Source: Author's calculation. (Based on Global Burden of Disease Program data and World Bank Population data) (2016)*

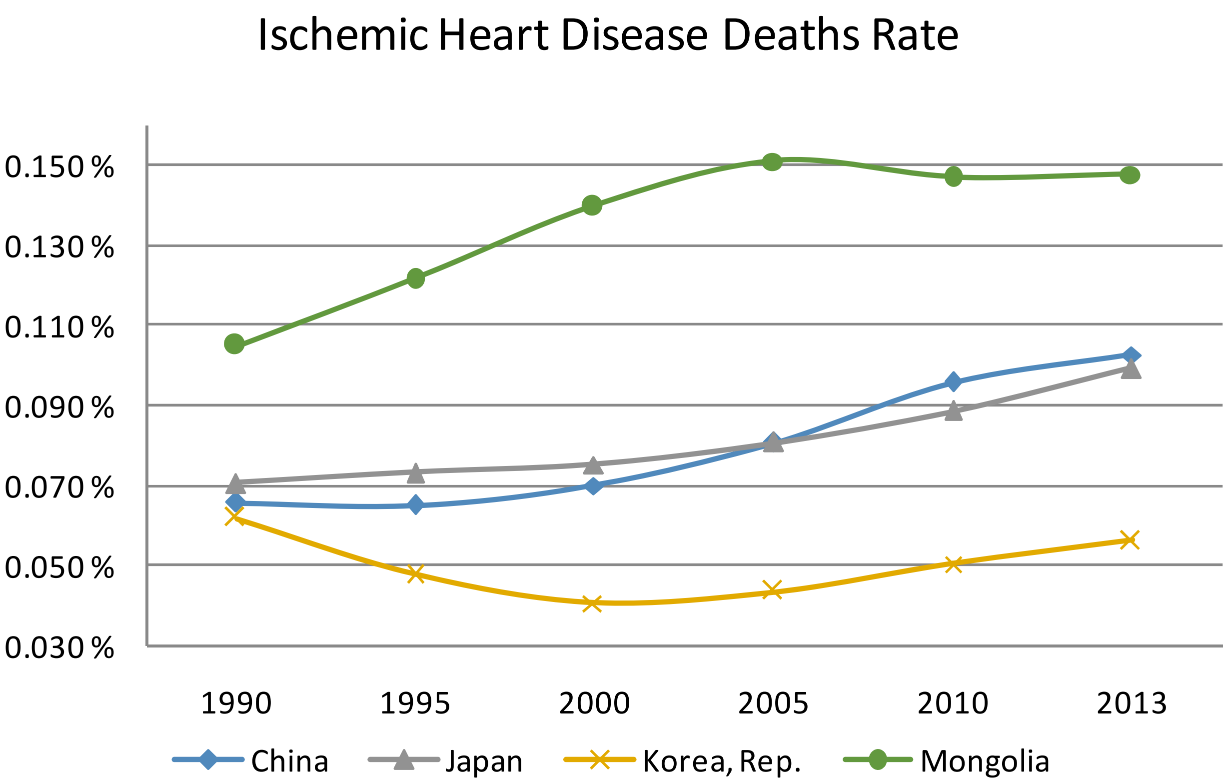


*Figure 84 Ischemic Heart Disease Deaths Rate*

*Source: Author's calculation. (Based on Global Burden of Disease Program data and World Bank Population data) (2016)*

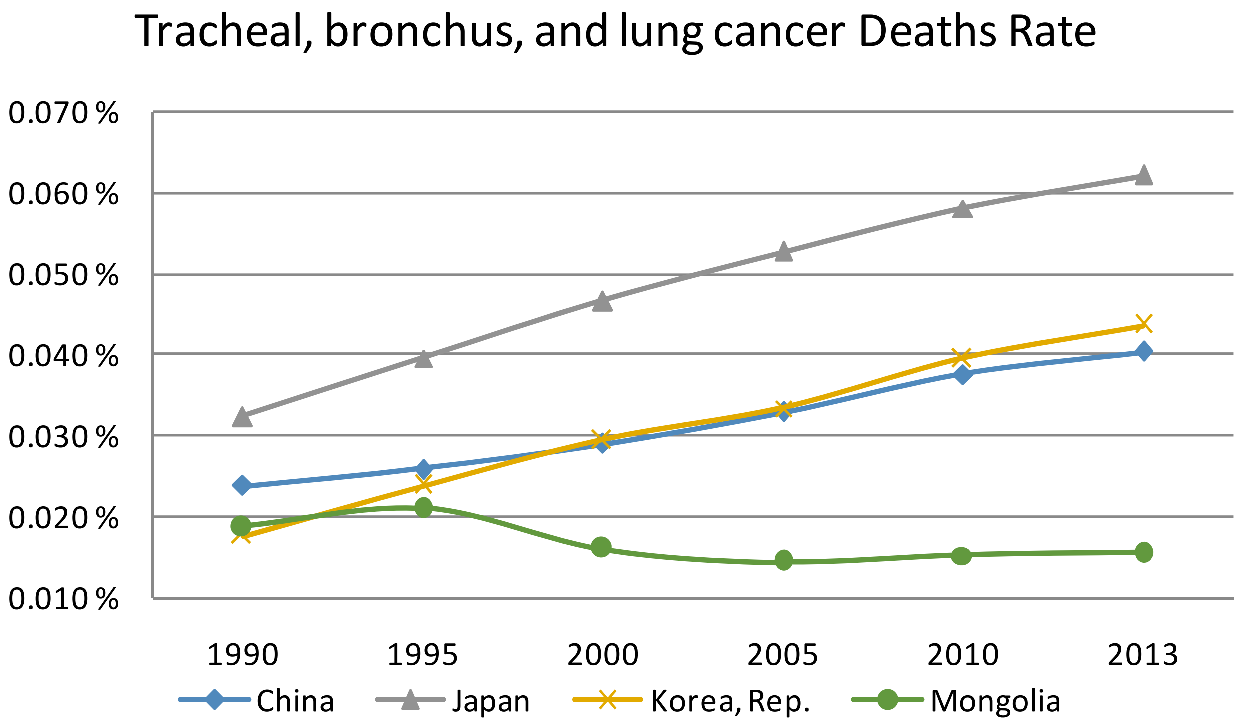


*Figure 85 Tracheal, bronchus, and lung cancer Deaths Rate*

*Source: Author's calculation. (Based on Global Burden of Disease Program data and World Bank Population data) (2016)*

## 7.2 Public Health and Education Expenditure

According to the figure below, Japan expends huge amount of money on public health sector since 1999, in contrast, China just expends 15% of money compared with Japan in 1990. Until 2013, the public health expenditure is almost equal between China and Japan. By comparison, health expenditure per capita in China and Mongolia has the more or less the same level of investment, and it is not even close to the level of Korea, Rep., let alone the highest level of Japan in Northeast Asia. The average public health expenditure per capita in Japan is around € 3,000 annually [55].

On education expenditure sector, the huge expenditure begins since 2006 in China, for Japan the average expenditure is around € 155 billion annually during 14 years, in contrast, China is around € 109 billion annually even with a huge increasing since 2006 [54].

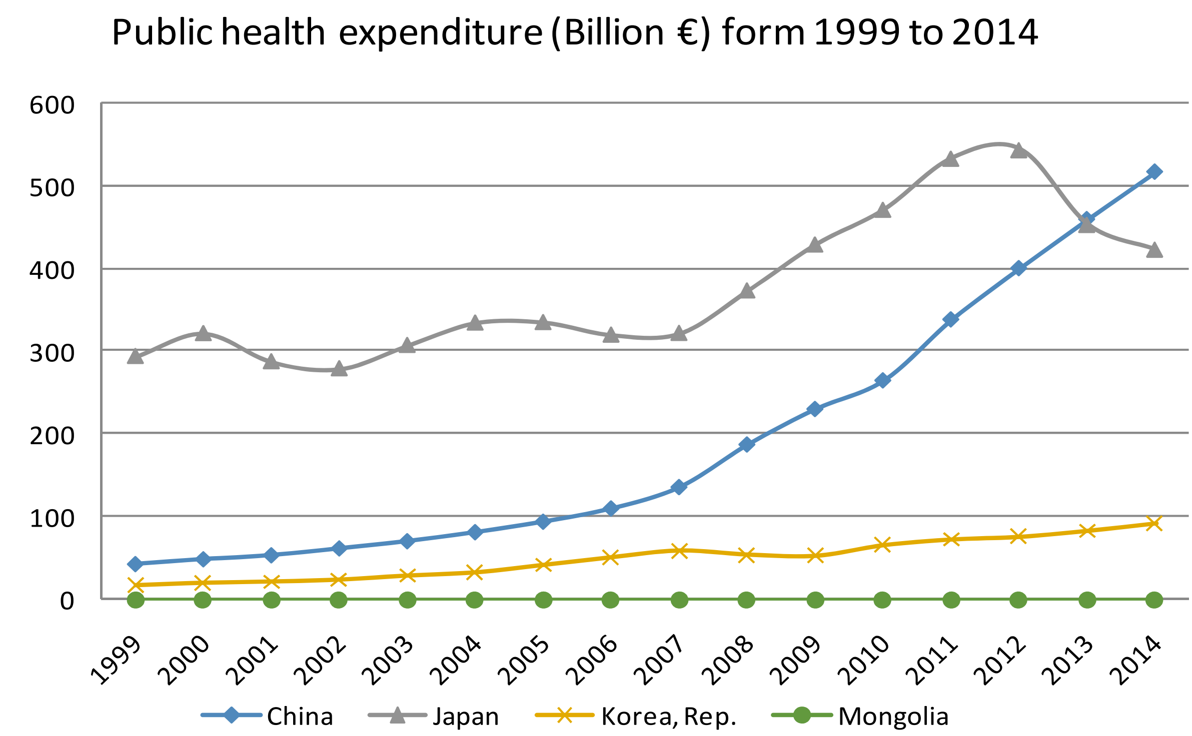


*Figure 86 Public health expenditure (Billion €) from 1999 to 2014*

*Source: World Bank (2016).*

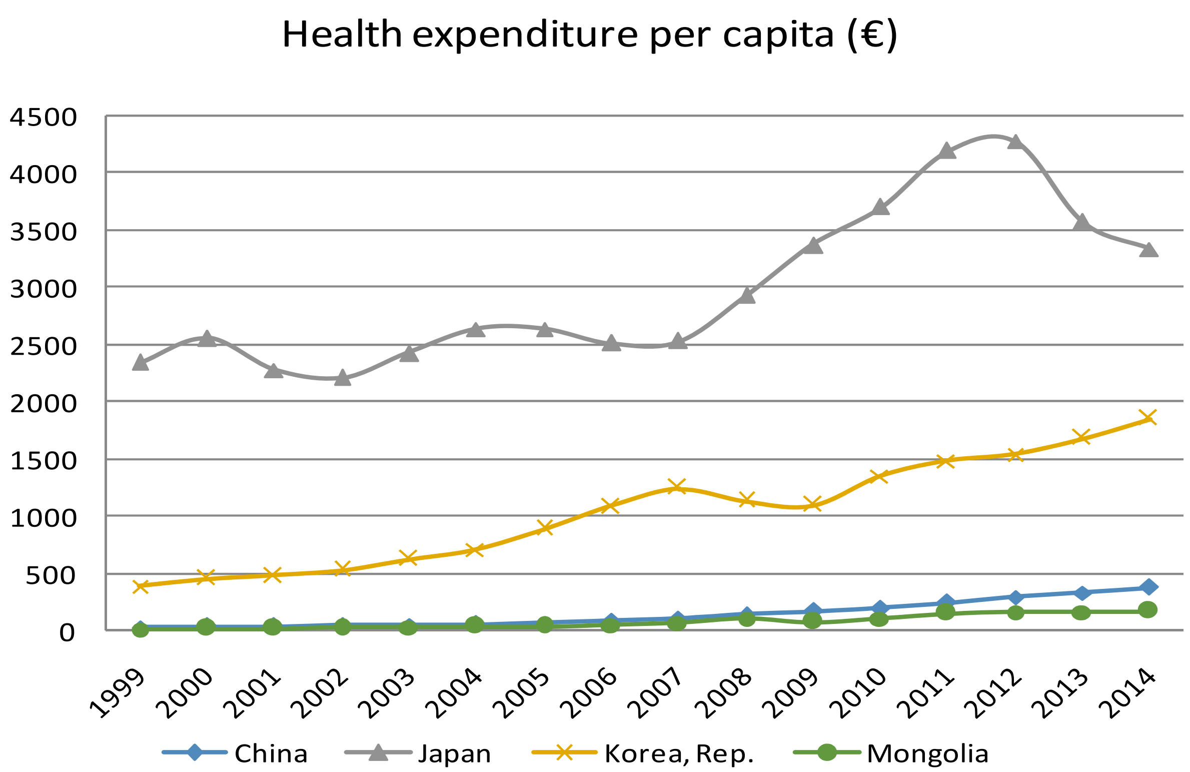


*Figure 87 Health expenditure per capita (€)*

*Source: World Bank (2016).*

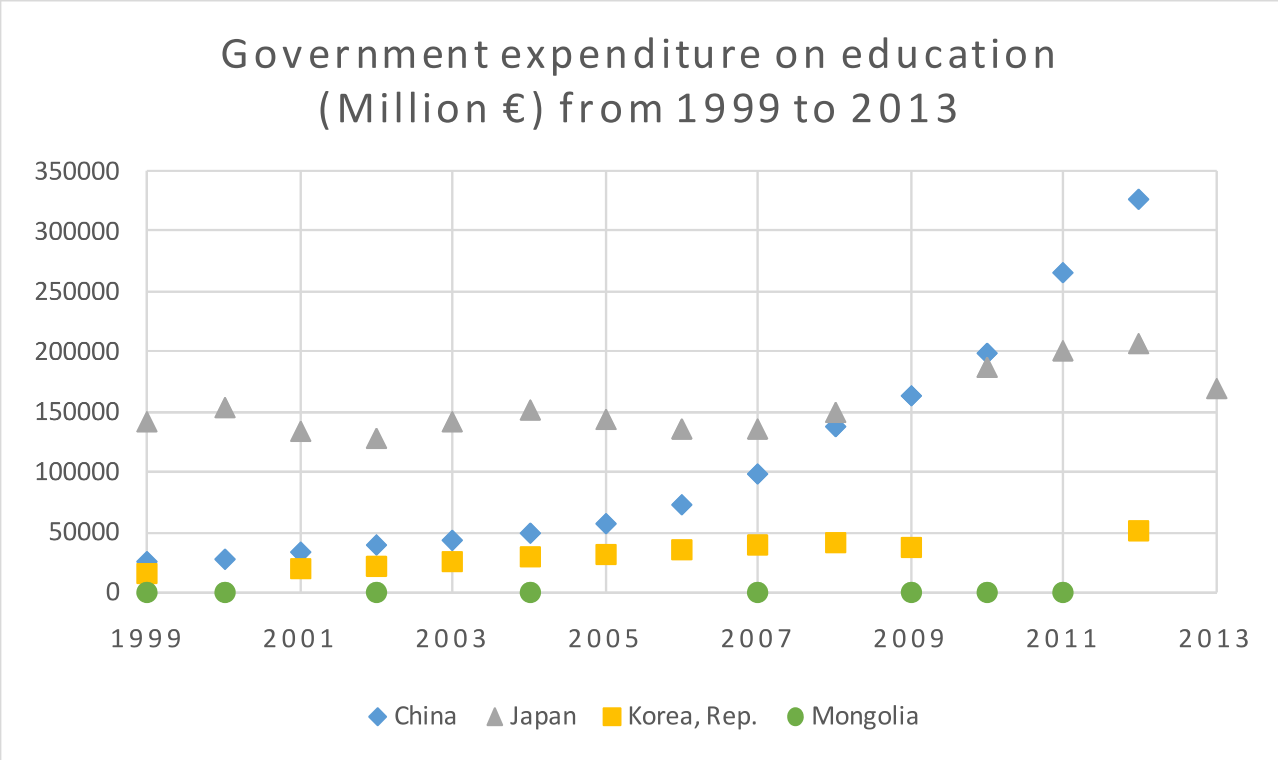


*Figure 88 Government Expenditure on Education (Million €) from 1999 to 2013*

*Source: Author's calculation. (Based on World Bank database) (2016)*

## 7.3 Health Effects

Air pollution from coal-fired power plants have effects on respiratory and cardiovascular systems, especially serious impacts on children, or even on the earlier stage of fetus growth. According to a study of life expectancy impacts on coal fired power generation, life lost estimation is closed to 2.5-year in India and 3.5-year in China [7]. For instance, the increasing consumption of coal results in higher mortality of infants in Australia, Chile, China, Germany, Mexico, and Thailand. Another aspect from indoor coal-combustion and coal miners also have quite noticeable effects. Considering coal as the heating and cooking source in households, it results in almost 1 million deaths from pneumonia and chronic obstructive pulmonary disease every year globally. Even though the risk of using coal as the indoor fuel is potentially high, it still widely used in China, especially in rural area which has no convenient access to natural gas. According to the WHO's study of burning solid fuels for heating and cooking in 2000, it pointed out over 16000 deaths/year from lung cancer due to the exposure to coal smoke of cooking amongst about 158 million adults in East Asia and about 20 million adults in South Asia [7].

The pollutants from burning fossil fuels are substantially enormous in China. According to statistics, there are more than 600 million tons of pollutants emitting to atmospheric environment by human activities every year. America accounts for one third of total pollutants, it includes over 30 million tons of toxic organic contaminants. Due to some chemical carcinogens emit from burning fossil fuels, serious atmospheric pollutions have higher morbidity on lung cancer and other organs cancer in cities, and even higher than rural area [59].

Inorganic pollutants from burning fossil fuels mainly include CO, $CO_2$, $SO_2$, $H_2S$, NOx, COS, $CS_2$, $C_4H_4S$, $CH_3SH$, $C_2H_5SH$, $C_2H_3SH$, $CH_3C_4H_3$ etc., moreover, it also includes fly ash, trace metal elements, radioactive particulates. Based on statistics, $SO_2$ emissions account for over 93% of fossil fuels pollution sources total emissions from burning coal in China. Coal accounts for more than 74% in primary energy consumption in China, and the situation of coal consumption is not going to change in the following 30 to 50 years. However, one third of coal reserves are medium and high sulfur coal, the gases from coal-burning cause serious damage for human health and plant growth. For example, $SO_2$ and other harmful gases in atmosphere could be converted to acid rain, which pollutes rivers and lakes, endangers aquatic organisms and crop growth, and severely damages ecological environment [59].

NOx emissions from burning fossil fuels have great impact on human health and environment as well. More than 90% of NOx emissions from burning fossil fuels are due to human activities. Although there are variety of NOx emissions, NO and $NO_2$ are the main emissions from burning fossil fuels. According to statistics of America, around 50% of NOx emissions are from fixed combustion sources, the rest of them are mainly from automobile exhaust. Since 1990s, automobile exhaust pollutions are aggravating in metropolis of China, NOx emissions are became main pollutants in few metropolis. Inorganic pollutants from burning fossil fuels also include heavy metals, such as Hg, Cd, Pb, and Zn etc [59].

On the basis of Zhang's summary in 2010, the authors estimate the health burden of electricity generation from coal and lignite [60]. In Europe, for example, there are 24.5 deaths, 225 serious illnesses, and 13288 minor illnesses for every TWh of electricity generation. Due to the fact that electricity generation from burning coal is account for 40% of the whole world. Based on a report from IEA, energy production from coal was 8572 TWh globally in 2010. The health impacts behind this number is that causes 0.2 million deaths, almost 2 million serious illnesses, and over 151 million minor illnesses every year. In contrast, a study conducted under Chinese environmental standards estimates around 77 deaths/TWh from burning coal in 2007. It leads to approximately 250000 deaths/year in China [7].

A study from Greenpeace indicates that 1100 premature deaths every year in South Korea, because of air pollutants emitted by domestic electricity generation from coal. The causes of deaths are listed as 370 deaths of stroke, 330 deaths of ischemic heart disease, 150 deaths of chronic obstructive pulmonary disease, 120 deaths of lung cancer, and other heart and lung diseases [37]. For instance, the social costs related to air pollutants from burning coal in South Chungcheong Province make up 37.5% of South Korea's total domestic social costs € 0.5 million out of €1.35 billion.

On the basis of WHO's estimation, there are 80000 deaths and 6.4 million lost life expectancy due to exposure to fine particulate air pollution globally in 2000. It is about two-thirds of people in developing countries of Southeast Asia suffer from this burden. In 2005, there are 1215180 deaths of people caused by ambient PM and ozone pollution in China, and the deaths of people even increased 5% in 2010. The mortality costs of ambient air pollution in China are US$ 741 billion in 2005 and US$ 1247 billion in 2010 [4].

With regard to UNEP Year Book 2014 [46], outdoor air pollution results in annually deaths of over 3.5 million people. The death rate went up to 4% worldwide, 5% in China and 12% in India between 2005 and 2010. A study given by OECD measured that US$1.4 trillion in China and US$0.5 trillion in India went to the cost of air pollution for society in 2010. In Europe, the cost from road transport sector is about US$137 billion annually. The estimation conducted by OECD countries on same purpose went to US$1.7 trillion in 2010. The WHO [46] estimates air pollution caused around 7 million premature deaths in 2012, of which more than half of the deaths are caused by outdoor air pollution. Even though developed countries pay more attentions on emission controls (vehicles included). However, the cost of the health impacts of air pollution on road transport sector still go up to US$ 1 trillion in OECD countries in 2010. Current vehicle emission standards adopted in China and India are definitely outdated due to explosively growth of traffic. Another notable aspect is the quality of refined oil such as gasoline and diesel. For instance, China started to upgrade the automobile gasoline and diesel quality from China I to China IV to reduce the emissions since 2000 and 2002, individually. At the beginning of 2017, China plans to upgrade the standards to China V with the sulfur content $\leq$ 10 mg/kg [60]. On the basis of the report from International Council on Clean Transportation (ICCT) [60], it shows modeling results for the annual incidence of premature mortality from vehicular emissions in China (2000-2030), under four scenarios. By upgrading the standard from China IV to China V, the premature mortality will almost decline by 60% in 2030. If the standard upgrades to China VI, it is going to almost decline by 40%.

With the regard of the statistics about air quality issues, WHO evaluated that 87% of the world's population have to suffer from the poor air quality with $10\mu g/m^3$ $PM_{2.5}$ (annual average) which is the WHO Air Quality Guideline in 2013. In the same year, the leading risk of global disease burden was ambient particulate matter air pollution with the estimation of 2.9 million deaths [5].

According to Brauer, 5.5 million deaths are caused by air pollution in 2013. More than 50% of deaths were due to ambient air pollution, and 64% of deaths appeared in Asia countries. Ambient air pollution attributes to emissions from things like: Power generation, Transportation, Agriculture, Open burning, and Household air pollution. Household air pollution is caused by burning solid fuels for heating and cooking, including: coal, wood and dung [5].

# 8 Nuclear Liability Insurance

When the Price-Anderson Act put into law in 1957 and amended in the Energy Policy Act in the year of 2005, $300 million of liability insurance are demanded for all commercial nuclear power plants [2]. In case of an accident has the losses over $300 million, maximum $95.8 million out of a pool of $10 billion are applied to each active reactor. The liability of industry is excluded from this limitation. Bodily injury, sickness, disease, or leading to death, property damage, and cost of individuals evacuation for living purpose are included (U.S. NRC 2008d). Under the regulation of Price-Anderson Act, $150 million has been paid in total to claim the Three Mile Island accident in 1979. The follow-up payment for indemnity settlements and expenses was beyond $70 million since 1997 [2].

The following sections are directly quote from the Price-Anderson Act as Public Law 85-256 issued by United States in 1957. Part of "Indemnification and Limitation of liability" clauses from Sec. 170 are quoted to have a better understanding of this act:

“b. The amount of financial protection required shall be the amount of liability insurance available from private sources, except that the Commission may establish a lesser amount on the basis of criteria set forth in writing, which it may revise from time to time, taking into consideration such factors as the following: (1) the cost and terms of private insurance, (2) the type, size, and location of the licensed activity and other factors pertaining to the hazard, and (3) the nature and purpose of the licensed activity: *Provided*, That for facilities designed for producing substantial amounts of electricity and having a rated capacity of 100,000 electrical kilowatts or more, the amount of financial protection required shall be the maximum amount available from private sources. Such financial protection may include private insurance, private contractual indemnities, self insurance, other proof of financial responsibility, or a combination of such measures.

c. The commission shall, with respect to licenses issued between August 30, 1954, and August 1, 1967, for which it requires financial protection, agree to indemnified, as their interest may appear, form public liability arising from nuclear incidents which is in excess of the level of financial protection required of the licensee. The aggregate indemnity for all persons indemnified in connection with each nuclear incident shall not exceed $500,000,000 including the reasonable costs of investigating and settling claims and defending suits for damage. Such a contract of indemnification shall cover public liability arising out of or in connection with the licensed activity.

d. In addition to any other authority the Commission may have, the Commission is authorized until August 1, 1967, to enter into agreements of indemnification with its contractors for the construction or operation of production or utilization facilities or other activities under contracts for the benefit of the United States involving activities under the risk of public liability for a substantial nuclear incident. In such agreements of indemnification the Commission may require its contractor to provide and maintain financial protection of such a type and in such amounts as the Commission shall determine to be appropriate to cover public liability arising out of or in connection with the contractual activity, and shall indemnify the persons indemnified against such claims above the amount of the financial protection required, in the amount of $500,000,000 including the reasonable costs of investigating and settling claims and defending suits for damage in the aggregate for all persons indemnified in connection with such contract and for each nuclear incident. The provisions of this subsection may be applicable to lump sum as well as cost type contracts and to contracts and projects financed in whole or in part by the Commission.

e. The aggregate liability for a single nuclear incident of persons indemnified, including the reasonable costs of investigating and settling claims and defending suits for damage, shall not exceed the sum of $500,000,000 together with the amount of financial protection required of the licensee or contractor. The Commission or any person indemnified may apply to the appropriate district court of the United States having venue in bankruptcy matters over the location of the nuclear incident, and upon a showing that the public liability from a single nuclear incident will probably exceed the limit of liability imposed by this section, shall be entitled to such orders as may be appropriate for enforcement of the provisions of this section, including an order limiting the liability of the persons indemnified, orders staying the payment of claims and the execution of court judgments, orders apportioning the payments to be made to claimants, orders permitting partial payments to be made before final determination of the total claims, and an order setting aside a part of the funds available for possible latent injuries not discovered until a later time.

f. The Commission is authorized to collect a fee from all persons with whom an indemnification agreement is executed under this section. This fee shall be $30 per year per thousand kilowatts of thermal energy capacity for facilities licensed under section 103. For facilities licensed under section 104, and for construction permits under section 185, the Commission is authorized to reduce the fee set forth above. The Commission shall establish criteria in writing for determination of the fee for facilities licensed under section 104, taking into consideration such factors as (1) the type, size, and location of facility involved, and other factors pertaining to the hazard, and (2) the nature and purpose of the facility. For other licenses, the Commission shall collect such nominal fees as it deems appropriate. No fee under this subsection shall be less than $100 per year.” [42]

Based on the Price-Anderson Act, each reactor site have to cover by offsite liability with $375 million in private insurance annually from the owners. This primary insurance is considered as the first tier, which complemented by the second tier. If the damages exceed the limit in first tier of $375 million, the excess part would be evaluated by a prorated share up to $121.255 million/reactor. The secondary tier of funds consist of 104 reactors in the insurance pool with the amount of $12.61 billion. When the expenses go up to 15 percent, the remaining amount of funds would be determined by federal district court on different priorities. In case the second tier is used up, Congress commits to make the determination of additional disaster relief is needed or not [45].

According to the research of Gérard Mondello [20], the liability boundary of operator in France till 2004 was €91.5 million/accident/facility, and €22.9 million/accident during transportation. A maximum of €228.6 million compensation for victims are applied in the State of which the accident happened. The cap of the compensation is up to €381.1 million by the signatory members of the Brussels Convention. As of the protocol from 2004, the available amounts of compensation reached €700 million/accident and €80 million/accident during transportation with greater coverage. The States is obligatory to repair the nuclear damage with the range from €700 million to a ceiling of €1.2 billion in total. Above this amount, States have to make contribution up to €1.5 billion as a party of Brussels Convention [36].

According to the study from Jakob Eberl and Darko Jus in 2012 [34], the figure above illustrates the two types of limited liability, *de facto* (which is by the amount of equity capital) or *de jure* (which is by law), converting the local currency to EUR for the listed countries in the table, the quantities in China, Czech Republic, India, United Kingdom, Vattenfall (Germany), Japan, and Switzerland are € 33.3 million, € 325.3 million, € 77.1 million, € 161.3 million, € 269.4 million, € 15.4 billion, € 234.3 million, and € 6.3 billion, respectively. The table below shows the results in € based on European Central Bank (ECB) currency exchange rates database of 2011 [12].

<table>
<tr><th colspan="2">Selection of countries with de jure limited liability</th><th colspan="3">Countries with de facto limited liability</th></tr>
<tr><td>China</td><td>€ 33.3 million</td><td rowspan="2">Germany</td><td>E.ON</td><td>€ 39.6 billion</td></tr>
<tr><td>Czech Republic</td><td>€ 325.3 million</td><td>RWE</td><td>€ 9.9 billion</td></tr>
</table>

| | | | | |
|---|---|---|---|---|
| France | € 91 million | | EnBW | € 6.4 billion |
| India | € 77.1 million | | Vattenfall | € 15.4 billion |
| United Kingdom | € 161.3 million | Japan | TEPCO | € 234.3 million |
| United States | € 269.4 million | Switzerland | Alpiq | € 6.3 billion |

*Table 11 De Facto Vs. De Jure Limited Liability, selected countries/NPCs (Nuclear Power Companies).*

*Source: Jakob Eberl and Darko Jus (2012), "*Evaluating policies towards the optimal exposure to nuclear risk*", 2012 9th International Conference on the European Energy Market, Florence*

From the table above, Germany and Switzerland have the largest liability investment in European Union, France is in the lowest level of the liability investment in EU, and China has the least quantity of liability investment among this list.

In accordance with Civil Liability for Nuclear Damage from World Nuclear Association [48], the main countries'[2] civil liability is summarized by the table below:

Civil Liability for Nuclear Damage (Million)

| | | | | | |
|---|---|---|---|---|---|
| Belgium | Canada | Czech Republic | Finland | France | Germany |
| € 1200 | $500 | € 296 | € 300 | € 91 | € 256 |
| India | Japan | Russia | Slovakia | South Korea | Sweden |
| $450 | $1120 | $350 | € 300 | $500 | € 356 |
| Switzerland | Ukraine | United Arab Emirates (UAE) | United Kingdom (UK) | United States of America (USA) | |
| € 1200 | $180 | $694 | £140 | $375 | |

[2] China is not party to any international liability convention but is an active member of the international insurance pooling system, which covers both first party risks and third party liability once fuel is loaded into a reactor. China's 1986 interim domestic law on nuclear liability issued by the State Council contains most of the elements of the international conventions and the liability limit was increased to near international levels in September 2007, though it is quoted at only $45 million in 2014. It is also setting up a reinsurance arrangement with Russia which seems more symbol than substance.

For insurance of the plants themselves, Hong Kong-listed Ping'an Insurance Company accounts for more than half of China's nuclear power insurance market, with its clients including nuclear power plants in Guangdong, Jiangsu and both first- and second-phase projects of Qinshan Nuclear Power Station in Zhejiang. Four Chinese Insurance companies provided US$ 1.85 billion worth of insurance to Tianwan Nuclear Power Station in Jiangsu, most of which will be reinsured internationally. About RMB 40 billion ($5.85 billion) insurance for the first two EPR units of the Taishan nuclear plant in being provided by Ping'an, All Trust, CPIC, PICC and others. In late 2009 seven insurance companies and China Power Investment Corporation (CPI) signed a RMB 100 billion insurance cooperation agreement with China Guangdong Nuclear Power Co to insure the ten CPR-1000 units that CGNPC plans to build in the next three years. In December 2007 Ningde Nuclear Power had announced a US$2 billion insurance agreement with Ping An Insurance Corp for its four-unit CPR-1000 nuclear power project in Fujian Province. All this is first party cover only.

*Table 12 Civil Liability for Nuclear Damage (Million)*

*Source: World Nuclear Association (2016), "Civil Liability for Nuclear Damage, Updated April 2016"*

There are three huge impacts nuclear accidents happened in past half century: Three Mile Island in 1979, Chernobyl in 1986, Fukushima Daiichi in 2011.

### Three Mile Island Accident

Based on the report from American Nuclear Society [2], the insurance paid almost US $12,000 for the living costs of families on the first day. The peak daily payments went up to US $167,286 on April 9. About 3,170 claimants were paid with $1.2 million in total of evacuation claims. Lost wage claims were paid from the pools by more than US $92,000 to 636 individuals. A court-managed fund with US $20 million from the insurance pool has paid for the harm of businesses and individuals in 25 miles range of the plant site in September 1981. Within the same area, a public health fund has established with US $5 million. Even though the health damages were not proofed yet, more than US $70 million were paid to more individuals through 1997. All the payments were covered by the primary insurance.

### Chernobyl Accident

According to Chernobyl Forum: 2003-2005 Joint Report [44], the costs of the Chernobyl nuclear accident could approach hundreds of billions dollars level over 20 years. In Belarus' estimation, the losses reached US $235 billion during three decades. The estimation of more than US $13 billion spend by Belarus on Chernobyl issues between 1991 and 2003.

### Fukushima Daiichi Accident

With regard to the accident in Fukushima, an annual report 2015 [43] revealed some information of the damage compensation expenditures. Based on the provision of the Corporation Act, the amount after deducting receipt on compensation and necessary compensation estimation went up to US$7.9 billion and US$57.3 billion.

# 9 Summary

According to the study of fossil fuel subsidies in Northeast Asia and Nuclear Liability Insurance, this thesis go through the historical and widely acceptable definition of energy subsidy and particularly the fossil fuel subsidy. During the review of fossil fuel subsidy, the concept of fossil fuel subsidy is redefined in twofold, direct subsidy and indirect subsidy. In the meantime, Inventory Approach and the Price-gap Approach in this thesis. Based on IMF's study, direct subsidy is pretax subsidy which means the direct cash payment from governments, indirect subsidy is posttax subsidy, which is also known as “externalities”. In general, indirect subsidies should include burdens, effects and impacts, and damages from burning fossil fuels. In the estimation of IMF, posttax subsidies are substantially higher than pretax subsidies, it is about US$5.3 trillion in 2015— account for 6.5 percent of global GDP.

Speaking of the emissions costs, $CO_2$, $SO_2$, NOx, and $PM_{2.5}$ emissions are the main study targets. Certain emissions can cause serious problems, such as global warming, acid rain, lung tissue damage and respiratory diseases. The deaths of stroke, chronic obstructive pulmonary disease, ischemic heart disease and lung cancer are discussed in this thesis. Surprisingly, the estimated deaths/ton by coal in China even larger than by natural gas in 2010. The reason could be from the quality of the fuel sources and the lagging emissions treatment technology. In 2015, $CO_2$ emissions from fuel combustion reached up to 10.83 billion tones in 2015.

In terms of the results of $CO_2$ emissions per $kWh_{el}$, the World level stays around 500 $gCO_2/kWh_{el}$, Europe level almost reaches 300 $gCO_2/kWh_{el}$, OECD Asia Oceania rises up a little bit towards 557 $gCO_2/kWh_{el}$, and a massive reduction is contributed by China with almost 28% in 2015. From the perspective of the $CO_2$ emissions per kWh of electricity per TPES in target countries from 2000 to 2015. At the end of 2015, the target countries in China, Japan, Korea, Rep., and Mongolia approached 261.5 $gCO_2/kWh_{el}$, 228.4 $gCO_2/kWh_{el}$, 190 $gCO_2/kWh_{el}$, and 310 $gCO_2/kWh_{el}$, respectively.

The cost of $CO_2$ emissions from fuel combustion by fuel sources is studied individually. Generally speaking, coal is the main fuel source used in China due to the cheap market price, the quantity of the total cost from fossil fuel combustion even reached €75 billion in 2015. In contrast to the other three target countries, the amount was relatively stable in Japan with €9.4 billion, in Korea, Rep. with €4.8 billion, and in Mongolia with €0.1 billion. Certain diseases, such as asthma, lung cancer, and cardiovascular disease are caused by $PM_{2.5}$ emissions. From 1990 to 2015, China reached 57 $\mu g/m^3$ in 2015. It is almost the sum of the other three countries’.

The total electricity generation from fossil fuels reached to 5145 TWh and installed generation capacity went up to 823.9 GW in China, it equals more than three times of the sum of the other three countries, respectively. The percentage of electricity generation from fossil fuels in China, Japan, Korea, Rep. and Mongolia is accounted for 80%, 60%, 60% and 100% in average from 1990 to 2012, respectively. Due to the fact that electricity generation in Mongolia was by coal and oil, therefore, it was 100% in this case.

In accordance with the study on the cost of public health sector and education sector, Japan is the leading country of average public health expenditure per capita with € 3,000 annually. Even though the expenditure on public health sector in China became the largest one in 2014, it was still in the second lower place on capita point of view. In the perspective of education expenditure, China approached € 109 billion annually during 14 years, and Japan, as a contrast, reached the € 155 billion annually in average.

The WHO estimated that the mortality costs of ambient air pollution in China are US$ 741 billion in 2005 and US$ 1.247 trillion in 2010. Besides the indoor air pollution, UNEP estimates that annually deaths of people is over 3.5 million by outdoor air pollution. The report from OECD estimated that the cost of air pollution for society went up to US$1.4 trillion in China in 2010. In WHO's estimation, half of the deaths are caused by outdoor air pollution out of 7 million premature deaths in 2012.

Besides the discussion of fossil fuel subsidies and hidden cost from burning fossil fuels, nuclear liability insurance is also discussed shortly. Under the regulation of Price-Anderson Act, $300 million of liability insurance are required for all commercial nuclear power plants. If an accident has the losses beyond $300 million, maximum $95.8 million from a pool of $10 billion can be employed to each active reactor. The insurance covers bodily injury, sickness, disease, or resulting in death, property damage, and cost of individuals evacuation for living. Three huge impacts accidents–Three Mile Island in 1979, Chernobyl in 1986, and Fukushima Daiichi in 2011–happened in recent five decades are reviewed in this chapter. The estimating cost is US$70 million, US$235 billion, and US$57.3 billion, individually.

In conclusion, fossil fuel subsidies are covered by both direct and indirect payments, and nuclear liability insurance is covered by public fund and private insurance company. The more important thing is underestimate the cost of health effects and environment effects, no matter from burning fossil fuels or utilizing nuclear as the source. If the health and environment effects are considered, fossil fuels and nuclear would be never competitive with renewable energy sources. For instance, Portugal accomplished an electricity consumption record by utilizing completely renewable energy resources for 107 hours in May 2016. What if exchanges the subsidies from fossil fuels and funds from nuclear power plants to R&D in renewable energy, with the improvement and development of related renewable energy technology, it will solve many environmental problems in a row.

## 10 Currency Exchange Rate

| EUR to | USD | CNY | JPY | KRW |
|---|---|---|---|---|
| **1999** | 1.0658 | | 121.32 | 1267.26 |
| **2000** | 0.9236 | | 99.47 | 1043.5 |
| **2001** | 0.8956 | | 108.68 | 1154.83 |
| **2002** | 0.9456 | | 118.06 | 1175.5 |
| **2003** | 1.1312 | | 130.97 | 1346.9 |
| **2004** | 1.2439 | | 134.44 | 1422.62 |
| **2005** | 1.2441 | | 136.85 | 1273.61 |
| **2006** | 1.2556 | 10.0096 | 146.02 | 1198.58 |
| **2007** | 1.3705 | 10.4178 | 161.25 | 1272.99 |
| **2008** | 1.4708 | 10.2236 | 152.45 | 1606.09 |
| **2009** | 1.3948 | 9.5277 | 130.34 | 1772.9 |
| **2010** | 1.3257 | 8.9712 | 116.24 | 1531.82 |
| **2011** | 1.392 | 8.996 | 110.96 | 1541.23 |
| **2012** | 1.2848 | 8.1052 | 102.49 | 1447.69 |
| **2013** | 1.3281 | 8.1646 | 129.66 | 1453.91 |
| **2014** | 1.3285 | 8.1857 | 140.31 | 1398.14 |
| **2015** | 1.1095 | 6.9733 | 134.31 | 1256.54 |
| **2016** | 1.1069 | 7.3522 | 120.2 | 1284.18 |
| **2017** | 1.1297 | 7.629 | 126.71 | 1276.74 |

*Source: European Central Bank. (2018), https://www.ecb.europa.eu/stats/policy_and_exchange_rates/euro_reference_exchange_rates/html/index.en.html*

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