LUNDS UNIVERSITET

The Three Gorges Project: A Dilemma of Energy Security and Sustainable Development in China

Hao Fuchun

Scientific supervisor:

Per Svenningsson

Acknowledgements:
First of all I would like to express my deep gratitude to people whose invaluable help and support made this paper possible, especially my ever-patient advisor, Per Svenningsson who has always been available to help and guide me. Thank you.

Support has come from many fronts, particularly from those here--Ingegerd, Åsa and Mats who accepted me as one of Great LUMES students, your help has not gone unnoticed, many thanks.

Finally I owe a larger debt of gratitude to those who have supported me throughout my studies at LUMES – my lovely and respectable parents. Without your support and love this course would never have been possible, ever thankful.

Table of contents

List of Figures:

0 Abstract

Energy plays an important role in all dimensions of sustainable development including social, economic and environmental. There can be no sustainable development without a secure energy supply to underpin essential economic activity and provide services to society. All actions that provide secure energy services can be classified as energy security, which requires the affordable, reliable and available supply of energy for commercial and household use.

China, the most populous and economic fast-growing country in the world, suffers severe energy shortage because of widening gap between energy supply and demand, especially oil, natural gas and electricity. Due to stagnant domestic oil output and expanding oil demand from transportation and other sectors, China needs to import large amount of oil from abroad resulting in China's energy security concern. Currently, China's dependence on imported oil is growing, which has deep effects on China's national security, and would have great regional and global implications.

The Three Gorges Project, the biggest dam under construction, can generate a huge amount of electricity. Apart from energy supply, it still has potential to reduce the burning of coal, bring the serious floods along the Yangtze River under control, and provide some other benefits. However it also has many drawbacks and possible destructive consequences.

The big dam does provide renewable, reliable, and available electricity, which is an important factor in boosting China's development. However, since it does not directly alleviate the Chinese' dependence on imported oil, it does not bolster China's energy security; it seems not absolutely sustainable as well due to its negative effect on society and environment.

Due to lack of unified formula, it is hard to weigh gains against losses, and even difficult to choose energy alternatives if taking away big dams. This paper concludes by stating that energy efficiency is possible to play an important role in bolstering energy security and sustainability.

1Introduction

1.1 General information about this paper

Energy, which not only can be used to keep warm or cool, to cook food and to provide lighting, but also is essential for construction, transportation, communication and manufacturing, is crucial to civilization and modernization of humanity. Given that they can so dramatically increase human capabilities and opportunities, adequate energy services are integral to poverty alleviation and environmentally sound social and economic development.

Ever since the oil crises of the 1970s, there has been increased awareness that there are finite resources of carbon based energy sources, a renewed interest in the utilization of alternative and renewable energy sources, and a compelling focus on energy security issue. In addition, in Rio Conference in 1992, the international community agreed on the overarching goal of sustainable development and it adopted a plan on how to get there—Agenda 21. The importance of energy systems in supporting many dimensions of sustainable development was a theme that echoed throughout Agenda 21.

Since the first dam was built around 100 years ago, hydropower has been an important component of energy supply, accounting for 17.5% of the world's total electricity production and 3% of the world's total final energy consumption in 1999 (Koch, 2002). In developed countries, a large share of the potentially suitable sites have already either been exploited or been excluded because of environmental concerns. Most of the new hydroelectric schemes are situated in developing countries, particularly in South-East Asia and Latin America (IEA, 1998). In China, some large-scale dams are under construction or are going to be built, the most famous of which is Three Gorges Project.

Three Gorges Project has always been surrounded by media attention, controversy, and even opposition within China and abroad, especially international pressure, which peaked in 1992 when this project was approved by the Chinese government. Proponents say the dam does favor China's energy security as well as is beneficial to future generations, while opponents argue that the large dam has some negatively social and environmental influences on local people, which are enormously potential threat at present and in the future.

Even now, the Three Gorges Project is still an international concern as it is under construction. Sometimes the debate is even more serious than before. This paper is mainly focused on this big dam in which lots of scholars and students are interested.

1.2 The objectives and questions

This paper contributes to the understanding of sustainable development, sustainable energy and energy security, as well as their relationship. The study assesses the energy security and energy-related environmental problems. The thesis describes the basic knowledge of Three Gorges Project, and analyses its energy supply as well as environmental and social advantages and disadvantages. The current problems and concerns on big dams are discussed. Finally, the paper answers several questions as following:

- Does Three Gorges Project favor China's energy security?
- Is Three Gorges Dam sustainable?
- Are there some formula to balance the big dam's gains and losses?
- If the dam is taken way, is it easy to find some energy alternatives or other approaches to solve energy security issue?
- Is it possible to overcome the dilemmas?

1.3 Study method and limitations

This paper answers the questions posed mainly through a process of literature review: sustainable development, sustainability, energy security, pollution, and Three Gorges Project. Information data has been collected from various sources. Most of literature was from Lund University's Electronic Library Information Navigator and Lund University's library in Sweden. Textbooks were referred as well. Some literature was from websites by searching related information on Internet.

It is absolutely meaningful to visit and interview local residents and officials in order to get first-hand information. Nevertheless, although I once went to the Three Gorges Project several years ago, at that time I just traveled around and watched the scenery rather than interview local residents. In addition, due to political and security reasons, it is very difficult to get unpublished or so-called secret material from Chinese authorities. Consequently, there is no interview, which is one of the limitations of the paper.

Scientific literature was searched and used. Because of the difficulty to get recent official statistic data, some were traced back to 1990s. Furthermore, the data were from different journals and even internet-based, so the energy units used were different. Even worse, sometimes there is some discrepancy among different data, which is another limitation of this thesis.

2 Sustainable development and energy

Sustainable development has become an international common issue, which arose essentially from concerns related to the over-exploitation of natural and environmental resources (Anand & Sen, 2000). A well-known and influential definition was put forward by Brundtland (WCED, 1987), which is that humanity has "*to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs*".

According to Das (2001), sustainable development involves achieving objectives in three realms:

1. Ecological: Maintain a sustainable scale of energy and material flows through the environment such that the carrying capacity of the biosphere is not eroded.
2. Economic: Provide an efficient allocation of resources in conformity with consumer preferences and ability to pay.
3. Social: Strive for a just distribution of resources among people, including future generations.

Therefore, sustainable development provides a framework for integrating economic, social and environmental concerns over time, not through crude trade-offs but through the pursuit of mutually reinforcing benefits (Jonathan, 2003). Its challenge is to put material progress and the environment on parallel, complementary and hopefully mutually strengthening tracks (Johnston, 2002). It means economics and environment must be considered together in decision-making, both nationally and internationally (Hunt, 1990). In simple terms, societies should maximize economic growth and environmental improvement at the same time without endangering the natural systems that support life on earth: the atmosphere, the water, the soils and living beings. According to IEA (2001), "*Sustainable development is dependent upon balancing the interplay of policies and their effective implementation to achieve economic, environmental and social needs*".

2.1 Sustainable energy

Many factors contribute to achieving sustainable development. One of the most important is the requirement for a supply of energy services, which have deep and broad relationships with each of the three pillars of sustainable development – the economy, the environment and social welfare that are intrinsically linked. As mentioned in UNDP (2002), "*energy produced and used in ways that support human development over the long term, in all its social, economic and environmental dimensions, is what is meant by the term sustainable energy*". In other words, this term does not refer simply to a continuing supply of energy, but to the production and use of energy resources in ways that promote or at least are compatible with long-term human being and ecological balance.

Energy has always been important to humanity. The history of human beings is a history that human beings extend their capabilities and ingenuity of increasingly efficient and extensive harnessing of various forms of energy (UNDP, 2002). Since the industrial revolution, energy has been a driving force for modern civilization development (Afgan et al, 1998). It provides power, heat and mobility, which are indispensable for normal functioning of any modern society, and it is a critical production factor in virtually all actors of industry (Bielecki, 2002). It is considered a prime factor in the generation of wealth to improve people's living standard, and also a significant element in social-economic development (Kaygusuz, 2002).

However, energy production, transport, utilization and consumption, which generate undesirable by-products and emissions, affect the environment from the extraction of primary geological resources to end-use services (IEA Toward solutions, 2002). During the past several decades the risk and reality of environmental degradation—local, regional, and global, have become more apparent. It is evident that enormous environmental problems such as global warming, pollution, acid precipitation, ozone depletion, forest destruction, and emission of radioactive substances are related to energy (Dincer & Rosen, 1999). In addition, fossil fuels have been the dominant source of energy for the twentieth century; and they are a finite resource that will eventually been depleted or become too expensive to extract economically (Rogner 2000). Whilst there is much debate about the lifetime of these energy sources, there is a general consensus that they will eventually become less attractive, economically and technically, as the primary fuels for life.

Consequently, in spite of fact that adequate energy services is important for satisfying basic human needs, improving social welfare, and achieving economic development, production and use of energy has degraded the environment of current generation, and is likely to endanger the ability of future generations to meet their needs. At present, globally the demand for energy is increasing in consonance with socio-economic development, though in developing countries it increases a little bit more quickly than developed countries. Energy is sustainable when the energy system does not exceed the carrying capacity of ecosystems and not endanger the quality of life of future generations.

2.2 Energy security

A key element in any sustainable energy system must be that it is robust and can continue to provide the power regardless of changed situations. Clearly, whatever the energy system, it is important to have a secure energy supply.

In its most fundamental sense, energy security refers to the continuous availability of "*energy in various forms, in sufficient quantities, and at reasonable prices*" (UNDP, 20002). Energy security is a multi-faceted issue. It means uninterrupted supply that fully meets the needs of the local and global economy over time (Bielecki, 2002). It means undistorted pricing and stable, transparent relations between consumers and supplier (IEA Toward solutions, 2002). It also means to take into consideration the environment challenges (UNDP, 2002). Furthermore, the concept may have many different dimensions, ranging from political and military to technical and economic, and may entail various time dimensions such as the short and the long-term, as well as implicates that energy resources must be used as efficiently as possible (Bielecki, 2002).

For decades, energy security has been one of the goals of public policy. Concerns over it reached their peak during the period of the oil crises in 1973-1974 when prices first tripled because OPEC embargoes crude oil and in 1979-1980 when prices nearly doubled after Iran's Muslim Revolution (Jin, 1999). The highly increased prices of oil led to inflation and economic recessions involving substantial losses of GDP and high unemployment, consequently resulting markedly in the slowing down of global economic growth (Bielecki, 2002).

Today the ready availability of plentiful, affordable energy allows many people to enjoy unprecedented comfort, mobility, and productivity. Due to its growing importance to humanity, even very brief interruptions of energy supply can cause serious financial, economic and social losses (UNDP, 2002). Thus, it is clear that security of energy supply is crucial in the short and long term. There are four main implications with regard to energy security as following.

2.2.1 Oil security

Although over the past two decades, many changes in the oil market have improved the overall security of the energy market and the world economy has become less dependent on oil, energy security concerns continue to be determined mainly by the oil security concerns in the short or medium term (UNDP, 2002). Firstly, oil still remains one of the largest sources of primary energy, accounting for about 40% of energy consumption (Bielecki, 2002). Secondly, more than half of the world's remaining conventional oil reserves are concentrated in the Middle East, mostly in the Gulf region where there are security concerns; consequently, security is not a matter of absolute physical scarcity, but rather of regional distribution and the stability of supplier-customer relations (IEA Toward solutions, 2002). Thirdly, oil is the most massively traded source of primary energy accounting for two-thirds of international trade (Bielecki, 2002). Fourthly, some actors especially Asia-Pacific countries are expected to become more dependent on imported oil (UNDP, 2002). Finally, the oil supply prospects are not optimistic because oil production is approaching its highest level and the eventual depletion of the oilfields is to take place (Jin, 1999). So, the energy supply could become more vulnerable and there is potential decline in energy security in the future due to the oil market (IEA, 2001).

Dependence on imported oil means national economy is highly vulnerable to frequent swings in the price and supply of oil, because oil price is easily affected by political instabilities, trade disputes, embargoes, and other disruptions. The inability of oil markets to adjust rapidly to sudden changes in supply enables supply shocks, whether deliberate or inadvertent, to produce enormous increase in oil prices and, consequently, massive economic losses for oil consumer (David, 1997).

2.2.2 National security

Having abundant, reliable, and economical energy is also a national security issue. Energy remains a strategic commodity, and ensuring its availability is one of the important aspects of governments' ultimate responsibility for national security, because failure to meet increasing energy demand with increased energy supply, vulnerability to disruptions from natural or malevolent causes, could compromise nation's economic prosperity, lead to financial losses, and alter the way people live, which consequently would influence the national stability (Brooks, 2001).

Nowadays, some countries import most of oil that they need from foreign countries to meet domestic needs. High dependence on foreign oil not only leads to the possible vulnerability of domestic economy, but also brings foreign political pressures that can threaten national security (IEA, 2000). It is understandable that if there is conflict between two or among a few countries, oil sanction and embargo can be used as practical tool by relatively strong side to pressure or even threaten others, thus impairing their national security even sovereignty.

Motivated mainly by national security, currently countries have intensified their efforts to develop new energy sources, improve energy storage and transport systems, and secure existing supplies, sometimes to the point of waging war (Nolan et al., 2004).

2.2.3 Energy efficiency

One of the key initiatives that could be undertaken to address energy security is aggressive promotion of energy efficiency, which includes end-use energy efficiency meaning more efficient use of final energy in industry, services, agriculture, households, transportation and other areas, and supply-side energy efficiency including energy extraction, conversion, transportation and distribution. At present, the global energy efficiency of converting primary energy to useful energy is about one-third; on other words, two-thirds of primary energy is dissipated in the conversion processes, mostly as low-temperature heat and part of losses occurring when the useful energy delivers the energy service. Enhancement of end-use equipment can generally provide energy services more economically than improvements in generation or distribution (UNDP, 2002). With the increasing gap between energy supply and demand, using less energy for the same service is one way to avoid the conflict, because enhanced energy efficiency efforts would stretch the lifespan of currently utilized energy sources, buy time to improvise substitute sources of energy such as ethanol and other long-term oil replacement technologies, and cut oil imports quickly and significantly (Adnan, 2002). International experience has shown that vigorous energy efficiency measures can reduce the growth of national energy demand, lower energy imports and ease the energy constraints of economies therefore enhancing energy security (United Nations, 2001). Apart from energy security, energy efficiency also provides some other benefits including job creation, local economic development, enhanced international competitiveness, and reduced pollution (Rosenfeld, 1996).

2.2.4 Renewable energy

Renewable energy is created from the solar, wind, ocean, hydropower, biomass, geothermal resources, and biofuels and hydrogen derived from renewable resources, which are replenished constantly through natural process. Much attention was paid to renewable energy at a period when energy prices are volatile (IEA, 1998). Especially during the 1980s there was significant growth in renewable energy, fuelled in large part by the political desire to reduce oil dependence (Silverman & Worthman, 1995). Furthermore, environmental concerns have been affecting energy policy for more than a decade as the fossil fuel-based energy sector has been identified as a major contributor to recent environmental degradation. Directly or indirectly, environmental concern is one of the main drivers for expanded deployment of renewable energy technologies. In particular, the large potential renewable resource could be of great importance in reducing greenhouse and acid gas emissions associated with fossil fuel power generation. (IEA, 1998; IEA Renewable energy, 2002)

Renewable energy technologies produce marketable energy by converting natural phenomena/resources into useful energy form. The usage of renewable energy resources is a promising prospect for the future as an alternative to conventional energy. Consequently, it can relieve some of that increasing need for imported fossil fuel and reduce the dependence on foreign resources, which is beneficial to bolster energy security (IEA Renewable energy, 2002).

3. The challenges of energy for sustainable development in China

China, which has an area of 9.6 million square kilometers being the third largest country in the world next to Russia and Canada, is situated in eastern Asia. The border stretches over 22,000 kilometers on land and the coastline extends well over 18,000 kilometers (See Figure1). The territory of China spans over 49 latitudes from north to south and over 60 latitudes from east to west. China extends over 5000 km both from north to south and from east to west. In 2000 the population was 1.3 billion, amounting to about 22% of total population in the world. (Chinatoday, 2004)

China, characterized by the world's largest population, is also one of the most rapidly growing countries. During the last two decades, China's GDP grew significantly as a result of market reforms, open policy as well as social stability, and an data showed that between 1979 and 2002, Chinese real GDP grew from $177 billion to $1.25 trillion (2002 prices) (6th largest GDP in the world) and real GDP per capita grew from $183 to slightly less than $1,000 (CSA, 2003; SSB, 1989).

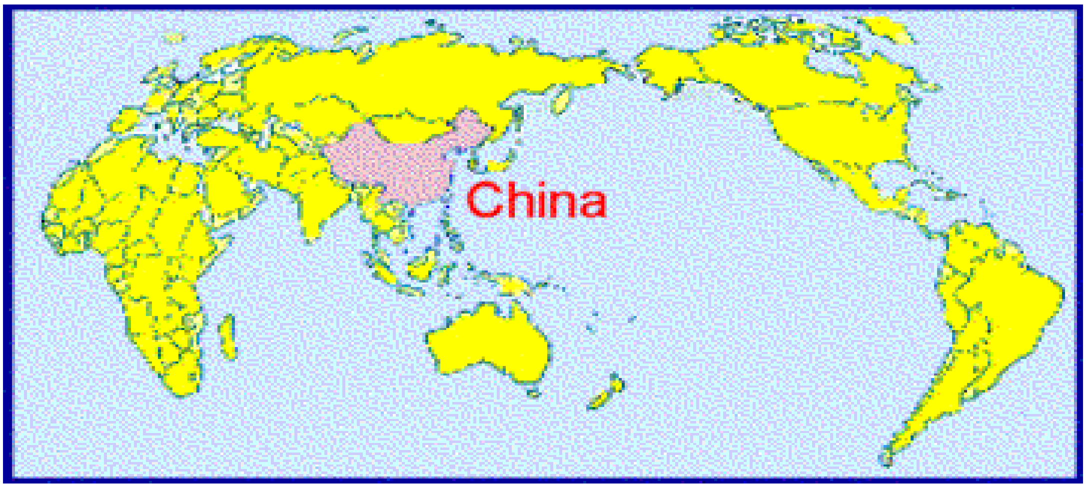

Figure 1. China' location in the world
Source: Chinatoday, 2004

3.1 China's energy system aspects

China, a global giant in terms of its current energy production, is the third largest energy producer after the United States and Russia. At present, there are four key features of China's energy system as following:

(1) Although China is rich in energy resources on an absolute basis, its energy resources are poorly low when considered on a per capita basis. China has in abundance of coal, with proven reserves of 55000 Mtoe accounting for 11% of world total (Shiqiu, 2000). At the end of 2000, China has a remaining proven oil reserve of about 3360 Mt (Jin et al., 2004). The geographical reserves of traditional natural gas including proven, probable, and possible are about 4650 Mtoe (Wang & Li, 2002).

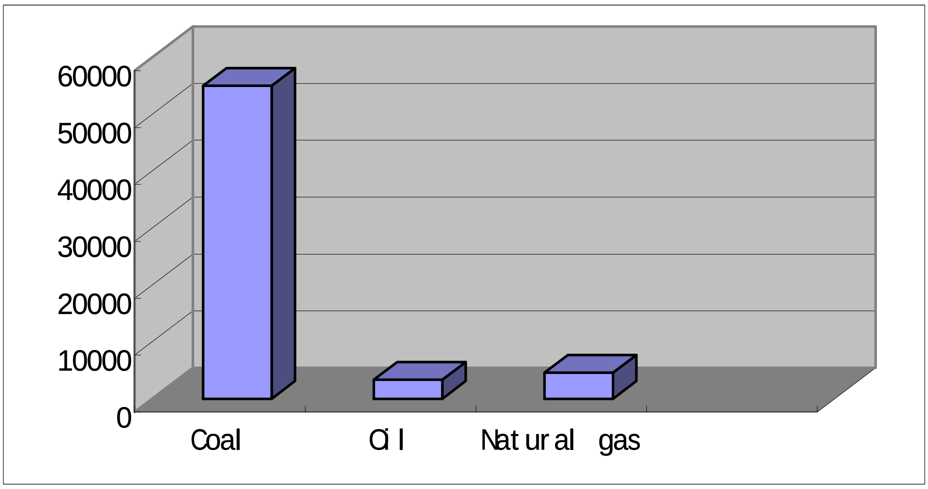

Figure 2. Conserves of coal, oil and natural gas in China (2000)

As Figure 2 shows, it seems that only coal is affluent compared oil and natural gas.

Every energy sector is one of the largest reserves in the world. Nevertheless if divided by 1.3 billion population, it is very small far lower than world average.

(2) Even worse, both the energy utilization and per capita energy consumption efficiencies are very low, wastage of energy is also common, and energy conservation and energy efficiency is not given priority (Chang et al., 2003). An example is that in 1990s, China’s steel industry consumed roughly two times more electricity to produce one tone of steel than western and Japanese steel producers (Minchener, 2000).

(3) China’s energy structure is coal-based, with coal consumption amounting to around 70% of total energy consumption (IEA World Energy Outlook 2000). Due to the constrain of energy resources structure, lack of alternative indigenous fuel resources to challenge its dominance, and the vast amount of proven coal reserves, China will continue to use coal as its main source of energy for the foreseeable future (Zhong, 2000).

(4) The distribution of energy resources varies widely from region to region, with nearly 67% of coal reserves situated in north and north-western China, while oil and gas reserves are concentrated principally in the north-east, east and far west of China, and off-shore. Northern China is the most energy rich region, followed by the southwest (due to hydro) and the northwest (Junf & Runq, 2003). The uneven distribution of China’s energy resources do not mesh with the distribution of economic activities, since the main energy-consuming areas are in the eastern and coastal regions. Consequently, distribution infrastructure is critical to Chinese energy development. Currently, transportation bottlenecks are already limiting energy resource shipments; however overcoming these obstacles will require substantial investment, which is a big challenge for Chinese government.

3.2 Rising energy demand

Alongside the rapid economic growth of china over the past two decades, its energy consumption has grown dramatically from 400 million tons of oil equivalent (Mtoe) in 1978 to 1036 Mtoe in 2002 (CSA, 2003; SSB, 1989), at an average annual rate of 5 percent (Buczek, 1996), which is well above the world average (1.5%)(Saskia, 2003). In 2000, China has become the second largest energy consumer, just behind the United States, equivalent to 11% of the world total (Wang & Li, 2002).

Energy demand of China is projected to rise dramatically over the next coming years. Three fundamental factors have been, an in the future may be, the determinants of China’s high and rising energy demand. The first is rapid economic growth, which sparks a surging demand for energy to serve an expanding industrial and commercial structure as well as households with rapidly rising living standards. It is widely estimated that China is likely to sustain a 6 percent economic growth in the coming 30 years (ZhiD, 2003). The second factor is market reform is far from complete and adjusting to globalization and WTO entry will need to be accomplished without further widening disparities between rich and poor. As recognized in the 10th Five Year Plan, growth will have to be more geographically balanced (Ni & Johansson, 2004). The third factor is China's huge population. Although China is already the most populous country, plausible demographic projections show it rising to 1380 million by 2010, 1470 million by 2020 and 1600 million by 2030 (SFPC, 2002). The last factor is that China's energy consumption per capita is one of the lowest in the world, standing at just 0.875 tons of oil equivalent (toe), which is only 60% of the world average level, and just one sixth that of OECD countries. Poverty alleviation and the satisfaction of basic human needs remain as urgent priorities. If China achieves its medium-term goal of development, there is certain to be a huge rise in the per capita energy consumption (Iain et al., 1996).

Based on these fundamental factors, and also taking into account changes in energy intensity and economic structure, it is estimated that total China's energy consumption will rise to 1500 Mtoe by 2010 and 1940 Mtoe by 2020, not much less than energy demand in the OECD Europe at that time (IEA World Energy Outlook 2000). China's demand for all sources of energy, notably oil, gas and electricity will increase dramatically.

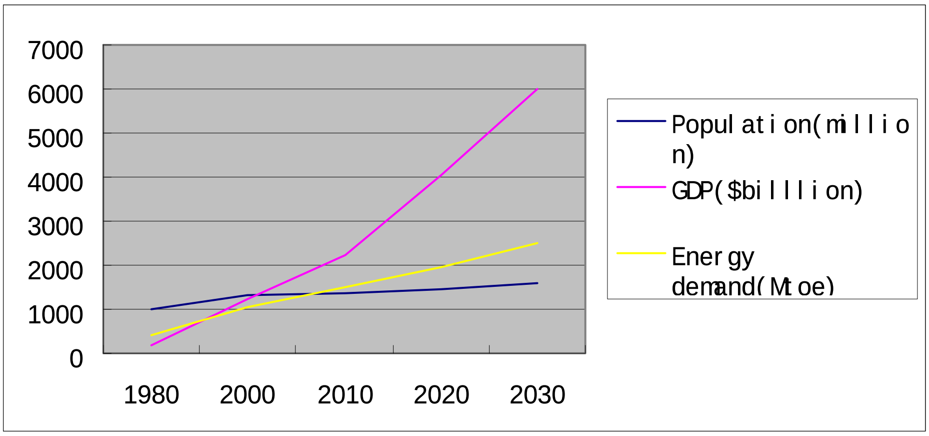

Figure 3. Population, GDP and Energy demand in China, 1980-2030

Population, GDP and energy demand in China have grown and will continue to grow; however the degree of increase is different, by which GDP is the highest, energy demand is medium and population is lowest. The comparison is shown in Figure 3.

3.3 Short energy supply

Coal

In 1996, China consumed almost 663 Mtoe, and the output decreased to 499 Mtoe in 2000. It is estimated that the output will rise again to 650 Mtoe in 2005, and 900-1000 Mtoe in 2020 (Wang & Li, 2002). Although there was fluctuation of coal consumption in the late 1990s, in the beginning of two decades of 21st century, the coal demand growth is estimated to sustain 2.6% per year in China (IEA World Energy Outlook 2000). Now, Chinese coal industry actually faces severe problems oversupply (IEA world Energy Outlook, 2000).

Oil

China's crude oil output was 169 Mt in 2000, and its average annual growth rate during 1990s was only 1.66%, far lower than that of petroleum products consumption (7.2%) over the same period. It is estimated that the output of crude oil in 2005 will be well over 173 Mt (Chen G, 2001). Due to the scarcity of petroleum resources, the production of oil is likely to maintain at current level (IEA World Energy Outlook 2000).

Natural gas

The output of natural gas was 15.8 Mtoe in 1995 and 25.5 Mtoe in 2000. It is estimated that the output of natural gas will reach over 46.5 Mtoe in 2005, and over 93 Mtoe in 2020 (IEA world Energy Outlook, 2000; Wang & Li, 2002). China's total gas reserves are estimated sufficient to last several decades at current consumption rates. However, if consumed at an ever-increasing rate, China's total gas is not adequate to last too many years (Pietz, 2000).

Hydropower

China has extensive hydroelectric resources. Official estimates total potential at 675 GW, of which 290 GW is economically exploitable (IEA World Energy Outlook, 2000). In theory, its energy output is 275 Mtoe. By the end of 1996 total hydropower capacity stood at 52 GW, amounting to 48.4 Mtoe energy output (Acker, 1997). In 2000 the installed capacity of hydropower was 77 GW, and the output was 71.6 Mtoe. China is making huge efforts to develop hydropower. A series of large-scale hydropower stations, such as the Three Gorges Project, is yet under construction. It is also estimated that in 2020 the installed capacity will be over 120 GW and output will be 111Mtoe (Wang & Li, 2002).

Nuclear energy

China started producing electricity from nuclear power in 1991 and now has 2.1 GW of nuclear capacity. Official long-term plans call for 20 GW of capacity by 2010 and 40 GW by 2020, but this target may be too optimistic, given the long lead times and the high capital costs entailed. Thus nuclear capacity is likely to reach 11 GW by 2010 and 20 GW by 2020 (IEA World Energy Outlook, 2000; Wang & Li, 2002).

Renewable energy sources beyond hydropower

China has abundant renewable energy resources and there is a long history of renewable energies usage. Their development can be economic in some areas, particularly remote, off-grid locations. Rural electrification programs often include renewable energy projects. However, except biomass energy, the proportion of other renewable energy used is still much small (Chang et al., 2003). It is expected that the new and renewable energy use was 9 Mtoe in 2001, accounting for 0.7% of the total energy consumption of the whole country, and about 300 Mtoe by 2050, making up 9% of the total primary energy of the whole country (Wang & Li, 2002).

According to the above data, I got Figure 4. As it shows, coal accounts for the largest share of energy supply, the increase of oil production is quite slow, and China's supply for natural gas is growing more rapidly than that for other sources of energy. In addition, hydropower has big potential to develop.

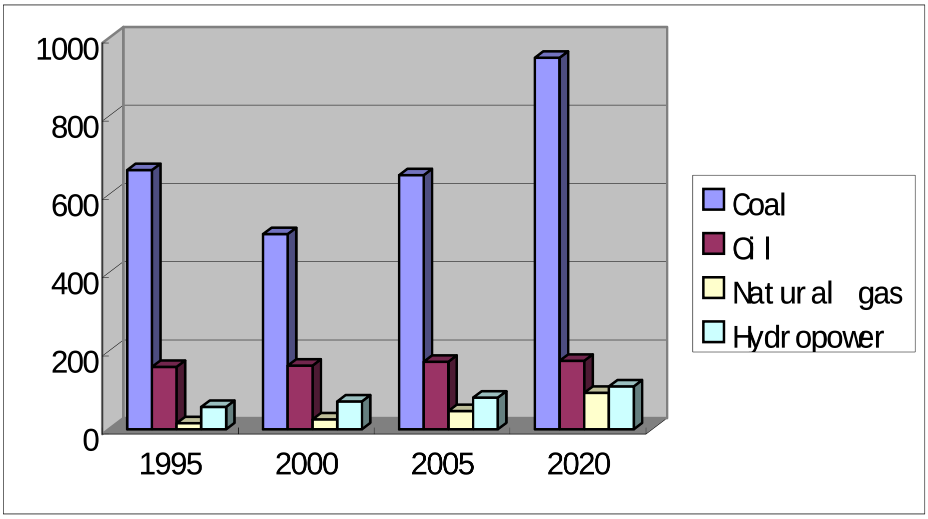

Figure 4. The production (Mtoe) of coal, oil, natural gas and hydropower in China from 1990s to 2020

3.4 China's environmental problems related to energy

China's large population combined with its growing energy consumption has resulted in severe environmental problems. China is the largest developing country, which seeks to meet the basic living needs of its people through economic development. Referring to the developing mode of the world civilizations that developed countries once went through a polluted period, China is in a situation of increasing the discharge amount of pollutants and carbon dioxide (CO^2) in the process of development and modernization (Shi & Su, 2001).

Because China's energy structure relies on coal, and because generally the use of oil and natural gas results in less pollution compared to coal—specific CO^2 emission from burning coal is 1.6 times that from natural gas and 1.2 times that from oil (He & Chen, 2002), the utilization of coal generates the biggest problems of environmental pollution in China.

Moreover, some aspects of China's coal industry also address the environmental problems. Two consumption features including low quality of coal and low pollution treatment level are the main reason resulting in serious air pollution (Shiq, 2000). On the hand, China’s coal-fired power plants emit more emissions than those in other counties especially developed countries due to low efficiency of coal combustion and power generation (Axel et al., 2000). In addition, because a large part of China’s plants are built to meet local power needs and they thus are often run at less than full capacity or cycled on and off, they cannot combust coal at a standardized rate, which leads to much emission (Buran et al., 2003).

Continuous attention needs to be paid to health and national and international environmental issues induced by energy supply and use.

3.4.1 Human health effects

The emissions from coal-fired plants have caused 500 major Chinese cities to fail to meet the clean-air standards set by the WHO (Zhong, 2000). Of the urban population, about 240 million people are exposed to some form of air pollution (Li, 2003). Air quality is so poor that nine of the ten cities with the worst air pollution in Asia and five of the ten worst air polluted cities in the world are in the China, based on the WHO’s guideline (Haye, 2002). The resulting emissions of particulate matter have led to increased respiratory disease and reduced pulmonary function (Lew, 2000). Currently, respiratory diseases have become the leading cause of death in China, as a result of high average concentrations of Total Suspend Particle (TSP) (Zhong, 2000). Furthermore, contaminated food, water and material used by people in daily life have severe negative effects on human health as well.

Indoor air pollution, especially from coal-burning stoves, is a more serious threat than out-door air pollution In China. An estimated 800 million of China's 1.25 billion people use coal in their homes, and about 22% of rural homes depend on coal for domestic fuel. A central problem is that the vast majority of China's coal is not cleaned before it is used, and it is burned in unvented stoves. Therefore, smoke fills the home and especially affects the women and children who spend more time cooking and staying indoors, and contaminates food with arsenic, fluorine, lead, and mercury, which result in chronic poisoning, obstructive pulmonary diseases such as emphysema and chronic bronchitis, lung cancer, etc. (Beach, 1999; Mumford et al., 1987)

3.4.2 Local environmental pollution

Increasing energy consumption causes striking damages to the local environment. Among the gas components, sulfur dioxide (SO^2) is one of the largest quantities from the burning of fossil fuels, because sulfur content in coal is relatively high and because more than 95% of the sulfur content in the fuels transforms into SO^2. In 1997, the total SO^2 emission amounted to 23.46 Million tons (Mt), accounting for about 15.1% of world total, which is the first place in the world (He & Chen, 2002). According to the estimate conducted by Gan (1998) that without controlling measures,

SO^2 emissions will reach 44.6 Mt by 2010. A large quantity of SO^2 emissions combining with water vapor in the atmosphere produces acid rain; therefore, acid deposition issue is one of the most seriously environmental problems in China. According to official estimates, 30% of the country, which is the third-largest area in the world after Europe and North America, is drenched by acid rain that damages natural and human-made surfaces whit which it comes into contact, acidifies lakes leading to the demise of fish populations, causes forest damages, attacks manufactured materials, and impairs cropland exceeding its carrying capacity and thus resulting in significantly financial losses (Tefft, 1995).

Another notorious emission of pollutants is Total suspended particle (TSP). Because control systems on stationary and mobile sources are not effective in limiting the release of particles, in the outdoor environments of many Chinese cities concentrations of particles are very high, exacerbated by domestic solid-fuel combustion, small-scale industrial activities, and inefficient transportation systems (UNDP, 2002). Annual daily average TSP concentration in cities of China was 339 ug/m^3 in the northern cities and 179 ug/m^3 in the southern cities, much higher than the safe level of 60-90 ug/m3 recommended by the WHO (Wang & Li, 2002). The concentrations of NOx, CO, and O^3 are relatively high in large cities due to better economic development and thus more vehicles (He & Chen, 2002).

3.4.3 Global environmental impacts

China impacts greatly upon the global environment. China’s dependence on coal means that most GHGs emitted in China is in the form of CO^2, leading to a significant contribution to world CO^2 emissions. Accompanying the growth in fossil fuel use, China’s CO^2 emissions grew with an average annual growth rate of 5.2% from 1980 to 1997(He & Chen, 2002). It amounted to 3.3 billion tons, accounting for 14% of world total in 1997. Although some improvements are expected, it is estimated that China’s share of world CO^2 emissions will increase to 18% of the world total by 2020, amounting to 6.6 billion tons (IEA World Energy Outlook, 2000). At that time, China’s share in global CO^2 emissions, which is likely to exceed that of the United States, will be the world’s largest emitter of GHGs (He & Chen, 2002). However, large population makes per capita CO^2 emissions low by international standards, 2.6 tons per capita in 1997 compared with 11.2 tons per capita in the OECD and 4.5 tons in 2020, compared with 14 tons in the OECD (IEA World Energy Outlook, 2000).

In addition, China’s environmental problems extend well beyond its national borders. High pollution levels dispersing from China have an effect on the environment of some other neighboring countries in the eastern Asia region. For example, the huge emission of sulfur oxides is threatening Japan, Korea and other Asian neighbors. It is estimated that sulfur blown from China mainland have contributed over 30% of all sulfur deposits in Japan and North Korea and about 60% in South Korea (Zhong, 2000). The sulfur oxides have been dispersed so widely that complaints of acid rain have arisen in these countries (Buran et al., 2003).

4 Energy security in China

China's achievements over the last 20 years are impressive. Economic growth has been rapid, development extensive and poverty has been drastically reduced in rural areas. A socialist market economy is successfully negotiating its difficult initial stages, and there is a wider opening to the outside world. Most scientists and socialists regard the fact that food supply and demand has been brought into balance as one of the most remarkable achievements.

Food is the most basic need for human beings. People cannot live without it. As a country with vast population—22% of world total and scarce land—7% of world total, China always puts the food security issue high on its agenda (Tong et al., 2003). Furthermore, an international debate on China's ability to feed itself has further heightened the concern with the publication of Brown (1995)'s query '*Who Will Feed China?*' in which the author predicted that by 2030, China would not be able to feed itself, and the surplus of the rest of the world would also not be enough to fill China's grain shortfalls. Although the prediction was primarily based on observation of the author who took the most extreme position, it did elucidate the importance and seriousness of food security in China.

In the past decades, China has successfully demonstrated to the world that it has the ability to feed its own people rather than "starve the world". The cereal production increased from 110 million tons in 1961 to 410 million tons in 1997, and production per capita increased from 164 kg in 1961 to 385 kg in 1997 (Tong et al., 2003). However, between 1978 and 1996, total cultivated land decreased by 4.73 million hectares, or about 4.45% of total through urbanization, industrialization and degradation (Yang & Li, 2000). With arable land decreasing, output growth mostly comes from yield increase. The yield per hectare for all crops has increased from 1.21 ton in 1961 to 4.83 ton in 1998 (Tong et al., 2003). Factors contributing to this success include rapid adoption of improved technologies, the improved rural infrastructure and institutional reforms (Zhu, 2004). Consequently, although China is still under huge pressure on food problem, it has successfully provided adequate food for its people, and seems to continue to feed its population over the next two to three decades and domestic food production can largely keep pace with population growth and economic development.

However, another security—energy security, which is closely relevant to the Chinese development as well, is becoming more prominent than before.

4.1 The initiative of China's energy security

With around 1.3 billion inhabitants, China is an energy-scarce economy with per capita energy endowments far below the world average. Not only does China face serious energy-related environmental consequences, but it also faces a compelling energy security problem. Concerns about China's energy security are rooted in projections of the country's future energy demand and supply. Along with surging energy consumption, energy security issues, to which little attention was paid for the last several decades, have become conspicuous. Energy security has rapidly become an overt problem in China. How to get a secure energy supply without endangering the environment is really a significant concern for the Chinese. A low-cost and uninterrupted energy supply is fundamental for economic and social development and political stability.

Like other countries, currently concerns about China's energy security are more focused on oil security because of a high degree of dependence on imported crude oil.

4.2 Growing dependence on imported oil

China's growing dependence on imported oil stems from domestic causes. Oil is China's second largest energy resource, contributing to about 20% of China's total energy needs (Zhong, 2000). In the 1990s, oil demand in China grew by nearly 7% per year, from 117Mt in 1990 to 210Mt in 1997 and to 224 Mt in 2000. Having nearly doubled over the last decade, oil demand will still climb steeply over the future 20 years, reaching 560 Mt in 2020 (IEA World Energy Outlook 2000). Demand for oil is mainly driven by a rapidly expanding transportation, which is the fastest growing energy-consuming sector. In addition, growth in Chinese oil consumption has accelerated because of a large-scale transition away from bicycles and mass transit toward private automobiles. Given China's current very low ratio of car ownership to GDP and its increasing dependence on road and air transport, an expected demand for freight and passenger travel will lead to a rapid expansion in oil consumption (Iain et al., 1996).

Currently, the most serious problem China's government facing is that its crude oil production seems to be stagnant. One reason is that major oil fields in the eastern have passed their peak production since 1985 despite the continuous addition of new wells (Zhong, 2000). On the other hand, although China has many unexpected areas, both onshore and offshore, which are anticipated to have huge potential oil reserves, its estimates remain extremely uncertain in general as a result of low exploration and development (IEA, 2000). Since the beginning of 1990s, the Chinese have begun to develop potential oil resources in the western desert, specifically a basin the size of France called Tarim. However, despite Chinese optimism, propaganda, and several years' exploitation, the production potential of the region is disappointing (Iain et al., 1996). Even though exploration is being shifted to deeper waters and remote frontier areas, production increase is considered to be difficult (Mehmet, 1998). As a result, the production of oil in China will be maintained at the present level or will even decline slightly in the medium and long term (IEA World Energy Outlook 2000).

Due to stagnant domestic crude oil production and increased need for oil, China became a crude-oil importer in 1996, although it had been a net importer of oil products since 1993. In 2000, China was ranked as the world's 7th largest importer (Li ZhiD, 2003).

The gap between consumption and production of crude oil will continue to increase because demand accelerates further beyond the limits of domestic production. The imported oil was 20.5 Mtoe in 1996, and in the medium and long run imports are likely to exceed 255 Mtoe by 2010 and 409 Mtoe by 2020. This degree of import dependence will be the third highest in the world, just behind the USA and Japan (IEA World Energy Outlook, 2000). Figure 5 shows oil balance in China in the past and future.

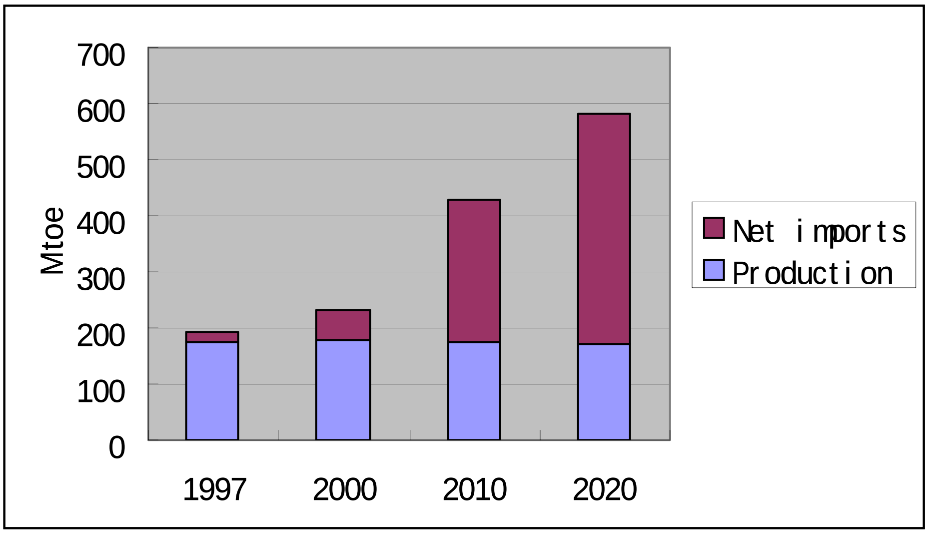

Figure 5. Oil balance in China
Source: IEA World Energy Outlook 2000

As Figure 5 shows, China's net import dependence increases from 22% in 1997 to 76% by 2020 (IEA World Energy Outlook 2000). Today, the Middle East is the principal source of China's oil imports. In 2001, the Middle East accounted for 48% of China's oil imports; another 22 per cent came from the Asia Pacific region and about 18% from Africa. No less than 64% of China's oil imports pass through the Strait of Malacca, exposing to the insecurities of a congested passage, which has long been under the control of the US, and where pirates run wild in the absence of naval protection (Nolan et al., 2004)

4.3 Regional influences

Rapid economic growth in Asia has been followed by spectacular growth in oil demand. However, Asia produces around 11% of global oil output and consumes about 26% of global total (Fesharaki, 1999). Thus the imbalance between resources availability and consumption is considerable. The growth-led increases in oil demand combined with Chinese oil requirements and slowing growth of Asian oil resources, have impelled both China and other Asian countries to import crude oil from other sources (IEA, 2000). Currently almost all Northeast Asian countries have become net oil importers, and it is expected that their oil imports will increase dramatically in the future (Michael & Gregory, 2000). Being the largest energy consumer in the region, China is becoming a strong competitive actor in international oil market, which means less access to oil for other countries in the region. Consequently, China’s energy security is closely related to other Asian countries’ energy security, and they are inseparable from each other. (Jin. 1999)

Since such a large portion of oil demand must be satiated with imports, the geo-political environment of Asia can be expected to change dramatically in the coming years (Strecker, 2000). It is supposed that the growing gap between oil supply and demand and the thirst for oil in the region would strain relations among Asia counties, and would pit energy customers against one another more directly (Jin. 1999). The concern of the South China Sea dispute is a good example to interpret the importance and reliance of oil in current international environment. Little attention had been given to the sovereignty of the South China Sea until the 1960 and 1970s, when this region was estimated to have enormously potential hydrocarbon resources reserve. Now China, Philippines, Vietnam, Malaysia and Brunei all claimed the sovereignty of all or parts of this territory, thus leading to heightened tensions and periodic conflict among these countries. (Scott, 1997)

4.4 Global impacts

How much will China rely on energy imports? How will China ensure access to these energy imports? These are questions that have potentially huge implications for the international community. The impacts of China's energy development are already being felt internationally.

China is asserting itself as a powerful new force in the international energy markets (IEA, 2000). Since China will be forced to tap the supply of many other parts of the world, it will have a significant impact on the worldwide supply of oil. With China’s entry into the WTO, a rise in its impacts on the world energy market is becoming more likely. Just as stated in a report of IEA (2000), China requires a strong place in the system, while other players will need to make room for it. Because of China’s increasing oil demand, the price of crude oil grows (Iain et al., 1996). Energy security does not mean total independence, but rather refers to the ability to “*keep the initiative in one’s own hands*” (Strecker, 2000). Since last decades, with domestic reserves insufficient to satisfy demand, and hoping to reduce the cost of importing oil from other nations, the government has started to implement a plan to acquire energy reserves (mainly oilfields) around the world, and take control of strategic stakes in major pipelines that might carry the oil back to China. For example, in Kazakhstan, Venezuela and even Iraq, people can see Chinese stated-owned oil and gas companies investing or buying local oil fields (Lee & Hengst, 1998).

Nevertheless, although market forces play important roles in achieving energy supply and security, they cannot solve all the problems (Jin, 1999). For example, China’s efforts to acquire Russian oil assets during its 1990s oil privatization were repeatedly blocked, mainly by political maneuvers (Nolan et al., 2004). The concern to meet its energy requirements will fundamentally affect China's foreign and security policy, and energy issues have clearly taken a higher priority in Chinese diplomatic activities and goals (IEA, 2000). For instance, although energy linkages between China and resource-rich countries are still relatively new, they are expected to become wider and stronger due to China’s growing energy dependence on these areas (Mehmet, 1998). It is also possible that the combination of China’s independent streak and drive for energy self-sufficiency with existing American national strategic interests may lead into collision in the future (Michael & Gregory, 2000).

5 Three Gorges project (TGP)

The Three Gorges Project, when completed, will be the largest dam in the world and it is being called the largest construction project in China since the Great Wall as well. However, international criticism regarding the social and environmental viability of the project has also made it one of the world's most controversial development projects.

5.1The background

The Yangtze River, known in China as simply the "long river" (Changjiang), originating from the Qinghai-Tibet plateau with a total length of 6,380km is China's longest river and the third longest river in the world after the Nile and the Amazon. It has a strong flow (14,000 to 19,000 cubic meters a second) to an amazing depth of 60 meters. The extensive river flows through China from west to east, it therefore cuts through the heart of China and is regarded by the Chinese as the division of the country into north and south geographically. In addition, the Yangtze River basin with more than 3000 tributaries and 4000 lakes is about 180 million square kilometers, equal to one fifth of China. With its numerous tributaries, the Yangtze provides a great transportation network through the heart of some of the most densely populated and economically important areas in China. It has played such a central role in nurturing the country that it is often seen as the "mother" of the Chinese people and the land. (Qing & Sullivan, 1999; Fu et al., 2003)

Three Gorges including Qutang Gorge, Wuxia Gorge and Xiling Gorge are in the middle reaches of the main stems of the river close to Sandouping in Yichang city, Hubei Province (See Figure 6). In the Qutang Gorge, the river is only 100 meters wide.

In the Wu Gorge, mountains rise to a height of 500 to 1,000 meters. The Three Gorges Dam Project is located in the middle section of Xiling Gorge. (Liang, 2001; Lu, 1996)

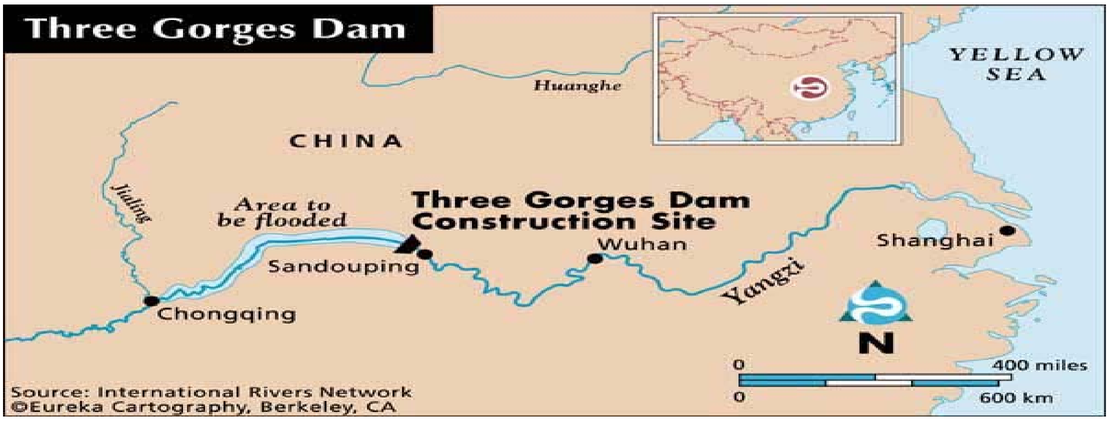

Figure 6. The location of Three Gorges project. *Source: IRN (2003)*

The project includes the following subjects: the dam, flood-relief buildings, hydropower plant, navigation buildings and etc. The length of the concrete gravity dam will be 3,035 meters long on the top, with the height of 185 meters. After completion, the unusual huge reservoir is 663 Kilometers long (Lu, 1996). The expected Three Gorges after finishing is shown in Figure 7.

Figure 7. The model of Three Gorges project
Source: Yangtze cruise (2003).

The construction of the project consists of 3 stages and is expected to take 17 years from the preparation in 1993 to the completion in 2009. Upon completion, the huge dam will be the world's biggest hydropower plant in terms of both total installed capacity and annual average power generation volume. Twenty-six turbine generator sets, with a per-unit generation capacity of 700MW, will be installed on the left and right banks of the Three Gorges Hydropower Station. By the year 2006, the first 14 generators installed in the powerhouse on the left bank will begin the new distribution of electricity; and the other 12 on the right bank additional generators will begin operating by the year 2009. (Liang, 2001)

5.2 Issues related to energy

There is no doubt that one of the drivers to construct Three Gorges Project is to generate electricity for China and it has some special aspects regarding to the Chinese energy system. The overall generation capacity is estimated at 18.2 GW with average annual energy output of 78.8 Mtoe, which accounts for one ninth of annual electricity in 1993 (Lu, 1996).

5.2.1 Hydropower is renewable

The Three Gorges Project is the biggest hydropower in the world until now. Hydropower is generated by the force of gravity. Its conversion is usually obtained by rushing water down a steep gradient and through turbines, which converts the water’s motion into mechanical and electrical energy (Walkade, 1988). Given the fact that water supplies are replenished by rains in the annual hydrological circle, and the rivers and oceans do not seem to dry, hydropower is considered to be essentially limitless in supply or nearly inexhaustible (Silverman & Worthman, 1995). Thus if used wisely in appropriate and efficient ways, it can provide reliable and sustainable supply energy almost infinitely.

Public electricity supply is 100 years old and hydro turbines have always been utilized as prime movers (Twidell, 1993). Hydropower is also the most technically mature form of renewable energy and accounts for a significant share of electricity generation worldwide, representing approximately 18 per cent of world electricity production in 1997, most of which comes from large hydro dams that are greater than 10 MW (IEA Renewable energy, 2002).

5.2.2 important component of China’s diversified energy mix

Although China will still continue to stick to the guiding principle that the energy supply relies mainly on domestic resources, and the coal dominance primary energy mix remains unchanged, China is readjusting its energy structure. The long and general trend is that China’s energy structure tends to shift towards diversification, from the current situation of coal domination to an increasing share of hydroelectric and nuclear power, and other renewable energy sources. (Chen, 2001)

Since the disparities of economic development and the energy resource distribution in China are very substantial among different areas, energy transportation, especially for coal, is a heavy burden on the national transportation system and increases the energy costs in the well-developed regions considerably. Development of hydro energy not only increases energy supply but also mitigates the issues of uneven resources distribution (Wang & Li, 2002). The electricity produced by Three Gorges Project will be available within a 1000 kilometers radius of the dam, as far as Shanghai and Guangzhou, which are both well-developed cities (Kuo, 1998). Since HVDC transmission over long distance is becoming cheaper and electricity networks are getting interconnected, electricity can be transmitted economically from remote places (Oud, 2002). Consequently, the annual power generation of Three Gorges project is an important component in the future energy mixes in China. It increases diversity of energy supplies, adds to the energy supply portfolio.

5.2.3 Favorable to acquire secure energy

Because fighting the temptation to "*put all your eggs in one basket*" is one element of supply security, diversification of energy supplies and distribution — both by energy type and by source – is an important measure to help improve energy security (IEA Towards solutions, 2002).

Large hydro plants have some advantages. They use indigenous or domestic resources and thus less subject to supply disruptions; as a result, they should be seen as an important means of providing some relief to security concerns (IEA Renewable energy, 2002). They have long life spans around 50-100 years compared with other forms of electric power generation (Charles et al, 2001). They require little maintenance because once the loans for the construction of the project have been paid back, the annual cost to operate and maintain the scheme are of the order of 1% of the investment costs (Oud, 2002). They are controllable, because it is easy to quickly adjust the amount of power produced in response to shifts in demand (Charles et al, 2001). According to Ciocci (2003), hydropower is one of the most important resources in ensuring grid reliability. In addition, although electricity production can be affected during periods of drought or reduced precipitation, these factors are often predictable and thus reasonably well managed (IEA Renewable energy, 2002).

5.3 Issues related to environment

A reservoir is an impounded body of water created when a river or stream is dammed and water is allowed to store. This impoundment of water has an immediate and afterwards impact on the physical and biological systems within the reservoir (IEA, 1998). The Three Gorges Project has both environmental disadvantages and advantages.

5.3.1 Positive environmental effects

The big dam can play an important role in reducing emissions GHGs and other major air pollutants. It will lower China's reliance on fossil fuel by reducing mainly fossil fuel fired generation, which is equal to 50 million tones of coal yearly (Lu, 1996). It also means that, therefore, the yearly discharge of pollutants amounting to 120 million tons of CO^2, 1.5 million tons of SO^2, 10000 tons of CO, 370000 tons of NO_x

compounds as well as large amount of flying dust will be reduced (Acker F, 1997). Compared to the total (1997), it can reduce 3.7% coal consumption and 3.6% CO^2 emission.

Whilst large dams produce few or no emissions during operation, some opponents argued that Three Gorges Project could release CO^2 and methane (both GHGs) from the formation of anaerobic conditions and the subsequent breakdown of impounded vegetation, and that the other parts of its life cycles (such as construction of dams, dikes, and power stations, decommissioning, and etc) would produce emissions associated with the energy expended during those activities indirectly or directly. However, in terms of GHGs emissions, hydropower, in most cases, is a good alternative to fossil fueled power generation, because after the inundated vegetation has already broken down, there will be no longer emissions of CO^2 or methane, and because for hydropower plants around the world, a typical GHGs emission factor is 15 g CO^2 equivalent/kwh, which is 30-60 times less than the factors of usual fossil fuel generation. (Luc & Joop, 1997; IEA, 1998)

5.3.2 Negative environmental effects

Ecosystem conversion

A large-scale hydro project with a reservoir will definitely convert some amount of terrestrial ecosystem to an aquatic ecosystem, thus it can indeed have negative environmental consequences on a river ecosystem including *"destruction of aquatic and terrestrial habitat, interruption of water flows, alteration of temperature patterns, disruption to the natural flow of organic materials and nutrients through the aquatic ecosystem and consequent decrease in biodiversity"* (March & Fisher, 1999). Not only does it divert the river, but it will also threaten hundreds of acres of land that is the habitat for many species. Yangtze freshwater dolphin, Chinese sturgeon, paddlefish, the Siberian crane as well as rare vegetation species, have all been focus of concern (Fuggle & Smith, 2000). In general, as migration of fish either upstream or downstream would be blocked by the dam, it is estimated that more than 20% of all freshwater fish species are now considered threatened or endangered, mostly due to damming (Truffer et al, 2003).

Pollution

At the beginning there have been little made to remove of garbage, wastes and toxic materials in dozens of deserted towns and abandoned industrial sites that will be inundated, therefore the huge pool of stagnant, polluted water will be a significant threat to the health of local and downstream communities (McCormack, 2001). Afterwards, there is also the potential for dramatic increases in water pollution, especially in the reservoir, which predicts to be gradually poisoned by the billions of tons of largely untreated wastewater from outworn civilian and industries that flow into the Yangtze above the proposed dam site. It is likely to get worse when water slows down and stratification occurs after the dam is finished (Wen & Qui, 1998).

Siltation
The rapid siltation due to suspended silt, gravel and sand without flowing downstream, will build up around the installation thus reducing the dam's effectiveness, blocking shipping traffic along the river, and even causing floods upstream, which all result in the uselessness of Three Gorges project and eventually the demolishment of it (Burton & FlorCruz, 1994).

Dam safety
Finally, another problem is that the weight of water would increase seismic activity in the area and consequently trigger earthquakes and landslides, which could devastate the whole structure even though the earthquakes are only on the scale of 4.0 to 5.0 on the Richter scale (Kuo 1998; McCormack, 2001).

5.4 Issues related to economic and social development

It is widely recognized that the huge dam, which has both economic and social advantages and disadvantages, generates a combination of gains and losses.

5.4.1 Advantages

Apart from supplying electricity as well as negligible amounts of greenhouse gas emissions, there are numerous social befits such as flood control, irrigation, improved navigation, fisheries enhancement and increased opportunities for recreation (Frey & Linke, 2002).

Flood control
The Three Gorges Project is of greater significance in that there is a strong incentive—its flood control capability in the middle and lower reaches of the Yangtze. The river has a historical record of flood catastrophes, and the flood problem still remains unresolved here as in other rivers in the country. Devastating floods that occur during rainy season every year has claimed around 700000 lives since 1870 (Dodman, 1998). Only in 1998, in the flood which is considered to be the most serious in recent 40 years, 32 million hectares of lands were flooded including 197000 hectares of cultivated land, 1562 people were killed, and more than 200 million people were affected (Fuggle & Smith, 2000).

In addition, the importance of the Yangtze River Valley is emphasized by the fact that it is the home to approximately 35 percent of the Chinese population, who produce about 40 percent of the country's agricultural output and 40 per cent of the industrial output. Each year large numbers of people are engaged in flood control work due to the serious flood problem in the valley (Lu, 1996).

The Three Gorges Project involves constructing a dam with a height of 185 meters. At completion, the normal water storage level will be 175 meters. The water level in the reservoir is to be reduced during the flood season to make room for floodwater, and the flood restriction level during this season would be 145 meters. The total water storage capacity of the reservoir would be 39.3 billion cubic meters, of which 22.15 billion would be for flood control purposes (Lu, 1996). When finishing, the dam with a tremendous reservoir can reduce the frequency of flooding disasters from once a decade to once a century (Fuggle & Smith, 2000).

Flood control is difficult to price in terms of avoided drowned people; consequently it is a feasible construction in flood mitigation that will protect the lives and livelihood of millions living downstream and help protect multiple billions of dollars of economic assets that are otherwise at risk each year (Kuo, 1998).

Navigation

The Yangtze River is called the 'Golden Waterway', a name that characterizes the river's importance as a transport system between east and west. It carries 80% of China's internal waterborne traffic. Navigation on the Three Gorges has always been dangerous due to shoals and currents in the river. The big dam will improve the navigational facilities by making the river deeper and expanding the width, which enable 10000-ton ships to travel to the interior, and thus the shipping capacity is expected to increase from 10 to 50 million tones a year, boosting trade and economic development of the region (Xue & Yuan, 2002; Fuggle & Smith, 2000).

Irrigation

Moreover, the dams have played an import role in farmland irrigation, and even now they are still very effective. One of major concerns of the Chinese government is feeding its growing population. With only 10% of its vast territory suitable for agriculture, this is not an easy task. Nature does not help in this respect either because most of China is subjected to a very uneven rainfall pattern, with most of the rain falling in a short 4-month period. The government has to maintain a delicate balance between keeping the food price low enough, so the general public can afford it, and maintaining the farm income high enough to keep 80% of the population in its rural areas. This can only be achieved by making extensive use of irrigation. (Sweet, 2001; McCormack 2001)

Others

Like other large-scale dams, the dam will also improve recreational opportunities, such as boating, lake fishing, tourism or other leisure activities (Egre & Milewski, 2002).

5.4.2 Disadvantages

There is no question that the Three Gorges Project will have significant far-reaching, irreversible impacts on the local communities and national economy.

Resettlement

One of the most controversial aspects of Three Gorges project is that an estimated 1.3million people will be displaced, which is considered to be the largest challenge for the government agencies involved (Cooper, 1997). With a large rural population and only small fraction of its land suitable for agriculture, the available land in the river valleys is fully utilized. Any change in the river level due to dam building will result in resettlement. Since all the arable land is already under cultivation, the resettlement areas are usually less attractive (Li, 2002). Some problems caused by relocation such as serious underestimation of the number of person, not sufficient land for replacement of land lost, insufficient provision of non-agricultural jobs, and involuntary resettlement leading to lack of respect for human right, have been public concerns within China and have attracted worldwide attention as well (Fuggle & Smith, 2000).

Land inundated

After completion, the dam will permanently submerge about 50000 acres of land, including 19 cities, 150 towns, 4500 villages and 1,500 factories and 28000 hectares of arable farmland (Kuo, 1998). The area, which is famous for its breathtaking scenery, has 828 historical and cultural sites including ancient temples, carvings and archeological importance, and is an inspiration for poets and painters and the source of legends, is slated to be flooded. Most irreplaceable, according to some experts, are sites that are remnants of the homeland of the Ba, an ancient people who settled in the region about 4,000 years ago. This project will completely destroy the legendary beauty of this culture (Wen & Qui, 1998).

Sediment

The Yangtze is not only a river of water; it is also a river of sediment. In theory, the river will add million tons of silt into the reservoir per year. Silt brings nutrient to the soils downstream, which benefits agriculture. By stopping the silt-flow down stream and decreasing the water-flow, it will decrease the crop yields by a great amount (Burton & FlorCruz, 1994).

Cost

All studies show that the initial cost of constructing this big dam is high, and financial support is a big problem. At a minimum, the entire process will cost around US$ 25billion according the Chinese government’s estimation. In this case, the market price for all the costs and benefits is rational. However, some have predicated that it will exceed US$ 70billiion, because huge, state-run construction projects often have a structural tendency toward massive cost overruns sometimes because of corruption. Under this situation, this project is not cost-effective, which is a big financial burden for the Chinese authorities during the construction period and even after completion. In addition, since China is investing a large amount of money to construct the dam, other projects in need of investment will suffer, such as education. Experts believe this project will drain the local bank and hit taxpayers hard, wrecking rather than boosting the Chinese economy (Kuo, 1998; McCormack, 2001).

6 Dilemmas of building big dams

Now, Three Gorge Project is the most controversial dam in the world, just because it is the project's environmental and social impact that has been the main subject of debate, and because it is the enormous size of the project that has attracted such widespread international attention. Actually not only Three Gorges Project, but also other big dams are under criticism.

6.1 Changing context of large-scale dams

Twenty years ago, most large dams were generally considered to be a good thing, because it was believed to be an important means of meeting water and energy needs, and as a long-term, strategic investment with the ability to deliver multiple benefits, some of which are unique to dams and specific to particular projects, while others are typical of all large infrastructure projects. Hydropower, irrigation, water supply and flood control services were widely seen as sufficient justification for the huge investments required. Other benefits gained including the economic prosperity brought to a region by multiple cropping, the installation of electricity in rural areas, and the expansion of physical and social infrastructures, such as roads and schools, were used to justify dams as the most economically and financially competitive option (Oud, 2002; WCD, 2000).

Because far more comprehensive environmental and social studies were to be taken in the past few decades, there is increased understanding and awareness of complex technical, environmental and social issues, which are inherent to dams, and realization that the development of hydropower projects involves a trade-off between the gains and losses (Oud, 2002). Especially, the increased violation of the rights of minorities, small groups and primitive people living in the neighboring communities during the planning, construction and operation phase of big dams has been an local and international concern (Koch, 2002).

6.2 Increasing global debate and pressure

At present, the debate about large dams has been transformed from a local process of assessing costs and benefits to one in which dams in general are the focus of global concern about development strategies and choices. Today, the decision to build a large dam is rarely only a local or national one. Opponents in general have appealed to global opinion, and opposition has now evolved into a global debate about large dams: their impact on neighboring communities, livelihoods and ecosystems, and whether they represent the best investment of public funds and resources. (WCD, 2000)

Although, some international organizations advocated a set of international social and environmental standards, which would apply to all dam projects wherever they are, one question arising is which issues are international and which issues are local. Some environmental concerns such as GHGs and biodiversity are globally recognized, while the social concerns are normally considered to be left to national authorities to decide. Nevertheless, relocation of people is a particularly controversial question; global concerns are always focused on human rights of minorities or small groups, which is still a conflicting conception between developed and developing world, regardless of a fact that each country has its own notions of fairness and standards of compensation. Too much global debate and pressure by using introduced standards is, to some extent, thought to infringe on the sovereignty of governments. (Koch, 2002; WCD, 2000)

6.3 Increasing public opposition

It is essential that there is public acceptance of such initiatives in order to develop large dams in an equitable and sustainable manner. Gagnon et al (2002) advocated public participation at every stage of project, with the goal of achieving acceptance of projects: *"The social, environment and economic trade-offs required to establish a national energy policy should be supported by public debates and be the result of a consensual approach"* and *"Proponents must seek community involvement and partnership throughout the project cycle"*. By bringing to the table all those whose rights are involved, and who bear the risks associated with different options, it is effective to address competing interests and resolve conflicts in a positive manner (IEA, 1998).

Nevertheless, it is possible that conflicts may arise when the concerns of certain groups are ignored or rejected, particularly when they involve fundamental issues of control over resources and distribution of wealth (Klimpt et al., 2002). And it is also difficult to reach consensus among stakeholders who have different interests and value systems about overall best alternative (Oud, 2002).

Because of lack of an overall study of all dams, or a complete statistics, which represent all samples, most studies have usually chosen some dams, which are controversial or have interesting problems. At the same time, the literature always repeats the problematic dams frequently and the same cases are cited over and over again by different authors. Thus the image of the big dams in public is significantly affected by the criticisms of negative environmental impacts and of unfair treatment of persons who were involuntarily relocated or otherwise adversely affected. It has become more difficult to know where the truth lies and to form a balanced, objective opinion about large dams (Koch, 2002; Klimpt et al., 2002). Now public opposition tends to increase over time, because whatever the objectives about environmental friendliness may be, it has become apparent that large hydro projects have negative impacts and become controversial (Frey & Linke, 2002).

7. Discussion

7.1 Does Three Gorges Project bolster China's energy security?

Energy security has traditionally been understood in terms of import dependence on foreign oil, and the threats to supply from war, instability or political embargos mounted by foreign suppliers. China's energy security also comes from the growing dependence on imported crude oil. Three Gorges Project is estimated to annually generate energy 78.8 Mtoe, hence, in theory it can offset 25 million tons of crude oil, which means the number of electricity generated by the big dam is amount to that produced by 25 million tons of crude oil. Some Chinese official documents celebrate the big dam can be especially useful in enhancing a country's independence from external supplies especially imported oil, helping offset nation's reliance on foreign energy sources, and thereby bolstering energy security (Lu, 1996). Nevertheless, the increasing demand on oil in China is mainly driven by a rapidly expanding transportation sector. It is unrealistic to use imported oil to generate electricity. Although the project can supply large amount of secure electricity and diversify energy mix, it has no direct effect on China's dependence on oil imports.

As to energy, although the energy generated by Three Gorges Project is estimated to account for one ninth of annul output in 1993; it is impossible to fulfill this objective after its completion in 2009 because at that time the total energy consumption is likely to double as expected.

With regard to security, energy infrastructure safety is also a very important problem. Many major assumptions about the dam's design, which mainly include seismic activity, earthquakes and catastrophic landslides, are likely to result in the risk of dam failure, which is not only a big threat to local and downstream residents but also a big disruption to secure electricity supply. Even worse, if wars break out, the big dam is susceptible to be attacked by enemies.

7.2 Does Three Gorges Project incorporate with sustainable development?

This is a simple question, which has two totally different answers. It is sustainable, largely because of its potential contribution in reducing burning of coal or oil and the fact that it emits little GHGs. Moreover, according to the definition of sustainability—meeting present needs without comprising the ability to meet the future needs, the big dam, which is likely to provide electricity for a long time and can be used by future generations, is sustainable. Broadly, sustainability is about an obligation to future generations. One of the most important functions of this big dam is to control flood, which has claimed less than 1 million lives in the past 100 years and led to big economic losses. China's government has to contribute large amount of manpower and material resource to preventing flood almost every year. Thus, Three Gorges Project is beneficial for future generations. In this sense, it is sustainable as well.

On the other hand, it is unsustainable because the dam converts terrestrial ecosystem to an aquatic ecosystem and has some possible even irreversible serious consequences on local society and environment. According to an extreme standard that sustainability means totally environmental protection and no changes in environment, the huge dam is unsustainable. Moreover, this project needs to relocate more than 1 million local residents leading to human rights violation, thus it is difficult to regard sustainable. Furthermore, as calculated that the big dam can reduce 3.7% coal consumption and 3.6% CO^2 emission of total, it is only in a medium level thus difficult to entitle the big dam sustainable.

However, whether Three Gorges Project is sustainable or not, it can provide a large amount of electricity production and thus is beneficial to the Chinese economic and social development. China is now in the stage of industrialization, and if compared with developed countries, still has a long way to go. Energy supply is a basis and prerequisite to achieve modernization and alleviate poverty. Electricity plays an important role in boosting China’s development. Firstly, in general, with the widespread use of computers and other voltage-and frequency-sensitive electronic equipment, people are more dependent on electricity than before, which means an interruption of electricity can lead to inconvenience for people and even create grave chaos in cities and urban centers. Secondly, the living standard in China is increasing gradually meaning that more and more electric appliance such as television, air-conditioner, refrigerator and etc goes into common families. In addition, with the progress of urbanization, the rural-to-urban migrants are expanding, which will lead to the increase in electric consumption. Therefore, China needs much more electricity than before. Thirdly, in China only some 80% of the population is currently connected to the electrical grid, and too many people are still absolutely poor. To reduce the number of the impoverished is one of the most important and pressing goals of China’s development strategy. Inexpensive and readily available electricity is indispensable to raising people out of poverty and ends the cycle of poverty. (IEA World Energy Outlook, 2000) Fourthly, at present, industrial electricity shortage in some areas often happens, and there are already many reports that electricity shortages have obstructed local economic growth. In the end, given the fact that China is the most populous country combined with low per capita energy reserves and uneven energy distribution, hydropower, which is renewable, is a good approach to supply endless electricity.

7.3 Dilemmas of balancing gains and losses

It is generally accepted that big dams have environmental and social advantages and disadvantage, so in some cases, the weighing of benefits against losses is difficult.

One of the most important reasons is that there is no unified formula, which can give an answer when putting them in the balance.

Firstly, in case of water exploitation development, there is a strong ethical tradeoff between developed countries and developing countries. Currently, in many developing countries hydropower potential is huge, on the contrary a large share of the potentially suitable sites have already been exploited in developed countries; another fact is that opposition to large dams has arisen greatly as a result of social environmental impacts, mostly led by developed world. Consequently, the ethical value or criteria put forward by developed world is difficult to be accepted totally by developing world (Muhammad & Olli, 2003).

Secondly, it is hard to formulate practically unified guidelines in the world because every county has its own developmental, economic, environmental and social priorities and its own culture and value system.

Thirdly, the diversity of hydropower projects in size and nature sets it apart from most other electricity production technologies. Due to different electrical services sought and the specific site conditions, there are a wide variety of hydroelectric projects, each providing different types of services and generating environmental and social impacts of different nature and magnitude. Because many of the potential impacts are extremely site-specific, the environmental impacts of any large-scale hydro scheme must be assessed on a case-by-case basis. Each hydro project should be judged on its own merits.

Finally, when society requires all stakeholders including project proponents, opponents, government representatives and the public to be involved in decision-making process, in most cases, they do not share similar values, codes of conduct or interests, expressing a wide diversity of viewpoints, some of which are even competing. One benefit of a certain stakeholder sometimes is an impact on another stakeholder. Thus it is difficult to identify acceptable social, economic and environmental trade-offs. (Klimpt et al., 2002; Oud, 2002)

When facing the difficulties in balancing benefits against impacts, increased global debate and pressure, as well as public opposition, policy-makers will find them in an awkward predicament—if the big dams are taken away, power demand will not reduced. Then what is the solution for China's energy needs? Thus, the policy-makers have to be prepared to call upon other energy sources to replace the lost power production. In this situation, they, by any means, need to select alternatives. More coal burning? Or the dramatic expansion of nuclear power, which also has its many critics? Or other renewable energy? It is also difficult to choose energy alternatives.

Any project, whether fossil-fueled or driven by wind, solar or hydro energy, may prove totally inappropriate, if it imposes on sensitive ecological habitats (Russo, 1995). In another word, each source of energy affects environment, society and economy in some ways; none is perfect. Even renewable energy has impacts on environment and society such as noise, visual intrusion, land occupation ant etc (IEA, 1998). Apart from these environmental and social disadvantages, there are also some obstacles to prevent renewable energy from utilizing on a large scope. One example is wind power. China is a big country, and many wind areas are far from most demand centers. Wind energy cannot be transported without the use of expensive energy storage such as batteries, which means that the cost to develop large-scale wind plants is too high. If mainly developing small-scale wind power programs locally, it occupies too many lands, which is a big problem for China (LEW, 2000). Others such as solar power, biomass and etc also have some difficulties to encourage on a large scale.

7.4 Is it possible to overcome the dilemmas?

Fossil fuels generation is still the main competitor of hydropower. Now most of the world electric energy comes from thermal resources and it is easy to assume that the replacement energy will come from those sources, and too strict limits placed on hydropower development would result in the increase use of fossil fuels.

However people don't need to be pessimistic. As mention before, energy efficiency is a good approach to hence energy security and sustainable development. Most importantly, energy efficiency will be important to prevent demand for oil growing too fast, therefore buying time to stretch its life span.

The role of energy has often been overlooked in sustainable development strategies. In fact, energy is at the heart of the sustainable development challenge, since nearly all activities in our societies depend upon adequate supplies of energy. Achieving a more sustainable energy path will contribute significantly to the realization of the sustainable development of society, economy and environment. The rational use of energy is one of the fundamental vectors of responsible energy policy for the implementation of sustainable development and national energy security strategy.

Although energy efficiency improvements are often confronted most with institutional and financial barriers, it is still one of the most important measures to boost energy security and sustainable development in the future.

8 Concluding remarks

From the point of energy security, although the main attraction of Three Gorges Project is the supply of renewable and secure energy, which is an important supplement to solve the problem of electricity shortfalls in China, it does not reduce the number of imported crude oil. So, the big dam cannot strongly foster China's energy security.

From the view of sustainable development, the big dam is a complex issue. Three Gorges Project is sustainable because it generates “green” electricity and is a beneficial welfare for the future generations. On the other hand, it is unsustainable as result of changes on local ecological systems and because of immediate and afterwards environmental and social impacts. Thus, according to strict standard, the big dam is not sustainable.

Consequently, although the energy generated by Three Gorges Project is renewable, the huge dam itself is neither closely relevant to China’s energy security nor absolutely sustainable. Nevertheless, people cannot neglect a fact that it can provide a huge amount of available and reliable electricity and it plays an important role in boosting China’s development.

Almost all the people admit Three Gorges Project has negative and positive impacts on environment, society and economy, so the attitude towards it is dependent on balancing between gains and losses. Currently, due to the lack of a unified formula, it is difficult to weigh benefits against impacts and reach an unbiased evaluation. Moreover, if big dams are taken away, it is also hard to choose energy alternatives because they all have environmental and social consequences, and other obstacles preventing them utilizing on a large scope. Currently, maybe especially in the future, energy efficiency is likely to play an important role in bolstering energy security and sustainability.

References:

Acker F. 1997. Electricity in China. *IEE Review*. 43: 55-58

Adnan Shihab- Eldin. 2002. New energy technologies: trends in the development of clean and efficient energy technologies. *OPEC Review*. 26: 261-307

Afgan N.H. Gobaisi D.A. Carvalho M.G. & Cumo M. 1998. Sustainable energy development. *Renewable and Sustainable Energy Reviews.* 2: 235-286

Anand Sudhir & Sen Amartya. 2000. Human development and economic sustainability. *World Development*. 28: 2029-2049

Axel Michaelowa. Asuka Jusen. Karsten Krause and Tobias Koch. 2000. CDM Project in China's energy supply and demand sectors—opportunities and barriers http://www.hwwa.de/Publikationen/Discussion_Paper/2000/90.pdf Accessed on 16th Sep 2003

Beach, Marilyn. 1999. Millions choke while stoves burn. *Lancet*. 354:137-138

Berube Gilles G & Villeneuve Francois. 2002. Ethical dilemmas and the decision-making process. Is a consensus realistic? *Energy Policy*. 30: 1285-1290

Bielecki, J. 2002. Energy security: is the wolf at the door? *The Quarterly Review of Economics and Finance*. 42: 235-250

Buczek Mark. 1996. Fueling China's growth. *The China Business Review*. 23: 8-14

Brown Lester R. 1995. Who will feed China? The Environmental Magazine. 8: 36-42

Brooks Amy. 2001. National Energy Security: Implications for National Energy Policy. Environmental and Energy Study Institute. http://www.eesi.org/publications/10.04.01nationalsecurity.pdf. Accessed on 25th Aug 2003.

Buran, B. Butler, L. Currano, A. Smith, E. Tung, W. Cleveland, K. Buxton, C. Lam, D. Obler, T & Rais-Bahrami, S. 2003. Environmental benefits of implementing alternative energy technologies in developing countries. *Applied Energy*. 76: 89-100

Burton Sandra & FlorCruz Jaime A. 1994. Taming the river wild. *Time*. 144: 62-65

Chang J, Leung DC, Wu CZ, Yuan ZH. 2003. A review on the energy production, consumption, and prospect of renewable energy in China. *Renewable and Sustainable Energy Reviews*. 7: 453-468

Charles A. S. Hall, Cutler J. Cleveland and Robert Kaufmann. 2001. Characteristic and magnitude of U.S energy resources system. *Energy & Resource Quality*. University Press of Colorado. P308

Chen G, 2001. The Chinese petroleum industry achievements during 1996–2000 and targets for the next five years.International Petroleum Economics 9 (1), 7–8. (In Chinese)

Chen, J.H. 2001. Current Situation of Energy in China and Energy Policy in Tenth Five-Year Plan—A Speech at the Minister-Level Conference of IEA. http://www.gzii.gov.cn/middle2/jjrd/05/52202.htm (in Chinese) Accessed on 14th November 2003

China's Agenda 21. 1994---White Paper on China's Population, Environment, and Development in the 21st century. 1994. *Sustainable energy production and consumption*. P124-136

Chinatoday. 2004. http://www.chinatoday.com (Accessed on 16th Oct 2003)

Ciocci Linda. 2003. Hydropower licensing reform: What's all the fuss? *Power Engineering*. 107: 70

Cooper Martin. 1997. China powers ahead. *International Construction*. 36: 67-69

CSA (2003) *China Statistical Abstract*. China Statistics Press, Beijing

Das A.K. 2001. Sustainable development. *Chemical Business*. 15: 7-9

Dai Yande, Zhu Yuezhong, Jonathan E Sinton. 2004. China's energy demand Scenarios to 2020. The Sino Sphere Journal. 7: 7-15

David L. 1997. Economic scarcity. *Harvard International Review*. 19: 16-19

Dincer I. 2000. Renewable energy and sustainable development: a crucial review. *Renewable and Sustainable Energy Reviews*. 4: 157-175

Dincer I. & Rosen M.A. 1999. Energy, environment and sustainable development. *Applied Energy*. 64: 427-440

Dodman Kevin. 1998. Energy solutions from environmental disasters. *International Power Generation*. 21: 24-26

Egre D & Milewski J.C. 2002. The diversity of hydropower projects. *Energy Policy*.

30: 1225-1230

Fesharaki Fereidun. 1999. Energy and the Asian security nexus. *Journal of International Affairs*. 53: 85-99

Frey W & Linke M. 2002. Hydropower as a renewable and sustainable energy resource meeting global energy challenges in a reasonable way. *Energy Policy* 30: 1261-1265

Fu, Cuizhang. Wu, Jihua. Chen, Jiakuan. Wu, Qianhong. Lei and Guangchun. 2003. Freshwater fish biodiversity in the Yangtze River basin of China: patterns, threats and conservation. Biodiversity & Conservation. 12:1649-1685

Fuggle & Smith. 2000. Experience with dams in water and energy resources development in The People's Republic of China. *World Commission on Dams (WCD) country review paper*

Gagnon Luc. Klimpt Jean-Etienne and Seelos Karin. 2002. Comparing recommendations from the World Commission on Dams and the IEA initiative on hydropower. *Energy Policy*. 30: 1299-1304

Gan Lin. 1998. Energy development and environmental constraints in China. *Energy Policy*. 26: 119-128

Hayes, D. 2002. Catching the wind: Clean and sustainable solutions to China's energy shortfall *Refocus*. 2002: 18-20-21

He B. & Chen C. 2002. Energy ecological efficiency of coal fired plant in China. *Energy Conversion and Management*. 43: 2553-2567

Heywood Neil. 2000. Highly political energy. *Petroleum Economist*. 67: 5-7

Hunt Janet. 1990. Our Common Future. *Social Alternatives*. 9: 9-14

Iain McCreary, Alan Y. Gu, Verne W. Loose and Joseph M. Roop. 1996. China's energy a forecast to 2015. U.S Department of Energy. Washington D.

IEA (International Energy Agency). 1998. Benign Energy? The Environmental Implications of Renewables. OECD, Paris.

IEA (International Energy Agency). 1999. Coal in the energy supply o f China. OECD, Paris.

IEA (International Energy Agency). 2000. China's Worldwide Quest for Energy

Security. OECD, Paris.

IEA (International Energy Agency). 2000. World Energy Outlook 2000. OECD, Paris

IEA (International Energy Agency). 2001. Statement on sustainable development. OECD, Paris.

IEA (International Energy Agency). 2002. Renewable Energy…into the Mainstream. OECD, Paris.

IEA (International Energy Agency). 2002. *Toward solutions: Sustainable Development in the Energy Sector*. OECD, Paris.

IRN (International Rivers Network). 2003. *http://www.irn.org/programs/threeg/map.shtml* (accessed on 12th Dec 2003)

Jin Z, Bai and Mansoori.2004. An introduction to petroleum and natural gas exploration and production research in China. *Journal of Petroleum Science and Engineering*. 41:1-7

Jin Guoxing. 1999. Energy Security: A View From China. http://www.csis.org/pacfor/pac2599.html. Accessed on 2nd Sept 2003

Johnston Donald j. 2002. Sustainable development: Our common future. *Organisation for Economic Cooperation and Development. The OECD Observer*. P: 3

Jonathan Porritt. 2003. Sustainable Development. *New Economy*. 10: 28-33

Junfeng, Li & Runqing, Hu. 2003. Sustainable biomass production for energy in China. *Biomass and Bioenergy*. 25: 483-499

Kaygusuz K. 2002. Sustainable development of hydropower and biomass energy in Turkey. Energy Conversion and Management. 43: 1099-1120

Klimpt Jean-Etienne. Rivero Cristina. Puranen Hannu and Koch Frans. 2002. Recommendations for sustainable hydroelectric development. *Energy Policy.* 30: 1305-1312

Koch F.H. 2002. Hydropower-the politics of water and energy: Introduction and overview. *Energy Policy.* 30: 1207-1213

Kuo Alexander. 1998. Breaking the wall. *Harvard International Review*. 20: 28-31

Lee Handel & Hengst Benjamin. 1998. China. *International Financial Law Review.*

P: 19-24

Lew D.J. 2000. Alternatives to coal and candles: wind power in China. *Energy Policy*. 28: 271-286

Liang Weiyan. 2001. Power equipment of the gigantic Three Gorges Project. *Electrical Machines and Systems, 2001. ICEMS 2001. Proceedings of the Fifth International Conference.* 1: 676-678

Li Francis. 2002. Hydropower in China. Energy Policy. 30: 1241-1249

Li ZhiDong. 2003. Energy and Environmental Problems behind China's High Economic Growth-A Comprehensive Study of Medium-and Long-term Problems, Measures and International Cooperation. http://eneken.ieej.or.jp/en/data/pdf/188.pdf Accessed on 25th Sept 2003

Lu Youmei. 1996. The Three Gorges project and the sustainable development of Yangtze River. *Chinese engineering consultation.* 5: 23-27 (In Chinese)

Luc Gagnon & Joop F van de Vate. 1997. Greenhouse gas emissions from hydropower: The state of research in 1996. *Energy Policy*. 25: 7-13

March Patrick A. & Fisher Richard K. 1999. IT'S NOT EASY BEING GREEN: Environmental Technologies Enhance Conventional Hydropower's Role in Sustainable Development. *Annual Review of Energy and the Environment.* 24: 173-188

McCormack Gavan. 2001. Water Margins: Competing Paradigms in China. *Critical Asian Studies*. 33: 5-30

Mehmet Ogutcu. 1998. China's energy sector and outward-looking linkages. http://www.iea.org/new/speeches/ogutcu/shang.pdf Accessed on 16th Sept 2003

Michael B Frolic & Gregory T. Chin. 2000. The challenges of energy security in Northeast Asia. http://www.norpac.or.jp/main2/follow/1999-4.pdf Accessed on 23rd August 2003

Muhammad M. Rahaman & Olli Varis. 2003. The ethics of water: some realities and future challenges. http://www.water.hut.fi/pdl/Publication_3.pdf. Accessed on 21 Sept 2003.

Minchener Andrew J. 2000. Technology transfer issues and challenges for improved energy efficiency and environmental performance in China. International Journal of Energy Research. 24: 1011-1027

Mumford J. L, X. Z. He, R. S. Chapman, S. R. Cao, D. B. Harris, and X. M. Li. 1987. Lung Cancer and Indoor Air Pollution in Xuan Wei, China. Science. 3-235: 217-220

Ni Weidou & Johansson TB. 2004. Energy for sustainable development in China. Energy Policy. 32:1225-1229

Nolan, P. Shipman, A and Rui, H. 2004. Coal Liquefaction, Shenhua Group, and China's Energy Security. *European Management Journal*. 22: 150-164

Oud E. 2002. The evolving context for hydropower development. *Energy Policy*. 30: 1215-1223

Qing Dai & Sullivan Lawrence R. 1999. The Three Gorges Dam and China's Energy Dilemma. *Journal of International Affairs*. 53: 53-72.

Rogner HH. 2000. Energy resources in WEA (2000). *Energy-and the challenge of sustainability.* UNDP, USA

Rosenfeld A. 1996. Consumer non-energy benefits as a motivation for making energy-efficiency improvements. *Energy*. 21: 707-720

Russo Thomas N. 1995. Making hydro sustainable. *Public Utilities Fortnightly*. 133: 14-20

Saskia Hieber. 2003. International and Chinese Projections for Future Energy Demand in China. Round Table, *Securing Energy - China's Policy and its Wider Strategic Implications*, Federal Foreign Office, Berlin

Scott Snyder. 1997. The South China Sea Dispute: Prospects for Preventive Diplomacy.
http://www.usip.org/pubs/specialreports/early/snyder/South_China_Sea1.html
Accessed on 12 Oct 2003

SFPC (State Family Planning Commission of China). 2002. The projection of China's population By SEPC. Beijing

Shiqiu Zhang. 2000. China's energy, environment and policy perspective. *Journal of Environmental Sciences* 12: 270-275

Shi ZuLin & Su Wangsheng. 2001. Energy Use and Environmental Pollution in China. http://www.weea.org/Paper%20Series/chinapaper.pdf Accessed on 28th Sept 2003

Shiqiu Zhang. 2000. China's energy, environment and policy perspective. *Journal of*

Environmental Sciences 12: 270-275

Silverman, M & Worthman, S. 1995. The future of renewable energy industries. *The Electricity Journal*. 8: 12-31

SSB (1989) *China Statistical Yearbook*. China Statistics Press, Beijing

Stanford A. 1997. A vision of a sustainable energy future. *Renewable Energy*. 10: 417-422

Strecker Downs Erica. 2000. China's Quest for Energy Security. http://www.rand.org/publications/MR/MR1244/MR1244.ch2(3,4).pdf Accessed on 25th August 2003

Sweet W. 2001. China's big dams. *IEEE Spectrum*. 38: 46-51

Tefft Shiela. 1995. Rush to burn coal turns China into Asia's polluter. *Christian Science Monito*. 87: 1-1

Truffer, Bernhard. Bratrich, Christine. Markard, Jochen. Peter, Armin. Wust, Alfred and Wehrli, Bernhard. 2003. Green Hydropower: The contribution of aquatic science research to the promotion of sustainable electricity. *Aquatic Sciences*. 65: 99-110

Twidell J. 1993. Renewable energy: implementation and benefits. *Advances in Power System Control, Operation and Management, 1993. APSCOM-93, 2nd International Conference on*. P:418-424

United Nations. 2001. Energy efficiency and energy security in the Commonwealth of Independent States. *ECE Energy Series No. 17. Geneva (Switzerland)*

UNDP. 2002. Energy and the Challenge of Sustainability. *World Energy Assessment*. New York.

Veltrop J. 2001. Harnessing untapped hydropower in the context of the World Commission on Dams. *Power Engineering Society Summer Meeting, 2001*. 1: 537-538

Walkade N. S. 1988. The use and supply of renewable energy-policy issues and related analytical problems. *The economic Development Institute of The World Bank. Finance, Industry, and Energy division*.

Wang Dazhong & Li Yingyun. 2002. Roles and prospect of nuclear power in China's energy supply strategy. *Nuclear Engineering and Design*. 218: 3-12

WCED -World Commission on Environment and Development (1987) Our Common Future in eds. Nelissen N, Vander Straaten J & Klinkers L (1998) *Classic in Environmental Studies.* International Books, The Hague

Wen & Qui. 1998. The energy utilization of Yangtze River and sustainable development. *World science and technology.* 20(5): 7-14 (In Chinese)

WCD (World Commission on Dams). 2000. Dams and Development: A new framework for decision-making. Earthscan Publications Ltd. http://www.dams.org/report (Accessed on 26th August 2003)

WCD (World Commission on Dams). 2003. http://www.dams.org/ (Accessed on 17th November 2003)

Xue & Yuan. 2002. Cognise the situation of a country and establish the right strategies of Chinese energy development. *China three gorges construction.* 2: 8-11 (In Chinese)

Yang H, Li X. 2000. Cultivated land and food supply in China. Land Use Policy. 17: 73-88

Yangtze cruise. 2003. http://www.yangtze.com/ (Accessed on 16th Nov 2003)

ZhiDong, L. 2003. An econometric study on China's economy, energy and environment to the year 2030. *Energy Policy*. 31: 1137-1150

Zhong Ling. 2000. Nuclear energy: China's approach towards addressing global warming. *Georgetown International Environmental Law Review*. 12: 493-522

Zhu J. 2004. Public investment and China's long-term food security under WTO. Food Policy. 29: 99-111

Appendix1: List of Abbreviations and Acronyms Used in the Text:

CO2	Carbon dioxide
GDP	Gross Domestic Production
GHG	Greenhouse gas
GW	Gig watt.
HVDC	High voltage direct current
IEA	International Energy Agency
Kb/d	thousand barrels per day
Kg	Kilogram
Km	Kilometer
Mb/d	million barrels per day
Kwh	Kilowatt hour

Mt	million tons
Mtce	million tons of coal equivalent
Mtoe	million tons of oil equivalent
MW	megawatt-hour
NGOs	None government organizations
Nox	nitrogen oxides
OECD	Organization for Economic Co-operation and Development
OPEC	Organization of the Petroleum Exporting Countries
SO2	sulfur dioxide
toe	tones of oil equivalent
TSP	Total suspended particle
TW	terawatt
UNDP	United Nations Development Program
USEA	Untied States Energy Association
WCED	World Commission on Environment and Development
WHO	World Health Organization
WTO	World Trade Organization

Appendix 2: Explanation of units used

Energy is often expressed using the unit of a joule (J)

Power is the amount of energy for a unit of time. The most commonly used unit is the Watt (W), which is one joule every second. This unit is often used to show the potential of an installation.

Kilowatt-hour (KWh) is a commonly used unit when describing a total amount of power.
1 KWh = 3 600 kJ = 3 600 000 J

Installed Capacity
Installed Capacity, measured in MW, is the maximum rate that a turbine can produce electricity. For example, 500 MW installed capacity will produced 500MWh (0.5 GWh) in the course of an hour.

Chinese Electrical Capacity Equivalency: 1 GW = 4.5 TWh

Tonnage
1 ton = 1000 kg.
1 kg = 2.2 lbs

Mileage
1 kilometer = 5/8 mile
1 tce=7,000,000 kcal

Standard Coal: 1 ton = 29.310 GJ = 1.000 tce = 5.14 bl oil = 7.00 kcal
Chinese Average Coal 1 ton = 20.943 GJ = 0.714 tce = 3.68 bl oil = 5.00 kcal
Chinese Average Crude 1 ton = 41.868 GJ = 1.429 tce = 7.35 bl oil = 10.00 kcal
Chinese Average Crude 1 bl = 5.694 GJ = 0.199 tce = 1.00 bl oil = 1.36 kcal
Standard Natural Gas 103 m3 = 37.68 GJ = 1.29 tce = 6.62 bl oil = 9.00 kcal
Chinese Avg. Nat. Gas 103 m3 = 38.98 GJ = 1.33 tce = 6.85 bl oil = 9.31 kcal

Coal to Oil Conversion: 1.0 tce = 0.7 toe
Oil to Coal Conversion: 1 toe = 1.429 tce
Oil to Oil Conversions: 1.0 toe = 7.19 bl oil