Primary Energy Consumption in China and its Environmental Impact

Bachelor Essay by

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May 2013

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EKHK31

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Abstract: This paper is a literature survey of the primary energy consumption in China since 1978 and its impact on environment. The high dependence on fossil energy resources, coal in particular, has together with the rapid growth of energy consumption during the past decade increased the outlet of pollutants to air, soil and water. The paper focuses on air pollutions in the first hand. The development from 1978 until around 2010 is described and discussed. The scientific articles found are mostly funded or influenced by Chinese authorities. Therefore the paper also reviews some environmental NGO's and newspapers to get a counter weight. This has supported the view that there is an urgent need for action in China to stop degradation of the environment. A handful of options to reduce the environmental impact of primary energy consumption are discussed together with the challenges China faces today. The urgency for action is obvious and the question to be answered in the near future is if the government in China has the capacity to implement the options discussed.

Keywords: China, energy consumption, environmental impact, energy mix, energy intensity, energy security, renewable energy

Content:

Acronyms:

CDM	Clean Development Mechanism
CNN	Cable News Network
CO2	Carbon Dioxide
ECA	Energy Conservation Assessment
EIA	Energy Information Assessment
EKC	Environmental Kuznets Curve
FGD	Flue Gas Desulphurisation
FYP	Five Year Plan
GDP	Gross Domestic Product
GHG	Green House Gases
GM	General Motors
LUBSearch	Lund University Database
NGO	Non Governmental Organisation
PM	Particular Matters
PV	Photo Voltaic
R&D	Research and Development
SEHC	Solar Energy Heating and Cooling
SO2	Sulphur Dioxide
SWH	Solar Water Heater
tce	ton coal equivalent
WHO	World Heath Organisation

1. Introduction

The Open Door Policy introduced in China 1978 was the start of a remarkable economic development never seen before. China, the largest developing country in the world, showed during the following 30 years an average annual economic growth rate (GDP) of almost 10 %. The world's average GDP growth was "only" 3.3 % during the same period (Zhang et al, 2013). The economic growth has improved the standard of living for the Chinese though many still struggle under the poverty line. The access to energy has been an important part of the development and energy consumption has increased significantly during the period. China reached the first position in the world for both energy production and consumption in 2009. The impact on environment has successively increased and is today of major concern for the Chinese society and for the free world (Fan et al, 2012).

The development is more or less a Chinese industrial revolution, and in some aspects even comparable with the development in England during the First Industrial Revolution roughly 200 years earlier. Though the economic growth in England was much slower than in China the access to energy was one key to the development in both cases. England was at that time considered Factory of the World and today China has the same label. The increased use of coal in England also negatively impacted environment. The environmentalists argued for restrictions and better technology to avoid pollutions. But the coin had two sides, the use of coal also contributed to wealth and economic growth. Black smoke from chimneys was for a long period synonymous with prosperity. Not until the 1950s, after a few days with heavy smog in London and the deaths of thousands of people, the authorities took action and the environmental regulations were tightened and the environmental impact was successively reduced (Logan, 1953).

China is certainly facing the same dilemma as the English did, to choose between economic growth and an acceptable environmental impact. The World Bank highlighted the Chinese dilemma already in a review of the energy sector in China in a report 1995 (Johnson, 1995). Here it is pointed out that the increasing use of energy could result in serious environmental problems in the long run. The severe air pollutions already then recognised in many major cities in China and the increasing outlet of CO2 from burning more and more coal were discussed. It is stated in the paper that "the environmental implications of a high energy

growth scenario are frightening". An essential question: is this still the case, or has China managed to take actions?

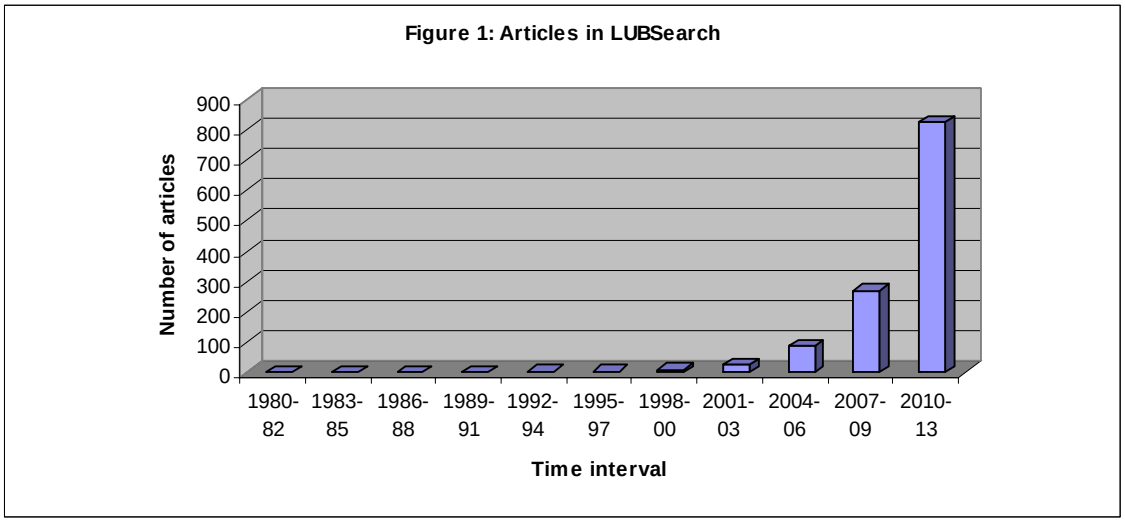
The objective of this paper is to review the development of energy consumption in China and its impact on environment until today and possible future implications. The research question is formulated: "How does the Chinese energy consumption impact the environment and what are the future challenges for China?"

The formulation of the research question is rather wide in one sense and can cover many different aspects and therefore the analysis will be kept on a macro level as much as possible. China is not only the most populous nation in the world but also geographically a huge country with various characteristics concerning energy consumption and environmental impact in different provinces. The main focus in the analysis will be on a nation level rather than a provincial level. The impact of energy consumption on environment will focus on main problems on the nation level rather than going into detailed issues on provincial level though some examples might be used to illustrate the wide span of environmental impact in China. In another sense the research question might be considered too narrow. Though the ambition is to keep the analysis on the macro level there are additional questions which have to be dealt with to be able to discuss the Chinese opportunity to handle the future challenges in the environmental area. Therefore questions like energy intensity, energy efficiency, the structure of the energy consumption, the potential for renewable energy resources and the security of energy supply also have to be elaborated.

The research question is approached through a literature survey and the methodology is described in chapter 2. Chapter 3 reviews and discusses the development of the energy consumption in China since 1978. Chapter 4 gives a basic overview of the environmental impact of primary energy consumption in general. In chapter 5 the environmental impact since 1978 including the current situation is described and discussed in terms of what has been done so far to mitigate the impact of increased energy consumption. Chapter 6 raises the options available to improve the current environmental situation in China. The outlook for the future and the challenges are discussed in chapter 7. In chapter 8 the findings in this literature survey are summarised but also reviewed in the light of the applied methodology. An idea for future work is also revealed in the last chapter.

2. Methodology

The literature survey started in a database available at Lund University (LUBSearch) with the following keywords: “China”, “Energy consumption” and “Environmental impact”. The first search resulted in more than 1400 articles up to April 2013. The criteria: “peer reviewed” was added to ensure best quality and the number of articles was reduced to slightly above 1200. A first step in the selection process was to study the frequency of articles meeting the keywords over the entire period of time 1978-2013. The result below shows the number of articles published during the respective time interval of three years starting in 1980. The last time interval includes January to April in 2013.



The last interval 2010-2013 shows the highest frequency, more than 800, of published articles and obviously the interest for the topic under research has increased in a remarkable way from the beginning of the new millennium. The latest articles are supposed to describe the current situation and represent the “state of the art” knowledge of this topic. The assumption is made that relevant articles prior to 2010 are used as basic work for the recent articles dealing with the researched topic. A great number of the articles are published in Chinese and a further limitation to articles published in English reduced the number of articles to about 350. The source of the articles is Academic Journals.

In a second step the abstracts of the articles published in English during the period 2010-2013 were reviewed and the most relevant articles, about 30, were selected to be used for this essay.

In addition to LUBSearch The Open World Bank database has been used with the same keywords and the search resulted in about 25 articles and 15 articles were selected in the same way as above. In the third step these articles were studied in more detail and at the end about 30 articles were used as references in this paper.

The articles found in LUBSearch are mostly written by Chinese scholars with support from the Chinese government or Chinese authorities. An example is Xiao-Hong Zhang from the University in Sichuan who has recently published articles with relevance to the research question in this paper. The most recent article published in Ecological Indicators in 2013 has the title "The interactions among China's economic growth and its energy consumption and emissions during 1978-2007". This paper is supported by the Sichuan Province Office of Education, the National Eleventh Five Year Research Program of China and the National Science Foundation of China. With this type of support it can be questioned if the Chinese scholars are in the position to be critical to the hand feeding them.

An interesting article published in 1995 by Johnson working for the World Bank referred to in chapter 1 has been used to compare the real outcome in primary energy consumption and the environmental impact based on the outlook in the beginning of the 1990s. World Bank articles are not dominated by Chinese scholars but China is clearly an influential stakeholder in the World Bank.

It has to be stressed that the energy statistics play an important role in this literature survey and that most statistics are from Chinese sources. How much of domestic energy resources that are used in China by Chinese users is naturally not that easy to follow up and control for by international organisations. It could even be challenged how easy it is for Chinese authorities to collect and aggregate the correct information. The government in China is dependent on a great number of provincial authorities and information could be twisted for different reasons. It is often assumed in international media that China wants to downplay environmental problems. The conclusion is that the statistics are very much given on Chinese conditions. This means, that it is important to investigate sources not linked to Chinese government to answer the research question, to guarantee objectivity as much as possible.

There are a number of non-governmental organisations (NGO's), with focus on environment, working on the international scene, like World Watch Institute, Earth Watch Institute and

Greenpeace. Though they are mostly funded by donations it does not by necessity mean that they are not stakeholders. But if it would be expected that the Chinese stakeholders are putting economic growth before the environment and want to downplay the environmental impact it is more likely that environmental NGO's would have the environment as their highest priority. This approach will provide a balance between different stakeholders and help create a true picture of the current situation.

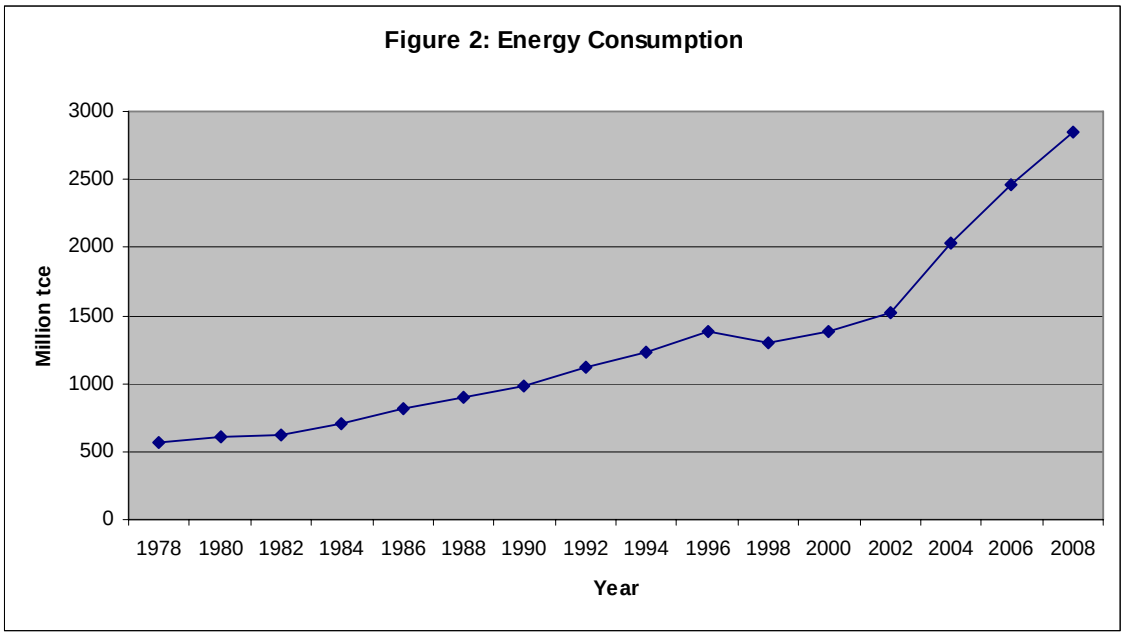
The websites of mentioned NGO's have been reviewed and Greenpeace has been chosen as the source to counterweight the articles found in LUBSearch and the Open World Bank databases. The reason for this choice was that Greenpeace had more focus on energy consumption related impact on environment than the other two. The Greenpeace website presented several articles of interest during the past 12 months.

In order to judge the current environmental situation in China a few recent newspaper articles have been reviewed as well. The articles are mostly based on interviews with Chinese people by western journalists. Many Chinese live in areas where the impact of consumption of energy is clearly very negative. These articles may not be considered as scientifically valid but give some local examples and trigger the discussion about environmental degradation in China. One recent and relevant article from April 2013 has been used in the discussion about China's challenges in the environmental field and is also commented upon in the last chapter of this paper.

The US Energy Information Administration (www.eia.us) has also been used for comparison of energy statistics for China.

3. Development of energy consumption since 1978

In 1978 the Chinese primary energy consumption was 0.57 billion tce (tons coal equivalent) which grew to 2.85 billion tce in 2008. During the same period primary energy production increased from 0.62 to 2.60 million tce indicating that domestic production in 1978 covered the consumption but that this changed to about 10 % deficit in 2008 (Zhang et al, 2011).



Source: Zhang et al, 2011

The major energy resource consumed in 1978 was coal accounting for about 71 % of the total, slightly decreasing to 69 % in 2008. Crude oil and natural gas, both fossil fuels as coal, accounted for 23 % respectively 3 % of the consumption in 1978, which changed to 19 % respectively 4 % in 2008. The primary energy consumption in 1978 relied to 97 % on fossil energy resources and 3 % on renewable energy resources (mainly hydro power). In 2008 the fossil energy resources still accounted for more than 91 % and non fossil energy resources including hydro, wind and nuclear power for the rest (Zhang et al, 2011).

During this 30 year period the primary energy mixture did not change significantly and the dependence of coal is still very high. As coal is abundant in China this is most likely to be a key energy resource during the foreseeable future. The domestic production of crude oil did cover the demand in China until around 1993. After that China is dependent on import of crude oil. Since the domestic production of crude oil has not kept pace with the increasing consumption the Chinese dependence on import of crude oil has been growing and in 2008 close to 50 % of the crude oil demand had to be imported. Though natural gas is only a minor part of the primary energy consumption the demand has increased between 1978 and 2008 and has mainly been covered by domestic production. Compared with coal, natural gas is not abundant in China (Zhang et al, 2011).

The growth rate in natural gas consumption has been particular fast since the beginning of the 21 century and exceeding 10 % on annual basis. China has undertaken new exploration and the domestic gas reserves have increased. But the government has also initiated collaborations with other countries to be able to import gas as a reaction of increased demand for natural gas in China (Li et al, 2011).

The non-fossil energy resources in 1978 were renewable resources like hydro and wind power, biomass and crop stalks. Wind power was at this time in a very early stage of its development. Biomass and crop stalks were resources used in rural areas and not always considered as commercial energy resources and probably not fully included in the energy statistics. Renewable energy resources are abundant and China has a great potential for wind and hydro power, but biomass energy is also a rich resource. Even solar energy has a potential in provinces with high solar radiation influx. Another non-fossil energy resource is nuclear energy. The first nuclear power plants were erected in the first half of the 1990s and have been followed by more plants but in 2009 the total electricity production by nuclear power accounted for less than 2 % of the total in China (Zhang et al, 2011).

The primary energy production and primary energy consumption during 2009 and 2010 have continued to increase and were in total 2.96 billion tce respectively 3.25 billion tce in 2010 (Fan et al, 2012). The dominance of coal in the primary energy consumption is still obvious though it has decreased a bit more since 2008 and is in 2010 estimated to 66 % of the total. The demand for oil and natural gas has increased to more than 20 % respectively 5 % of the total primary energy consumption. Though nuclear power capacity has increased rapidly during 2009 and 2010 the non-fossil energy resources have slightly decreased to around 8 % compared to 9 % in 2008 (Fan et al, 2012). The conclusion is that the demand for oil and natural gas has increased lately at the expense of coal and other non-fossil energy resources. Due to the lag in the statistics this is the latest official information. But the demand for oil and natural gas is likely to continue to rise when the Chinese are closing in on the lifestyle of developed countries. The development will require e g more cars and therefore more oil and natural gas.

China started the development of renewable energy resources in 1978 and during 1978-2000 renewable energy was part of the Five Year Plans (FYP) and national policies and laws. The renewable energy resources like biogas, small hydro and wind were growing, though from a

low level. In the beginning of the 21st century China started to use market incentives together with command and control management and state subsidies to promote renewable energy generation. A number of demonstration projects were initiated in addition to the Renewable Energy Law in 2006. Foreign capital and technology were transferred through international cooperation via the Clean Development Mechanism (CDM) to China. This cooperation has further supported the development of renewable energy like small hydro, wind power, solar thermal and bio-energy (Fang, 2011).

Wind energy can with modern technologies be converted to electric power. On shore wind power technology is the most mature but technologies for off shore are improving though still more expensive. China is rich of wind energy and the on shore potential at low height (10 m above ground) is about 250 GW though the off shore potential is about 750 GW. If the total potential instead would be calculated at the height of 50 m above ground it is doubled. China has a specific region suitable for wind power. Inner Mongolia accounts for 40 % of the on shore potential. In addition China has a long coastline (Han et al, 2009).

Solar energy has a great potential in China compared to other countries. The utilisation of solar energy in solar water heater systems (SWH), solar energy heating and cooling systems (SEHC) and solar photovoltaic (PV) power generation is in relative terms small. Among the technologies mentioned the SWH systems are the most economic, mature and also popular and used for heating water in various applications. The demand for hot water is high as the Chinese residents use far less hot water compared to western countries (Han et al, 2010).

Though China has only around 8 % renewable energy resources the installed capacity of hydro power is around 146 GW. This is about two times the capacity in the Nordic countries. By the end of 2008 China had the largest small hydro capacity, largest solar water heater installations, third largest production of bio-ethanol and the fourth largest capacity in wind capacity in the world. China has certainly the potential to overtake the developed countries as the leading producer of renewable energy (Fang, 2011).

The conclusion is that the primary energy consumption in 2010 is more than 5 times higher than in 1978. The mix of energy resources has not changed dramatically during this period. The fossil energy resources still account for more than 90 % of the primary energy consumption with coal as still the dominant energy resource. The share of natural gas in the

mix has increased slightly but is only about 5 %. The most noticeable change is that the import dependence of crude oil has grown during the period though its part of the energy mix has decreased. The significant potential for renewable energy resources and nuclear power has not been realised to any major extent so far.

The only energy resource China imports in significant volumes in 2008 is crude oil. China is among the three major net importers of oil in the world. About 35 % of the import came from Angola and Saudi Arabia. The most important region for China's supply of oil was Middle East accounting for around 50 %. The demand for natural gas has also recently started to grow and China is exploring how to secure additional imports of natural gas through pipeline and in liquefied form. China is both the largest producer and consumer of coal in the world today and is able to supply the demand with domestic energy resources to over 90 %. Energy is a key strategic issue for the Chinese development (Soile, 2011). The conclusion is that energy supply security is acceptable for China today, but the growing demand for primary energy and the increasing crude oil import worries and the situation is likely to change in a long term perspective.

In developed countries energy supply security is a question about the reliable supply and having access to enough energy at affordable prices. Further, protection from interruptions in energy supply is part of the energy security. For a developing country like China energy supply security is important in achieving the targets for economic growth and therefore a strategic issue. The model for economic growth chosen in China characterised by high energy consumption puts the focus on environmental issues and reduction of pollution (Soile, 2011).

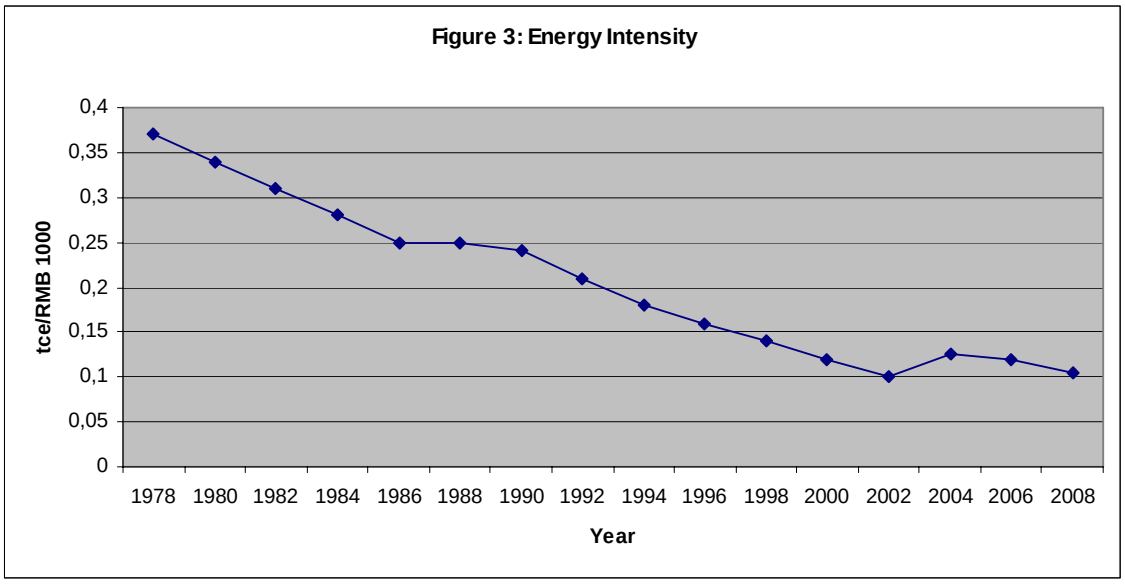
The urbanisation process has increased the level of people living in urban areas from close to 18 % in 1978 to almost 46 % in 2008. The total energy consumption related to urbanisation is around 20 % of the total energy consumption in China. Power generation accounts for roughly 50 % and the remaining 30 % of the total energy consumption relate to other industries like steel, cement, chemical and petrochemical (Zhou et al, 2012).

The energy consumption related to urbanisation has been rather stable about 20 % of the total since early 1990s. In the decomposition of the urbanisation related energy consumption since then the residential part has declined while the other parts, transportation and building materials, have increased. The residential part has benefited from successively more efficient

household appliances. The increased use of motor vehicles has on the other hand increased consumption in transportation. The continued urbanisation with demand on new infrastructure and housing has done the same (Zhou et al, 2012).

The energy consumption per capita in urban areas is higher and more diversified than in rural areas. The use of coal has decreased but the share of petroleum and natural gas has increased. In rural areas a single energy structure is often observed with coal as the major energy source. Though the energy efficiency is very low for coal the efficiency in Chinese households has increased overall (Feng et al, 2011).

Energy intensity is normally defined as the ratio between the energy consumption and GDP output. As energy intensity is related to both energy consumption and economic outcome it is an indicator of energy efficiency. In China the energy intensity has dropped all the way from 1978 to 2001 as the GDP grew faster than energy consumption. The increase in GDP was as an annual average more than 9 % while the corresponding average for energy consumption was slightly more than 4 %. Econometric analyses show that energy efficiency in industry was the key reason to the decline in energy intensity. In 2002 the downward trend was broken and the increase in energy consumption was higher than growth in GDP output and a slight increase in energy intensity can be seen. The major explanation to this is that total investment in fixed assets increased rapidly specifically during the period 2002-2005. In the industrial sector the part of heavy industry increased and caused a boom in energy intensive branches. The energy intensive industry in China has a high ratio of small scale plants contributing to low energy efficiency. In spite of the reversal of the downward trend in 2002 the energy intensity in the period 1978-2008 dropped almost 70 % (Zhang et al, 2011).



Source: Zhang et al, 2011

The reason for the significant decrease of energy intensity since 1978 has been debated and analysed in detail by several scholars on different time occasions. The debate focuses around the role of technology change, structural change in production sectors and the major industries. The most significant decline in energy intensity occurred during the period 1987-2002 with a 50 % decrease. Until around 2000 technology played a dominant role for the decline in energy intensity. After that technology development could not keep up with the structural change in industry (Fan et al, 2012).

The energy intensity in China was in 2008 more than 10 % higher than the world's average, more than 50 % higher than in the US and more than 100 % higher than in EU-15. China's energy intensity fell about 4 % between 2009 and 2010 and the ambition is to reduce the energy intensity by another 17 % until 2015 (Pao et al, 2012).

In 1979 China introduced a system for Environmental Impact Assessment (EIA) originating from the US. The aim was to protect the environment and before the authorities approved a new construction project its impact on environment had to be described. With this system as a model China in the 1990s decided to consider a similar mechanism for energy conservation to promote energy efficiency. This mechanism, Energy Conservation Assessment (ECA), was in 1998 adopted into the Energy Conservation Law in China. The ECA stipulations were not well enforced as procedures were vague, legal liability articles missing and the enforcement

mechanisms weak. These stipulations were improved and in 2008 an amended Energy Conservation Law was implemented (Hu, 2012).

The ECA system has demonstrated that it can promote higher energy efficiency when applied on fixed-asset investment projects. But the system still has room for improvement. Firstly, the legal framework supporting the application phase of the system has to be improved. Secondly, in the area of energy conservation there are too few professional consultants. Thirdly, fundamental information like statistics regarding energy consumption for buildings is often missing. Fourthly, compliance and enforcement are most often a problem (Hu, 2012).

Electricity has played an important role in the Chinese development and since 1990 up to 2009 the installed thermal power capacity has been around 75 % of the total capacity and generating 80-83 % of the total electric energy. Power plants fired with coal were in 2009 accountable for 97 % of the installed thermal capacity (Liang et al, 2011). Installed capacity in hydro power was the second largest with over 22 % of the total capacity in 2009 and generated 15 % of the total electrical energy (Zhang et al, 2011).

The electrification of rural areas in China has been an important way of reducing emissions from direct burning of coal and different types of biomass like firewood, crop stalks and straws. In 1980 these fuels were the primary resources used for cooking and space heating in rural households accounting for 84 % which was reduced to about 56 % in 2003. Electricity has a higher overall efficiency as it is generated in a few larger plants which makes pollution control easier compared to a great number of households firing the fuel directly without any or at least little control of pollutions. The development path with rural electrification reduces the annual deforestation which is also favourable to the environment (Wu et al, 2006).

The conclusion is that statistics are only including commercial energy resources. Fire-wood and waste from crops are often used in rural areas and could maybe change the official statistics a bit. But this will not change the overall conclusion that the Chinese primary energy consumption is dependent on coal and that around two thirds are coal based and around 90 % is fossil energy resources today. Nuclear energy plays a minor role in the Chinese energy mix and hydro energy is so far the dominant renewable energy resource. The renewable energy resources including hydro have significant potential and are growing but as long a the absolute demand for energy is growing faster or at least at the same pace as the renewable

energy it will be difficult and take time to change the energy consumption mix. The renewable energy resources are not always competitive with fossil energy resources. Another argument for a slow change of the energy consumption mix is that coal is used for the generation of electricity and once a power plant is built it has an economic life of 25-30 years.

Another remarkable conclusion is that the energy intensity is decreasing as long as GDP growth rate is higher than annual energy consumption increase. Though China has showed a decline in energy intensity during the past decades China still has high energy intensity when compared to developed countries. The improvement of energy intensity is a relative measure but it is also important to look at the absolute level of energy consumption in the discussion in the coming chapters about environmental impact. Before discussing the environmental impact of the energy consumption in China the general impact will be discussed in next chapter.

4. Environmental impact of primary energy consumption in general

The combustion of non-renewable energy resources pollute air, water and soil and can cause health problems for man. Burning fossil energy resources like coal, petroleum and natural gas always produce carbon dioxide in relation to the carbon content in these fuels. This is a result of the chemical process and unavoidable. The content of carbon in these fossil fuels varies and therefore the generation of carbon dioxide varies by the combustion. Carbon dioxide is a major greenhouse gas (GHG) and another one is methane which is released by mining coal or formed by decomposition of organic matters. An increased concentration of GHG in the atmosphere hinders the radiation influx from the sun to leave the atmosphere and temperature is increasing resulting in global warming. A higher temperature in the atmosphere is supposed to result in climate change on the earth with unpredictable effects.

In the combustion process sulphur and nitrogen oxides are formed depending on the content of sulphur in the fuel and the conditions for combustion. The content of sulphur varies in both coal and petroleum. Crude oil is refined and it is therefore possible to control the content of sulphur in the petroleum products and the level of sulphur is only a question of cost. Natural gas has normally a very low content of sulphur or even zero.

Coal consists of volatile matters and ash as well as small amounts of heavy metals forming different types of less wanted products by combustion. Crude oil has a much lower content of ash than coal. The ash content is released by combustion as solid particulates and these are of different sizes and cause different types of problems discussed later.

Coal is responsible for the major pollutions among the fossil energy resources. But burning oil always generates carbon, sulphur and nitrogen oxides and particulate matters though much less than coal. Natural gas is the cleanest fossil energy resource and generates less carbon dioxide than both coal and oil and no particulates. The amount of nitrogen oxides is very much dependent on the combustion temperatures as oxygen in the combustion air reacts with the nitrogen in the air (Wu et al, 2006).

Sulphur and nitrogen oxides are normally released from the combustion chamber through the chimney and transported and dispersed over wide areas. The oxides mix and react with rain and form acid rain which causes damage to crops and trees and even results in acidification of rivers and lakes. In severe cases the aquatic ecosystems can be in danger. Acid rain effects both soil and water negatively, but it also leads to corrosion and erosion affecting buildings and monuments (Wu et al, 2006).

The particles released by the combustion of solid fuels and oil found in the air pollution can be harmful to man. The potential threat to health is directly linked to the size of the particles. By inhalation particles smaller than 10 micrometer normally pass the nose and throat and enter the lungs. These particles may affect not only the lungs but also the heart and can result in serious health effects. The particles are normally divided in two groups. The first group is “coarse particles” larger than 2.5 micrometer but smaller than 10 micrometer. These particles are typically found close to roadways and industries. The second group is “fine particles” smaller than 2.5 micrometer. Fine particles may be emitted directly from power plants, industries or cars or formed when other pollutants like sulphur and nitrogen oxides react with the air, forming acid rain. The particles are part of the particulate matter (PM) pollution which consists of sulphur and nitrogen oxides, organic chemicals, black carbon, heavy metals and soil and dust particles. The coarse particles are called PM10 and the fine ones PM2.5. The World Health Organisation (WHO) gives guidelines for annual mean concentrations of PM10 and PM2.5 (World Bank, 2012).

Natural gas is the cleanest fossil energy resource and consists basically of methane, propane and small parts of nitrogen and sulphur. By combustion of natural gas mainly carbon dioxide and water are formed together with some nitrogen oxides. Natural gas can be considered a strategic energy resource for the future as it has the potential to replace coal and oil in the energy consumption mix. The air pollutions generated by burning coal and oil would decline and the outlet of carbon dioxide as well as natural gas generates less than both coal and oil (Lv, 2009).

Hydro, solar, wind and biomass are all renewable energy resources and in general considered to have low or non impact on environment. Concerning hydro a distinction has to be made between small and large scale hydro. Large scale hydro power plants need dams for regulation of the power generation. The dam normally takes a vast area of land into account. This leads to productive land and natural habitats coming under water. The local impact can be severe and the disturbance of ecology is a threat. As a further result people are displaced and cultural sites are lost. The dam in itself raises security concerns about a possible collapse. The project Three Gorges is an example of all this (Wu et al, 2006). Biomass is a renewable energy resource but burning biomass releases particulates and nitrogen oxides and impact the environment at the local level. Small scale hydro, solar and wind are the most environmental friendly energy resources though wind power generates disturbances in the form of noise.

Wind energy is a sustainable form of energy and pollution free. Wind power has instead the potential to reduce air pollutions from electricity generated by coal. The generation of 1000 kWh by wind power saves the combustion of around 290 kg coal and the pollution it causes. This would be the ideal case but then cost has not been taken in account. Power generated by coal is still significantly cheaper that wind power (Han et al, 2009).

Nuclear energy does not harm the environment in the way coal does. But the final disposal of the radioactive waste is not solved and the risk for severe accidents is still a major potential environmental problem which can not be forgotten. The Japanese accident in Fukushima has recently reminded the world about that.

The conclusion is that the major environmental impact of primary energy consumption in China is coming from the use of coal. This view is shared by Chinese scholars and other independent observers like Greenpeace. The environmental impact can be seen from two

different perspectives. The first is the local and regional perspective and the second is the global perspective. The local and regional impact on environment is clearly recognised in both urban and rural areas. Effects of air pollution in form of dust, sulphur and nitrogen oxides, acid rain, small particles and degradation of the fresh water resources are mostly local and regional phenomena and closely related to the vast mining and burning of coal. The global environmental impact is rather long term compared to the local and regional perspective and is related to the outlet of GHG. Carbon dioxide is the most prominent gas of GHG and is generated by combustion of all fossil fuels, mostly from coal. The global perspective is about global warming and the effect on climate change. In the next chapter the focus will be on these two perspectives.

5. Environmental impact in China since 1978 and the current situation

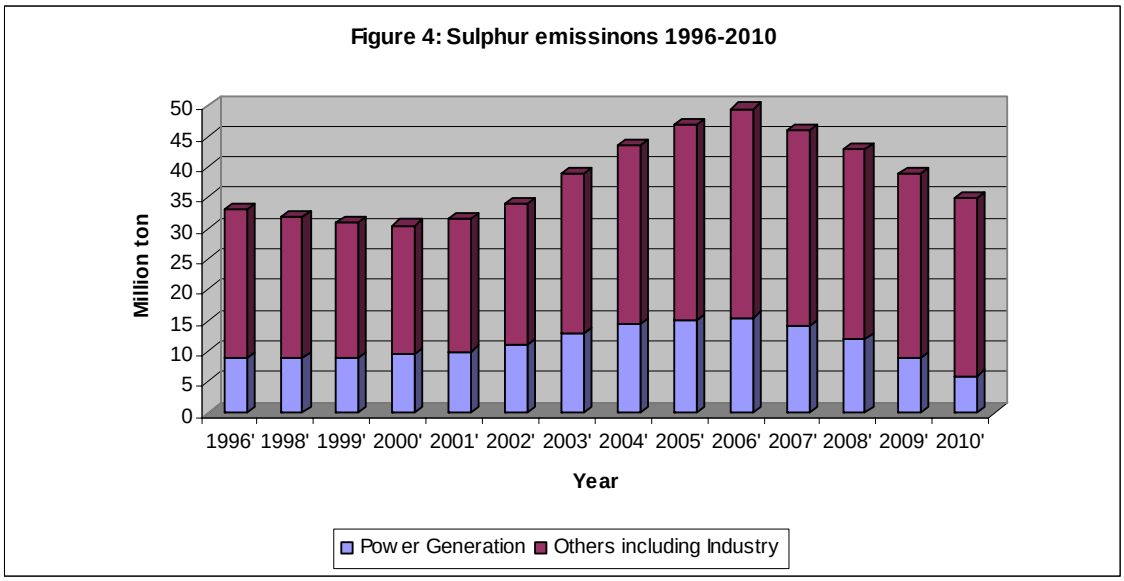
The development of pollutions in China will be described by referring to World Bank data and the selected articles. First, the local and regional perspective on the environmental situation in the beginning of 1990s will be discussed. Then the outlook from this point in time based on the development since 1978 will be described. Thereafter the development from mid 1990s up to around 2010 will be in focus. The outlook from the beginning of the 1990s will be compared with the real outcome concerning the emissions of sulphur and particles so far. Second, the global perspective with the outlet of GHG will be discussed. Third, both perspectives described by mainly Chinese sponsored scholars and the World Bank will be challenged by Greenpeace to help create a balnced picture as far as possible.

In a World Bank paper from 1995 the development of China's energy sector is described in terms of reform, efficiency and environmental impacts (Johnson, 1995). This paper states that coal is the only domestic energy resource available to satisfy a high demand for energy if China wants to continue with the GDP growth rates seen since 1978. The environmental situation in early 1990s, including the concerns over global climate change, is described as well as an outlook for the primary energy consumption and environmental impact for year 2000, 2010 and 2020 respectively. This will be further elaborated in following parts of this chapter.

In 1993 coal combustion was responsible for a big part of the particulates released in China and almost all the sulphur emitted. The total emissions of particulates and sulphur dioxide was 14 respectively 16 million tons this year. This amount can be roughly compared with the coal consumption in 1990 and 1995 estimated to 750 respectively 1000 million tons (Zhang et al, 2011). This shows that a significant amount of pollutions are released to the air. But it is obvious that the Chinese have taken action to reduce the outlet of particles as the particulate emissions are roughly on the same absolute level in 1993 as in 1981 though the use of coal has almost doubled during this period. On the other hand the doubling of sulphur dioxide emissions during the same period indicates that no actions to control these emissions have been taken (Johnson, 1995).

The emissions from particulates and sulphur dioxide were in 1993 related to the following sectors: electrical power 30 %, other industry 44 %, residential 16 %, transport 3 % and other 7 %. The use of coal in many small and inefficient industrial boilers and household stoves account for almost half of the emissions (Johnson, 1995). In many cities the concentration in the air of emissions in mornings and evenings were recorded and showed high values. This supports the conclusion that residential use of coal for cooking played a major role for the bad air quality in cities. In many of the Chinese big cities the recommended limits from WHO at this time for concentration of particulates and sulphur dioxide were exceeded as annual means by up to 6 times. Looking at seasonal averages it was even worse (Johnson, 1995). At this time carbon dioxide was not in the main focus. It was rather sulphur and nitrogen oxides which were debated by environmentalists.

China became in 1995 the second largest emitter in the world of sulphur dioxide. Estimated emissions of sulphur dioxide in China 1996 were about 24 million tons which declined to 21 million tons in 2000 and the then increased to 34 million tons in 2006. The emissions declined after that to around 31 million tons in 2010 (Lu et al, 2011).



Source: Lu et al, 2011

The level of SO2 emissions in 2010 had increased during the last 15 years by roughly 7 million tons or more than 25 %. But there are two periods of decline. The decline 1996-2000 can be explained by several factors. The downturn of economic growth caused by the Asian economic crisis and the restructuring of industry in China are a couple of explanations. There was further a decline in use of coal in residential and industry sectors and a reduction in the average content of sulphur during this period. The second period of decline started after the highest level of SO2 ever had been estimated for China in 2006 and major reasons for the decline are the application of new technology and the closing down of high emitting small power generation plants. The new technology was the removal of sulphur dioxide from the flue gases in power plants (Lu et al, 2011).

This technology, Flue Gas Desulphurisation (FGD), had been used in the developed part of the world for a long time when it started to be used in China around 2000. The penetration of power plants in China was only 1 % in 2000 but at the end of 2010 it had risen to 83 %. The estimation is that more than 19 million tons of SO2 were captured in 2010. Combustion of coal was responsible for around 90 % of the emissions (Lu et al, 2011). This means that without FGD technology the emissions of sulphur dioxide would have been more than 60 % higher.

The emissions in 1996 from the power generating sector were 37 % and increased to 51 % in 2004 and decreased then to 21 % of sulphur dioxide outlet. In comparison the industry sector decreased its emissions from 47 % to 38 % in 2002 but increased to 66 % in 2010 (Lu et al, 2011). The power generation sector has played an important role in the reduction of sulphur dioxide in China. However, about 70 % of all major cities in China have exceeded standards for SO2 emissions (Soile, 2011).

The variation between regions is another factor to be considered. In the northern part of China the climate is colder and therefore more coal is used. Therefore particulate emissions were much higher there. On the other hand the sulphur emissions trend were higher in the south of China as the sulphur content of the coal mined here was higher than in coal mined in the north (Johnson, 1995). The conclusion is that environmental impact is local and regional when it comes to air pollutions and the reasons can be different. The comparison with London in 1952 is obvious (Logan, 1953).

The next issue to be discussed is the forecasts for energy consumption and the environmental impact for the years 2000, 2010 and 2020. (Johnson, 1995) The main assumption made is that the average GDP growth rate is 8 % (in 1990 constant dollars) until 2020. Further more, the energy efficiency is improving at the same pace since 1980 and energy intensity of GDP in 2020 has fallen to approximately one-third. In this scenario the annual primary energy consumption increases by roughly 4 % between 1990 and 2020 and reaches a consumption of 3.3 million tce in 2020. The energy consumption levels predicted for year 2000 and 2010 were to 1.56 respectively 2.38 million tce (Johnson, 1995).

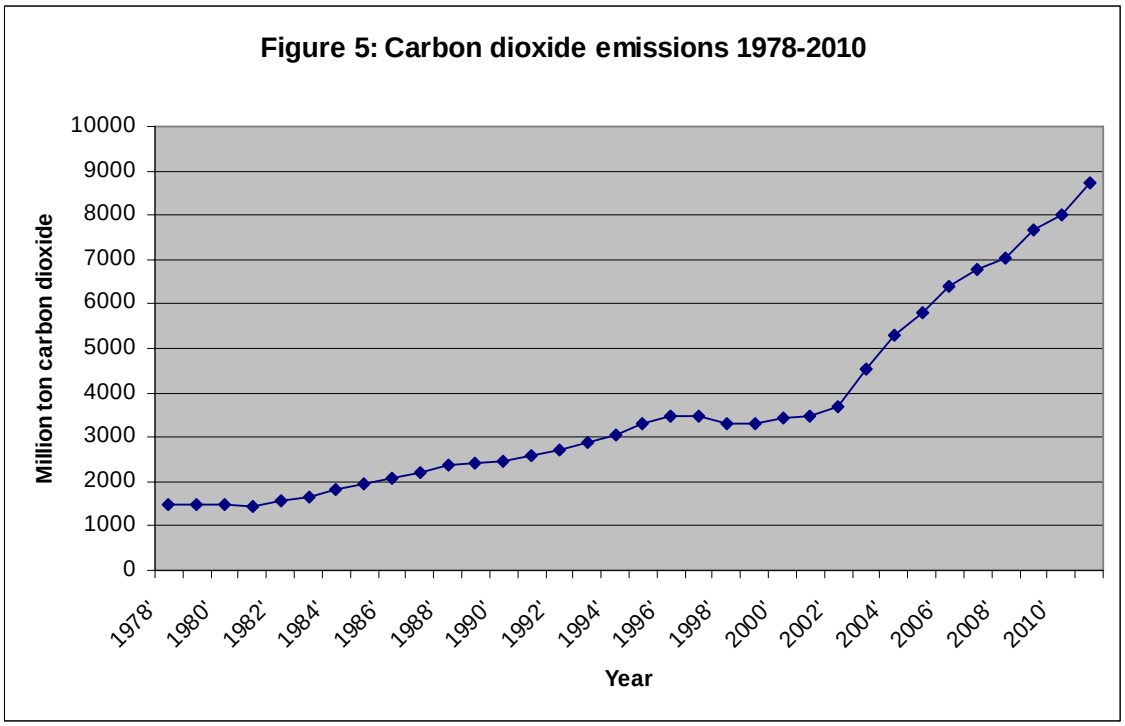
Though the scenario above overestimates the consumption level a bit in 2000 it has clearly underestimated the primary energy consumption in 2010. In chapter 3 the outcome for 2010 is stated as 3.25 million tce which is very close to Johnson's forecast for 2020. The conclusion is that this scenario is a conservative one and should be kept in mind during the discussion of the environmental impact. The predicted emissions of sulphur dioxide in year 2000 were 27 million tons and in year 2010 they were 41 million tons. The assumption is no change in emission coefficients from 1990. The absolute volume of the emissions is increasing in this forecast and the environmental impact as well.

Compared to the real outcome described earlier in this chapter the outlet of sulphur dioxide in 2010 was 31 million tons or 10 million tons less than forecasted in the early 1990s. But the remark has to be made that without the capture of 19 million tons by the FGD technology the outcome had been about 50 million tons of sulphur dioxide which is almost 25 % more than originally forecasted based on the emission coefficients from the beginning of 1990s.

China has during the past decade reduced air pollutant concentrations including particulate matter (PM). In some cases the reduction in urban areas has been achieved at the expense of rural areas when industries have been relocated. But on the other hand the air movement may transport regional rural air pollution to local urban areas. There are examples that the urban concentration of pollutants are only to about half coming from local sources. However, in the industrialised northern part of China the PM pollution is still severe (World Bank, 2012).

The monitoring of air pollution in 612 cities in China shows that in 2009 only a few met the Chinese standard for PM10 which is 40 microgram per cubic meter (WHO guideline only 20) and that 63 cities exceeded 100 microgram per cubic meter. That means that 10 % of the monitored cities exceeded the WHO guideline 5 times. China has no monitoring system or standard for PM2.5 and there are no policy or abatement guidelines either. The latest research indicates that PM2.5 pollution is serious in urban areas in the north (e g Beijing) with annual average concentrations in the range 80-100 microgram per cubic meter. This is significantly higher compared to the US standard of 15 microgram per cubic meter. This environment is a threat to man as PM2.5 is one the most dangerous pollutants to man as it can cause respiratory diseases (World Bank, 2012).

The global perspective is closely related to the outlet of GHGs where carbon dioxide is the most important one. The increasing concentration of GHG in the atmosphere is supposed to cause climate change which will affect not only China but the whole world. This is a more long term threat compared to emissions of particulates and sulphur to the air which show a more immediate effect.



Source: World Bank and US Energy Information Administration

The total GHG emissions in China were relatively constant during the period 1997-2001 but increased rapidly during 2002-2005 and the increase has slightly slowed down in 2006-2009, though the emission intensity is rather stable or even declining slightly (Liu et al, 2012). This paper has studied not only the aggregated outlet of 30 Chinese provinces but also analysed the carbon dioxide intensity in individual provinces and their industrial sectors. The outcome was that economic activity was the main driver in all provinces for GHG emissions during 1997-2009. Reduced carbon dioxide intensity could only partially offset the increase of total GHG emissions caused by the economic activity. There is a significant difference between the individual provinces in terms of GHG emissions but also in economic structure. A trend towards higher carbon dioxide intensity was found especially in less developed provinces.

The economy in China is to a great extent dependent on primary energy resources and these are mainly to be found in less developed provinces. The efficiency in specific sectors is very low in these provinces. The barrier to a better environmental situation is not only economic but also technological. Access to advanced technology and equipment is crucial to reduce the environmental impact of economic activity. The inequity of technology level among Chinese provinces is an effect of the mitigation actions by government. The disparity in technology

levels and the way of setting targets for energy intensity in different provinces are the reason for this. An illustrating example is that both Beijing municipality and the Liaoning province currently have the same targets for reducing emissions. Beijing is the capital city with service industries and electricity supply coming from other provinces while the Liaoning province has heavy industries and many state-owned manufacturing industries. It is not easy to change the industry and energy structure in a province like Liaoning. The officials in such a province may, without access to modern technology, not take the reduction targets seriously and stay with old low efficient technologies. The reduction of emission might not be realised (Liu et al, 2012).

The question if this is a true description of the current situation will now be discussed. According to the World Bank paper from 1995 it is obvious that China must have been aware of the potential impact on environment of a future high energy consumption rate. Greenpeace points out that in the beginning of 2013 Beijing faced a period with hazardous air pollution comparable to the London smog in 1952. Greenpace recruited volunteers to wear personal air pollution samplers simulating the human breathing. The samplers captured PM2.5 in a filter which could be sent for analysis. The analysis showed that the filter contained a cocktail of arsenic, lead, mercury and selenium which are known to cause cancer in the lungs. The hospitalisation in Beijing due to respiratory illness is estimated to have increased three fold during this period of time. The consumption of coal is seen as the major origin of these problems and pressure to reduce coal is growing (Myllyvirta, 2013).

In another recent Greenpeace article it is stated that “King Coal keeps still growing faster than renewable energy”. China is one of the world leaders in renewable energy investments but has not been able to change the energy mix significantly during the past years. Contributing to this is of course the fact that the coal consumption in China is almost 50 % of the total coal consumption in the world. A fast shift away from coal in China is necessary and the costs are declining for renewable energy. The energy policy has to be reformed to promote renewable energy (Kosonen, 2013).

China was already in the mid 1990s aware of the potential degradation of environment if the energy consumption should continue to grow. Have the Chinese established an energy policy and an air pollution regulation since then? Energy conservation and pollution control have been part of the FYP (Five Year Plans) in the past, but mostly in more general terms. In

addition Energy Laws, like Energy Conservation Law and Renewable Energy, have been approved. In the eleventh FYP energy conservation and pollution control were further emphasized with a target of cutting energy consumption per unit GDP (energy intensity) by 20 % and pollution discharges by 10 % from 2006 to 2010 (Liu et al, 2012). The official Chinese statistics show that the energy intensity, with great effort, was reduced by around 19 % by the end of 2010 (Hu, 2012). The 12th Five-year Plan (2011-2015) presented in March 2011 proposed to reduce energy consumption per unit GDP by 16 % and CO2 emissions per unit GDP (carbon intensity) by 17 % (Hu, 2012).

The conclusion is that the Chinese government has taken actions but it seems not to have been enough. The compliance with laws and policies are most likely weak. An indication of this is found in the newspaper Di Dimension in April 2013 (Hedelin, 2013). In the article it is stated that local authorities and industries are cheating and are not always keen to follow national laws and policies. A reason for this is probably that independent follow up routines are not in place and the lack of severe punishment when breaking the laws. Close ties between industry management and the local authorities are also creating an atmosphere for corruption. Though China has environmental regulations that can be considered reasonable they are not followed and the environment suffers.

A further conclusion is that target setting is relative and shows an improvement as long as GDP growth rate is higher than the increase in energy consumption. In absolute terms the energy consumption is then still growing and that is the most important issue as that means the concentration of pollutions in the air will continue to increase. Even if sulphur and particles are removed in the existing facilities the additional new consumption of coal in new ones will increase the outlet of pollutants in absolute terms as long as the energy mix is unchanged. Coal has been the main energy resource driving the economic growth for more than 30 years. In 2009 coal was still the abundant energy reserve in China representing more than 90 % of the total fossil energy reserve. China had only about 7 % of the world's oil and natural gas reserves respectively. A transfer from coal to oil and natural gas would be beneficial for the environment in China but it would raise the dependence on import of oil and gas. It is easy to understand why the Chinese government has been sticking to coal.

The impact of energy consumption described by mostly Chinese scholars can be considered as factual information but they are not addressing the risks of the environmental degradation and

they are not stressing the urgent need for action as NGO's like Greenpeace. A central question is if China is stuck in a negative spiral or if it is possible to change the current situation? It seems urgent to start action and some options available for China will discussed in the next chapter.

6. Options to reduce environmental impact

The rapid economic growth in China has literally been fuelled by fossil energy resources and the degradation of the environment is obvious today. In the literature the relationship between economic growth and the level of environmental degradation is known as the Environmental Kuznets Curve (EKC). This is an inverted U shape relationship where the initial stages of growth results in gradual environmental degradation. Then at a certain level of economic growth the degradation levels out and the environmental conditions start to improve. Several scholars have tested the EKC hypothesis but the results are conflicting (Jalil et al, 2011).

The Chinese government has emphasised environmental protection gradually during the last decade or so. The increased environmental awareness, education and investment in research and development (R&D) and environmental protection have not prevented an increase in the degradation of environment. The turning point according to EKC has not yet occurred in China. Therefore the government in China has to take further action to reduce environmental impact (Zhang et al, 2012b).

What is the potential to mitigate the environmental impact in China and which measures can be taken? When looking at the energy intensity and the energy consumption mix it is clear that the potential is significant. Energy intensity in China is, as seen in chapter 3, between 50 to 100 % higher compared to developed countries. The energy efficiency in China is low since modern technology is missing in many cases. The heavy dependence on coal, the most dirty fossil energy resource, is high compared to most developed countries. Substitution of coal with oil and natural gas is one way to reduce the environmental impact. A further way is to clean the flue gases by burning coal. This requires access to modern and mature technology.
Another way is to replace coal with renewable energy resources and nuclear energy. These measures will lead to a change in the energy consumption mix. Energy policies and

regulations are other ways to combat degradation of environment. The conclusion is that China has a potential to achieve a reduction of environmental impact through different measures.

The improvement of energy efficiency in energy consumption is one option to reduce the environmental impact. One way of doing this is to strengthen the ECA system. The ECA regulation has to be taken to the local level and the stipulations have to be further detailed. The rights and obligations for assessors and examiners and the legal liabilities for all parties must be defined clearly. Public participation and transparency have to be guaranteed. The education and training of energy conservation consultants is of importance. Further research in the area of energy efficiency improvement must be conducted and databases have to be established and publicly available. The projects must be supervised, monitored and penalties should be introduced (Hu, 2012).

China has a vast territory and the economic and energy structure as well as environmental impact differs from province to province. In spite of the increased market orientation there is a top-down approach concerning e g goals for energy and emission intensity. Provinces are grouped and different goals are allocated in the FYP. The provincial technology level is not always recognised in the goal setting process resulting in targets which are not anticipated as realistic. An option to improve environmental conditions in China is that the government realises the local differences and facilitates transfer of modern technology to less developed provinces (Liu et al, 2012).

The change of the over all energy consumption mix is another major option. The obvious way of doing that is to decrease the consumption of fossil energy resources and increase renewable energy resources and nuclear energy in the consumption mix. China has a huge potential for increasing the use of renewable energy resources in the energy consumption mix as described in chapter 3. Part of the option is increased use hydro and wind energy, bio-mass and solar energy. An example of the potential to change the energy consumption mix is to apply SWH systems for hot water generation which reduce the use of fossil fuels. Most of the renewable energy resources have at least so far faced a tough competition from coal. Though China has 60 % of all SWH systems in the world there is still a great potential which today partly is hindered by weak policies, lack of technology development and market conditions.

Another possibility to change the energy consumption mix and improve the environmental situation is to replace coal and oil by natural gas as pointed out earlier. China has compared to developed countries a low part of natural gas in the energy mix and this can be explained by the historical preference for coal in China. The governmental awareness of the degradation of environment by the high use of coal has increased the interest for natural gas. But as the demand for natural gas is growing fast in China there is at least three issues the government has to tackle to promote natural gas. New exploration and new infrastructure are two vital issues but the domestic natural gas resources will not be enough to meet demand (Li et al, 2011). The technical potential to reduce the use of coal for electricity generation by wind power is there but the economic conditions for wind power have to be improved (Han et al, 2009).

A further option related to technology is the potential of financial development. Recently the link between the financial development and the environmental performance in a country with rapid industrialisation has been studied. Evidence is presented showing that if the financial sector in a country functions well it can provide higher investment to lower cost. The financial intermediaries can not only provide resources for investment but also identify the best technology for the environmental project (Tamazian et al, 2010). Technological innovations are also encouraged by financial development (Tadesse, 2005). “Technological changes in energy supply mix can significantly affect the emission reduction in an economy which has a well-developed financial system” (Kumbaroglu et al, 2008).

Another option to reduce the environmental impact is to convince households to change their pattern of consumption. The behaviour of households would be changed in the direction of the use of more energy efficient and low carbon intensity goods and services. This may not be easy as urbanisation continues. When people are moving to urban areas the incomes increase and then the energy consumption increases as people want to catch up with western lifestyle. This means that energy intensity has to improve and people must be encouraged to change their way of consuming energy in direction of a low carbon society (Liu et al, 2011).

An option in line with changing the consumption pattern for households is to change the over all economic structure. A transfer from heavy energy intensive industrial production to less energy intensive production and services is a transition seen in developed countries in the

past. This will definitively change the energy demand in China and the pattern of energy consumption.

In conclusion Zhang summarises four possible options to reduce environmental impact of the increasing energy consumption. The first option is to invest more in education and R&D and not only by government but also through multi channel financing. The second option is to increase consciousness of people about environment and giving them the chance to participate in economic planning on regional and national level. Chinese R&D activities should not only consider economic and technological aspects but further weight should be put on environmental issues. Inclusion of environmental indicators in evaluation of these activities is recommended. The third option is to enlarge the governmental investments in environmental protection through public and social investment and, further strengthen supervision of existing environmental protection facilities to make sure they are in normal operation. The fourth option is to put more emphasis on the development of renewable energy and raise the efficiency of the use of fossil energy resources (Zhang et al, 2012a).

“New technological investments, financial assistance and targeted policies are inevitable for a sustainable evolution of the energy sector” (Jalil et al, 2011). In next chapter the challenges China faces today will be discussed.

7. Future challenges for China

China has a number of options to reduce the environmental degradation caused by the energy consumption. Although China already in the 1990s was aware of the environmental impact and options available to counter the development the environmental degradation has continued. In this chapter five major challenges will be addressed and elaborated. What has China to do to meet these challenges?

Improvement of energy intensity

One of the challenges for China is to improve energy efficiency in industry and the potential is significant. But there are several barriers to overcome. A first barrier is the low awareness by management on company level. Second, there is many times a lack of knowledge and

information within companies. Third, the companies do not have the money to finance the investment in energy efficiency. Fourth, the policies and the legislation are limited and the enforcement is weak (Punte et al, 2005).

In addition to knowledge and information the issues of access to technology and financial capacity are important. China faces the challenge to reform the legal system and strengthen enforcement of policies and legislation.

Changing the overall energy consumption mix

Another challenge for China is how to change the energy consumption mix to avoid the high dependency on coal. The demand for natural gas is increasing and is an option to replace coal and reduce impact on environment. China has only about 7 % of the natural gas reserves in the world and the government has to invest in new exploration and infrastructure but also import natural gas to be able to replace coal with natural gas. The government has to invest in these activities and subsidise the import if natural gas should compete with coal.

Wind power has a significant potential but power from coal is too cheap and the investment cost for wind power is still too high. The challenges here are three. First, a fuel tax could even out the cost difference. But that would raise the electricity cost and hamper the economic development, at least in the short run. This shows the dilemma, slower economic growth and better environment or higher growth and higher environmental impact. But if the collected tax from coal was directed to renewable energy development the long term consequences could be different. Further, the current concession model could be reformed to be more efficient than today. If the grid has a fixed feed-in tariff instead of the lowest price given to the winner of the concession it would be beneficial for the developer. The concession process could also be improved in terms of quality, locations with high wind speed should be given premium and the turbine manufacturer should be allowed to have contractual relations with more than one developer bidding in the same concession area. Another area of improvement is international cooperation on wind energy technology. China needs to build capacity in this field to be able to lower manufacturing cost and needs therefore access to western knowledge and technology (Han et al, 2009).

The potential for hydro power is also significant but the time span from planning a power plant until operation is very long compared to wind power. Large scale hydro power plants with dams occupy a vast amount of land and have a lot of implications both on landscape and people. The hydro power plant Three Gorges is a very good illustration to this. Therefore hydro power is rather a long term option than a short term one to replace coal.

Other renewable resources – biomass and solar PV – are still expensive compared to coal and need subsidies to be able to compete with coal. Cheap coal energy is still the most favourable economic alternative in most cases compared to renewable energy. This could be changed with higher taxation of coal or/and more subsidies to renewable energy resources. Solar energy in SWH systems is an example where the economics are fairly good but that is not enough. China has to strengthen the policies, improve technology and reform the market for SWH systems (Han et al, 2010).

In conclusion China has to reform the systems for taxation of fossil energy resources, coal in particular, and the subsidisation of renewable energy resources to change the energy consumption mix. Access to modern technology is also vital. The respect for property rights has to be improved if China wants to import modern technology. The enforcement of policies and regulations is another important aspect related to the legal system.

Financial development

In the case of China one option, to improve environmental conditions, is to further develop the financial sector. The bank sector is the most important institution to develop as it is mostly controlled by the government. The challenge is the stock of non-performing loans which amounts for roughly 20 % of the total national income. The Chinese authorities have to address this problem and start to reform the banking and financial sectors. The reforms have to include privatisation of state-owned enterprises and banks (Jalil et al, 2011).

The challenge here for China is to reform the banking and financial sectors and support the privatisation process in these sectors as well as in the energy sector. The government is likely to face powerful stakeholders who might reject such a process.

Structural change from industry to services

In developed countries the shift from industry to services has lowered primary energy consumption. The investment driven economy in China has at least so far countered such a development as energy intensive industry has grown during the first decade in the new millennium. The government faces a situation where a structural change would reduce the impact on environment but might harm short term economic growth. This is a real challenge for the government as economic growth seems to have the highest priority.

This challenge is about changing focus from investment in energy intensive industries to the service sector with low investment. Such a change would mean a new development path and partly a step towards a path which is less known and less comfortable for the government in China. Has the Chinese government the courage to promote a fast transfer from heavy industry to services?

Investment in new technologies

The successful reduction of sulphur shows the potential to mitigate environmental problems by new technology. The challenge for China is to get access to technology from developed countries and this is not always an economic question but often rather an issue of property rights. This has recently been demonstrated by the denial from General Motors (GM) to transfer the latest automobile technology to China. A stronger legal system with clearly defined property rights would improve the Chinese situation.

The challenge to get access to modern technology is very much about an independent legal system and the enforcement of a fair legislation not only for Chinese enterprises but also for foreign firms.

8. Summary of the literature survey and discussion of the outcome

The first conclusion of the literature survey is that the environmental situation is severe in China. The articles by scholars funded or influenced by the Chinese government describe facts and suggest relevant actions to reduce the impact on environment by primary energy

consumption. The speed of degradation is not emphasised and the urgency of action is not always obvious. This perspective is on the other hand more clearly stressed by environmental NGO's and newspapers. In summary this shows the urgent need to take action in a local and regional perspective though some areas in China are less affected than others. The global perspective is very much about the outlet of carbon dioxide and here China is one of the major polluters.

The second conclusion is that China has a number of options to reduce the impact on environment. Options elaborated in this paper are energy intensity, energy consumption mix, the financial development, change of economic structure in industry and investment in new technologies. But China has a number of challenges on the national level to handle in order to exercise the options. Education and involvement of citizens are key challenges as well as the enforcement of energy policies and regulations. Other challenges are access to know-how and technology and here the Chinese legal and property right system is a major obstacle. The potential for reforms in this area are also a potential for reducing environmental impact. Other reforms which could contribute to lower impact on environment are a modern energy taxation system and a modernisation of the banking sector. These actions could support a transfer from coal to renewable energy resources and a cleaner environment.

The third conclusion is that the current dependence of coal is high and the current economic growth rate is high. This means that the transformation of the energy consumption mix towards more non-fossil energy resources will be quite slow though China is among the world leaders in renewable energy. This is specifically a problem in the global perspective as the outlet of carbon dioxide is unavoidable when burning fossil energy resources. The technology of sequestration of carbon dioxide is not commercial like technologies for removal of sulphur dioxide, particles and nitrogen oxides. This is a major concern for the rest of the world.

Has the methodology used in this paper influenced the conclusions above? Without the view presented by environmental NGO's the urgency of action to reduce the environmental impact had not been obvious. On the other hand, are NGO's overreacting? It is of course possible as environmental NGO's want to focus on the problems to initiate action. The urgency to take action is of great importance and the frequent reports in media stresses that fact. Recently, on May 16th 2013, CNN reported about demonstrations in Kunming where the demonstrators expressed their fear of the environmental impact of a new refinery planned (Watson, 2013).

The lack of openness was criticized and this is a major problem and a great challenge in China. The government decides over the head of people and state-owned enterprises by party members build and operate new facilities without involvement of people living in the area. Corruption and cheating are other problems also highlighted by Hedelin (Hedelin, 2013). If this continues the trust between citizens and authorities will be undermined and the risk for social unrest will grow.

The statistics for the environmental impact used in this paper may be compiled on terms contrived by the Chinese government. Particularly in newspapers it is often stressed that Chinese authorities want to downplay the degradation of environment. This could indicate that the environmental degradation is even worse than described in this paper. The way of using energy intensity as a measure of reducing environmental impact is dangerous as the absolute level of outlet of pollutants to the atmosphere is what is really having an impact people's daily life. Even if the energy intensity could be curbed the fast growth of energy consumption will result in the outlet of more pollutants in absolute terms. The increased outlet of particulates, sulphur and nitrogen oxides might be captured today, at least to some extent, by modern technology and therefore reduced. But there is no commercial technology for capturing carbon dioxide today. The technological measures available to mitigate environmental degradation are costly and as the enforcement of current environmental laws is weak it is understandable that enterprises, in order to save costs, do not even use existing environmental protection facilities (Hedelin, 2013). This cheating is often in agreement with local authorities, who are many times stakeholders in the enterprises and fear the competition with other provinces in the country. This is clearly an evidence of the huge gap between the Chinese government and the local authorities and the weak enforcement of the legal system.

The growing awareness, manifested by numerous demonstrations reported in international media, among the middle class in China might be seen as a hope for the environment in the long term perspective. But short term it seems inevitable that degradation will continue. The hope could be that the development takes the same route as in Taiwan, towards democracy.

Finally, the question is if the Chinese government is able to take action before it is too late. Is it politically and economically possible to promote environment before economic growth on the local and regional level? Even if the answer is yes, there is still doubt about the global level. The coal dependence in China will continue to contribute to the increasing

concentration of GHG in the atmosphere and the threat of climate change in the world will persist. This could be a topic for further research.

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