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EVOLUTION OF CHINA'S ENERGY SECURITY:

THE IMPACT OF DOMESTIC REFORMS AND POLICIES

YAO LIXIA

S. RAJARATNAM SCHOOL OF INTERNATIONAL STUDIES

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S. Rajaratnam School of International Studies

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Abbreviations

Analytic Hierarchical Process	AHP
Asia Pacific Energy Research Centre	APERC
Acceptability by society	AC
Affordability of energy prices	AF
Applicability of technology	AP
Availability of resource	AV
British Petroleum	BP
Chinese Academy of Social Sciences	CASS
Coal-bed methane	CBM
Chinese Communist Party	CCP
Carbon capture and storage	CCS
China Energy Conservation Investment Corporation	CECIC
Coal-mine methane	CMM
China National Offshore Oil Corporation	CNOOC
China National Petroleum Corporation	CNPC
Carbon dioxide	CO₂
Contract Responsibility System	CRS
China Statistical Yearbook	CSY
Department for Business, Enterprise and Regulatory Reform	DBERR
Diversification of Primary Energy Demand	DoPED
Driving force-state-response	DSR
Energy Information Administration	EIA
Energy indicators for sustainable development	EISD
European Union	EU
Five-Year Plan of economic and social development	FYP
Group Company System	GCS
Gross domestic product	GDP
Greenhouse Gas	GHG
Hydro, Eolien, Light, Insulation, Organomass	HELIO
Household Responsibility System	HRS
Kuomintang	KMT

Kilowatt hour	kWh
International Atomic Energy Agency	IAEA
International Energy Agency	IEA
Independent power producer	IPP
Indicators for Sustainable Energy Development	ISED
Lawrence Berkeley National Laboratory	LBNL
Large and medium-sized enterprise	LME
Middle East Oil Import Dependency	MEOID
Modern Enterprise System	MES
Million tons	Mt
Megawatt hour	MWh
National Bureau of Statistics of China	NBS
Non-Carbon based Fuel Portfolio	NCFP
China's National Development and Reform Commission	NDRC
Net Energy Import Dependency	NEID
National Environmental Protection Agency	NEPA
Non-Governmental Organization	NGO
Not in my backyard	NIMBY
National Oil Company	NOC
Net Oil Import Dependency	NOID
National People's Congress	NPC
National Renewable Energy Laboratory	NREL
Organisation for Economic Co-operation and Development	OECD
Oil vulnerability index	OVI
Particulate matter-10	PM₁₀
People's Republic of China	PRC
Research & Development	R&D
Renminbi	RMB
Reserve-to-production	R/P
State Environmental Protection Administration	SEPA
State Electricity Regulatory Commission	SERC
State Economic and Trade Commission	SETC
Sustainability Indicator	SI
China Petrochemical Corporation	Sinopec
Small and medium-sized enterprise	SME

Sulfur dioxide	SO₂
State-owned Enterprise	SOE
State Power Corporation of China	SPCC
Total primary energy supply	TPES
Township and village coal mine	TVCM
Township and village enterprise	TVE
United Nations	UN
United Nations Development Programme	UNDP
United States	U.S.
World Energy Council	WEC
Work Programme on Indicators of Sustainable Development	WPISD

Abstract

Despite unprecedented energy consumption rates and environmental sustainability threats, China has seen fast economic growth in the past 30 years of reform. Within this context, this study applies both quantitative and qualitative analyses to the energy security situation in China between 1980 and 2010.

Two primary objectives are achieved in this study. The first objective is to examine how the energy security situation in China has evolved in the past 30 years. This study establishes a quantitative 4-As framework and identifies 20 indicators incorporated in the framework based on a comprehensive concept of energy security which covers availability of resources, applicability of technologies, acceptability by society and affordability of prices (the 4-As). The framework analysis shows that China's energy security situation has not improved during the economic reform. Its enlarging appetite for energy resources has made the quantitative value of the availability dimension decline. The acceptability dimension deteriorated along with the energy utilization, only improving a little recently. The affordability dimension improved after it hit the bottom in 1995. Although the country's technology continued to progress, the improvement of the applicability dimension cannot restore the overall energy security status to the early reform period level. The emphasis on energy policies during the 30 years of reform appears to have affected the energy security status directly.

The second objective of the study is to explore qualitatively why the energy security situation has not improved. To answer the "why" question, the study opens up a new perspective by analysing the relationship between energy security and energy policies from the macroeconomic reform perspective. This study discusses major reforms that took place over 30 years. It is found that China's macroeconomic reform has restricted the formation of China's energy policies and determined its energy security situation. In essence, China's energy policies are only a reaction to the macroeconomic measures. In other words, China's energy policies are not originally intended to improve energy security, but *passive reactions* to China's macroeconomic reform. This explains why China did not improve its energy security situation despite 30 years of reform.

Chapter 1: Introduction

1.1 Background

1.1.1 Energy security and energy policy

A country's energy policy and energy security status are closely related and influence each other. Having sound energy policies will improve energy security, whereas less prudent energy policies may worsen its energy security situation. Thus, ensuring energy supply security is fundamental for domestic prosperity and national security because "the advent of globalization, the growing gap between rich and poor, the war on terrorism, and the need to safeguard the earth's environment are all intertwined with energy concerns" (Wirth, Gray, & Podesta, 2003, pp. 132-133). China's huge appetite for energy consumption and its massive degradation of the environment have increasingly fostered international concerns. Therefore, analyzing the interaction between energy policy and energy security in China is an urgent task and will help address these concerns.

What makes energy policy and energy security so critical an issue is that the energy sector has specific features.¹ For example, a reliable energy supply is crucial to economies, energy projects involve high capital investment and large risks, and energy production and consumption may result in environmental degradation. These distinctive characteristics of the energy sector require every government to have its own energy policy (Andrews-Speed, 2001). This policy, in turn, has a significant impact on both energy production and consumption. Hence, the security of energy supply has even been deemed the "key element for the functionality of the modern societies" (Purhonen, 2005, p. 1).

¹ Energy sector here refers to the sector that is related to energy exploration and production, such as the coal sector, oil sector, and so on.

Energy is an economic commodity, but it has also become a political commodity whereby economics and politics influence the energy sector. Since energy is essential for fueling the economy, energy resources—especially fossil fuels—have often been a fuse for conflicts and wars. Fossil fuels are the most important source of energy, but also scarce and non-renewable. Therefore, competition for seeking fossil fuels is fierce and prone to tension and conflicts. The historical record shows examples of oil-importing countries that sought to eliminate their oil dependence through military expansion. A case in point is the Japanese invasion and expansion in East Asia during World War II (Yergin, 1991). There is a close relationship between a country's national interests and energy supply security. Energy *per se* is not a security issue, but any shortage of energy will become a security issue as states get involved in conflicts and resort to military action.

The underlying implication of the close relationship between energy security and energy policy is also reflected in geopolitical thinking. Geopolitics is an instrument of political warfare and helps explain the structure of security problems (Sloan & Gray, 1999, p. 10). In particular, geopolitics is a useful tool to analyze energy politics. Klare (2003) defines geopolitics in a traditional way: “the contention between great powers and aspiring great powers for control over territory, resources, and important geographical positions, such as ports and harbors, canals, river systems, oases, and other sources of wealth and influence” (p. 51).

Although there is no common definition of geopolitics, it is widely viewed as a driving force for world politics/conflicts. Geopolitical ideology was used by Hitler, Mussolini, and Japanese militarists to justify their expansion into neighboring countries. Their actions threatened the geopolitical interests of opposing powers, such as their sphere of influence on Eastern Europe and Southeast Asia, leading to World War II (Klare, 2003, p. 52). When Japan found that China and Southeast Asia

had dependable sources of energy, it realized that it could rely on these resources to grow its economy. It was Japan's decision to control these resources that further aggravated World War II.²

Although traditional geopolitics offers convincing arguments and supporting evidence for the main drivers causing conflict and war, it has been criticized for being trapped in state-centrism and acting as a mere narrative about resource wars. In response to this criticism and along with the process of globalization, a much broader notion of geopolitics, namely critical geopolitics, emerged in the late 20th century, when the more integrated world dwarfed the role of nation-states and enhanced the roles of non-state actors, such as transnational corporations and environmental organizations.³ In the energy sector in particular, big oil companies may play a key role in a state's energy policy decision-making process. Globalization makes a country's energy policy not just a national issue but a transnational issue; 'spill over' effects in other countries may cause an international security problem. That is to say, critical geopolitics defines space in a more socio-economic way such that different regions can be connected to best serve national interests (Amineh, 2003). In sum, geopolitics, traditional or critical, justifies the importance of a country's energy policy and its implications for security.

1.1.2 Definitions of energy security and energy policy

Energy security is defined in the literature in both a broad sense and a narrow sense. In the broad sense, energy security is a condition in which a country has access to adequate and reliable energy supplies at reasonable prices (Yergin, 1988; Clingendael International Energy Programme, 2004; IEA, 2007a; Chang & Lee, 2008; Lin, 2009a). In the narrow sense, energy security refers mainly to concerns with the

² This point is attributed to private talk with Dr. Loo Fook Weng.

³ Critical geopolitics breaks away from traditional great power competition conceptions of geopolitics.

security of primary energy resources, particularly with oil; it also focuses on the economic or national welfare aspect (Samuels, 1997; Nautilus Institute for Security and Sustainable Development, 1998; European Commission, 2001; Jansen & Seebregts, 2010; Loschel, Moslener, & Rubbelke, 2010).⁴

The narrow definition of energy security is often subject to criticism. It implicitly assumes that oil supply serves as the focus of energy supply security. This is ill-defined, since clarifying the risks related to other types of fuels constitutes the concept of energy security equally or even more critically than oil supply does (Nautilus Institute for Security and Sustainable Development, 1998, p. 15). Energy security should not only focus on the economic/welfare aspect. Several dimensions have been identified to make the concept of energy security more comprehensive. These dimensions include: the economic dimension, environmental dimension, social dimension, foreign policy dimension, technical dimension, security dimension, strategic dimension, political dimension, and systemic dimension (Alhajji, 2007; Purhonen, 2005). These dimensions constitute a new, comprehensive energy security concept.

The definition of energy security employed in this study is a comprehensive one, covering the dimensions of economy, environment, technology, and society so that energy security guarantees that a country, industries, and citizens have access to an adequate and reliable supply of energy resources (including primary energies and renewable resources) at reasonable prices.⁵ What underlies this definition is that energy insecurity would arise when any of the above-mentioned dimensions are not

⁴ For details of the literature on energy security definitions, see Chapter 2, Energy Security: Concepts, Frameworks and Indicators.

⁵ The term 'reasonable price' has been criticized by scholars. It is argued that 'reasonable' is sometimes difficult to understand. Firstly, it is not clear whether 'reasonable' is from the producer or consumer's point of view. Secondly, the terms 'affordable' or 'reasonable' are themselves vague. If 'reasonable price' means 'competitive price', it is unlikely to exist in all energy sub-markets, which are not perfect markets. Furthermore, the concept of 'competitive price' is also diffuse (Loschel, Moslener, & Rubbelke, 2010, p. 1666). This study defines 'reasonable price' as a price that is devoid of excessive market power (Chang & Lee, 2008).

met. Whether they are met or not is directly affected by the promulgation and implementation of energy policy. For example, severe fluctuation of energy prices affects the economic dimension of energy security, and a deteriorated environment in relation to fossil fuel utilization affects the environmental dimension. Hence, this definition underlines the integrated character of energy policy and national security, which forms a bridge between international political economy and security studies.

Winston Churchill's decision to switch ship fueling from coal to oil is an early example of an energy policy derived from the concept of energy security. This policy was 'bold, creative, and farsighted' (Wirth, Gray, & Podesta, 2003). Churchill's decision initiated the analysis of energy policy. Similarly, Deng Xiaoping's decision that China's oil companies should 'go out' to seek a diversified energy supply initiated the study of energy security and energy policy in China. Unlike the definition of energy security, there is little variation in the literature on the definition of energy policy. Energy policy is policy made by the government, industries, or NGOs to address issues in the energy sector, officially or unofficially (McGowan, 1996).⁶ These issues may cover the whole energy sector or deal with a specific subsector, such as coal, oil, renewable energy, energy R&D, energy conservation, and so on.⁷ Historical analysis of trends in energy policy shows the change in government thinking about policies on energy, from concentration purely on security of energy supply to greater emphasis on efficient and sustainable energy utilization (Finon, 1994). This change in policy priority exists in China as well.

⁶ Stakeholders of a country's energy policy making are the government, industries, and NGOs. However, in China, it is the government that has the power to make energy policies. Therefore, energy policy in this dissertation refers to energy policy made by the government.

⁷ For details of the literature on energy policy definitions, see Chapter 2, Energy Security: Concepts, Frameworks and Indicators.

1.1.3 The necessity of analyzing energy policy in China

The energy industry in China has a number of characteristics that are distinct from other sectors of the economy. First, the ownership of energy resources in China is largely in the hands of the state/government. The government has the right and responsibility to manage these resources. Second, exploration and development of energy resources involve large capital investments, long pay-back periods, and high risks. It cannot be easily tackled by the private sector. Third, energy production and consumption normally have negative consequences, such as environmental damage at the local, regional, and global levels. These issues need to be addressed by the government, either individually or collectively (Andrews-Speed, 2004). However, these issues have been neglected or not properly reflected in policy decision-making. Therefore, these characteristics make energy policy deserving of intensive research.

China's energy industry has gone through 50 years of transformation. It experienced a recovery early after the founding of the PRC, the Great Leap Forward period, the Cultural Revolution, and the reform era. The energy policy of China, an ultra-large economy and energy consumer, has critical implications not only for its own security situation, but also for the world's. China's energy security situation has increasingly drawn international concern. One reason for this is the current huge gap between its stagnating domestic energy production and its fast-growing consumption, which is projected to expand even further. The combination of China's rising energy demand and its limited indigenous energy resources has prompted its oil companies to acquire stakes in exploration and production projects abroad. Indeed, securing energy supply sources has become the key aim of China's energy and foreign policies. China's rising demand for energy has also raised serious concerns regarding global pollution and other environmental issues. Therefore, it is valuable to identify the way China's energy policy has evolved and its relevant impact on the security

situation. It is even more valuable to find the root reason behind the evolution of the energy security situation.

Energy policy stipulates objectives and the means to achieve these objectives, which may change to match a country's economic, political, and social conditions. The means to achieve the objectives are categorized into three groups: command, market, and persuasion. In a planned economy, command dominates the energy sector. Command, in the form of plans, regulations, and laws, regulates the flow of energy and players' actions. In a liberalized economy, a market mechanism dominates the energy sector. The market determines energy flow and prices. Persuasion, such as education and publicity for policy implementation, is required in both planned and liberalized economies (Andrews-Speed, 2001).

As China's economy shifts from planned to a market mechanism, it must adjust its energy policy accordingly. Facing the challenges of energy security problems amid rapid economic and social development, China's energy policy objectives have been amended to address emerging issues. The necessary means have been modified to realize these objectives and China's energy policy has evolved correspondingly. Research on the energy policy of China has both academic and practical significance.

1.2 Research questions and key findings

This study finds solutions for three policy-oriented questions. First, how has China's energy security situation evolved? The answer to this question is a quantitative study based on a framework (the 4-As framework) using indicators to quantify the energy security situation in China, with the conclusion that China's energy security has deteriorated over more than three decades of economic reform. Second, what impact do the energy policies have on China's energy security status? The answer

involves a whole chapter that analyzes the direct impact of China's energy policies on its security situation. Third, why has China's energy security deteriorated? The answer explores the nature of the evolution of energy policies and their impact on the energy security situation in China.

To put it briefly, this study evaluates the impact made by *past* and *current* energy policies and activities on the energy security status of China. Upon evaluation, it is found that China's energy security situation has not improved over three decades of economic reform. This study gives reasons for the evolution of China's energy security status: China's macroeconomic reform has restricted the formation of China's energy policies. In essence, it is macroeconomic reform that makes it difficult for China's energy security situation to improve. China's energy policies are only responses to the evolution of macroeconomic measures. In other words, China's energy policies were not originally intended to improve energy security, but only passive responses to macroeconomic reform. This study does not deny or disregard other factors that affect China's energy security situation such as international relations, institutions, interest conflicts, etc., while it finds that the macroeconomic reform is the key driver of China's energy security evolution.

1.3 Existing discussions on China's energy policy and energy security

The existing qualitative studies on China's energy security are mostly from the perspective of international relations. They discuss international or geopolitical advantages and challenges for energy security in China and offer suggestions (Zweig & Bi, 2005; Zhang, 1998 & 2003; Wang, 2001). In the context of international relations theory, the current literature addresses China's energy security and its geopolitical implications through either a realist perspective or a neo-liberal perspective, thus taking an energy perspective of China's foreign relations, which

entails either competition or cooperation. Realists take the international system as an anarchical one. Competition and a zero-sum game lead to conflicts. Realists believe peace is achieved through the balance of power between states, whereas neo-liberals believe that peace is achieved through cooperation.

From a realist perspective, China's oil dependence and increased demand for foreign energy resources will result in strategic competition between major powers such as the U.S. and China. The U.S. hegemonic oil strategy in the Middle East is the root cause of political instability in the region. This strategy has also severely constrained China's ability to secure a stable oil supply in the Middle East (Moran & Russell, 2009; Shu, 2010). Russia too faces fierce competition in its search for energy reserves in the Middle East and central Asia, which could provoke power warfare on a grand scale. The U.S., Russia, and China are trying to bolster their strategic positions and curb the influence of each other, hence a "three-way geopolitical struggle" has emerged (Klare, 2004, p. 162). Energy reserves in central Asia provide motives for the U.S. to secure a position in the region, albeit in competition with the interests of Russia. The latter will undoubtedly try to offset the deepening U.S. penetration in central Asia. The motive behind Russian-Chinese rapprochement can be traced to China's desires for central Asia to meet its future oil requirements (Noreng, 2006; Naughten, 2007).

From a neo-liberalist perspective, energy can be a platform for dialogue. Domestically-produced coal still dominates China's usage of energy. Therefore, China is less vulnerable to supply shortages than countries that lack domestic energy resources. As major coal producers and exporters, China and the U.S. share an interest in the development of coal-related technologies. Furthermore, China would prefer investment in expensive oil pipeline projects to conflicts with the U.S. and its neighbors over sea-lanes to ship its oil supplies from the Middle East. China's oil

imports from the Middle East offer China an interest in regional stability. It is China's investments in Iran's oil and gas sector that makes China interested in preventing a nuclear Iran (Shaffer, 2009). Since political instability in the Middle East poses high risks for the oil and gas supply from the region, China should work towards a long-term Sino-U.S. energy cooperation rather than risk confrontation in the Middle East (Sun & Pan, 2009). In other words, China's demand for foreign oil does not threaten U.S. global energy interests and is generally noncompetitive. The more China feels threatened by the U.S. and its allies, the more China will enhance its energy security by seeking alternative options, such as maximizing the use of its domestically abundant coal resources, developing expensive oil and gas pipelines, and cultivating relationships with oil-producing states such as Iran (Downs, 2000). As an oil-importing country, China is interested not only in collaborating with Middle Eastern countries, but also in finding common ground with other oil importers. The oil-importing countries should seek to acknowledge cooperation rather than competition in their search for energy (Jakobson & Zha, 2006).

Neither the realist nor the liberalist perspective gives an assertive evaluation of the evolution of China's energy security situation. Compared to qualitative studies on the energy security situation in China, energy security quantification makes it more operational to evaluate the evolution of China's energy security. Zhang (2007) and Chang (2010) apply the methodology of Analytic Hierarchical Process (AHP) in establishing evaluation frameworks that incorporate indicators to assess China's energy security evolution. However, Zhang (2007) only describes the dynamic change in China's energy security status, with the conclusion that its security status improved in 2005, compared with the 2000 level, and gives suggestions to guarantee China's energy security. Chang (2010) does not dynamically analyze the evolution of energy security in China, but he concludes that, currently, China is essentially an energy-secure country. At the same time, he points out that the 'degree' of energy security in China is not high and recommends policies and strategies to enhance it.

Using the AHP methodology, Shi (2011) makes the same conclusion that China is energy-secure. He analyzes general factors that affect the country's energy security and recommends policies. The AHP methodology has also been used to construct a framework to calculate the oil security index and evaluate China's oil security. It concludes that China's oil security has been worsening since 1991 (Zhang & Liu, 2005).

Besides the AHP methodology, other assessment systems can evaluate energy security in China with a more historical view. He, Sheng, and Wang (2011) use ten key indicators to assess the evolution of energy security in China and conclude that China's energy security situation generally improved from 1988 until 2004, after which it deteriorated. Liu, Shen, Gao, and Liu (2012) review several energy security indices and models and build an assessment model to evaluate China's energy security situation from 1990 to 2008. They conclude that China's energy security situation was the best in 2001 and then began to decrease. Since 2004, the deterioration has accelerated and the energy security situation reached its worst in 2008. However, none of these studies identify the key reason behind the evolution of energy security in China. They only superficially analyze factors that have an impact on energy security in China, such as international relations, domestic energy reserves, economic growth, industry structure, technology, environment, and so on. They fail to identify the key or the most critical reason behind the energy policies and energy security status evolution.

The research on China's energy policies has gained momentum since economic reform was initiated in 1979. From then on, China's energy policies have been extensively discussed. However, the discussion is either from one perspective without a comprehensive overview or does not combine energy policies with the country's energy security situation. In 2002, the Strategic Planning Department of

the State Power Corporation published *China's Energy in Fifty Years*. This book comprehensively reviewed the achievements in China's energy industry since 1949, summarizing the impact of China's energy policies on the energy industry and developments and changes in China's energy structure. It also mentioned China's energy policies, especially the energy policies in the individual energy sectors during the reform era. However, it only covered energy policies in general and omitted details on their evolution.

China's energy situation in the early 1980s is well-documented in the *Research Report on China's Energy Policy*. The report extensively reviews past implementation of energy policy and proposes a number of energy policy recommendations. It also points out the major energy challenges China faced in the early 1980s, such as rural energy shortages and coal transportation difficulties (China's Energy Research Institute, 1982). The report shows the background of China's energy policy formulation in the early 1980s and its dilemma in energy and economic development, but it does not evaluate the effects of China's main energy policies and specific measures on its security situation.

Some works have briefly discussed the evolution of China's energy policy. The evolution is generally categorized into three periods: before the economic reform, from the beginning of the reform to the tenth FYP period, and from the tenth FYP period to the present. The first period is a period of energy self-sufficiency. The second is a period of energy sector reform amid increasing international cooperation. The third is regarded as a period with more 'mature' energy policies where priority is given to energy conservation and sustainable development (Wang, Wang, & Fan, 2012; Zhao, 2008). However, this kind of categorization only takes a superficial view of the change in priority documented by the Chinese government. The actual motivation behind the evolution is ignored. Shi (2005) finds that market reform and

an open energy market are ‘objective requirements’ of energy security in China. She maintains that market liberalization is directly related to energy security. Perhaps she has some sense of the relationship between market reform and energy security, but she fails to explain how the relationship works. In a later work, she tries to find the motivation behind the energy policy evolution, and she almost gets there with the argument that energy industry reform is a component of Chinese economic system reform. But she argues that the purpose and steps of energy system reform reflect the stepwise process and characteristics of the energy industry, rather than going further to analyze the relationship between energy industry reform and reform of the Chinese economic system. She reviews the processes and contents of the reform in the energy sector from only three aspects—energy pricing mechanism reform, opening of the energy sector to foreign and private investors, and administrative institution reform in the energy sector—and evaluates the effectiveness of the reform (Shi, 2008). The failure to identify the essence of energy policy evolution makes it impossible to comprehensively discuss energy policies and the energy security situation with a firm stand.

Traditionally, China’s energy policy has a concrete target for each energy sector, such as coal, oil, gas, and power. However, the energy policy lacks coherence (Andrews-Speed 2004; Smil, 1981). Therefore, most literature tends to address China’s energy policy by targeting a specific sector. In this way, China’s energy policy can be divided into coal policy, electricity policy, oil policy, renewable energy policy, environmental policy, and energy conservation policy.⁸ These works address the policies and their effects in detail, with an analysis of the background of energy policy formulation. They serve as an important reference for the study of China’s energy policy, but they are lacking in research on policies throughout the whole energy sector. They also do not relate the policies to the overall energy security situation in China. The gap is filled by this study, which not only comprehensively

⁸ See Wang, 1999; Ma & He, 2008; Yeh & Lewis, 2004; Li, 1984; and Shen, 1988.

researches China's energy policy, but also relates the energy policy to energy security and identifies the essence of their evolution.

To sum up, the existing literature on China's energy policy and energy security does not identify the key reason behind the change and evolution of energy policy and energy security. Instead, it mostly focuses on quantitatively grading China's energy security status or describing the energy security challenges China is faced with. Most of the challenges and relevant strategies are analyzed from an international relations perspective or, for literature focusing on a specific energy sector, without a pan-energy industry view. This study fills the gap by quantitatively portraying the evolution of the energy security situation in China and qualitatively analyzing the critical reason behind its evolution from a pan-energy industry view and a domestic perspective.

1.4 Study value and contributions to knowledge

As reviewed in Section 1.3, a number of studies have examined China's energy policies and energy security. However, there are no systematic studies that synthesize the evolution of China's energy policy, energy security status related to energy policy, and macroeconomic reform in a single framework. This study analyzes China's energy policy evolution trends accordingly over different periods. China has experienced political changes since its founding in 1949. Different periods have different energy policies and related energy security situations. Taking into account China's distinctive socio-economic adjustments and its national Five-Year Plan periods of economic and social development, this study discusses China's energy security and energy policy evolution in terms of these Five-Year Plan periods, analyzing the relationship between energy policy and energy security situation in each period. As energy security status directly reflects the effects of energy policy,

relating the concept of energy security to energy policy evolution helps to identify the successes and failures of China's energy policies in each specific period, making the study of China's energy policy evolution a more valuable reference for future policy making. The identification of successful energy policies is meaningful because the degree to which China succeeds or fails in its energy policies is of great significance to the rest of the world. It affects other factors and behaviors such as China's import requirements for different types of energy, the nature and scope of China's diplomatic measures to secure energy supplies, the scale of China's greenhouse gas (GHG) emissions resulting from the use of energy, domestic economic and political stability, and so on.

International political economy and security studies on China have yet to explore the interaction among three important factors: China's energy policy, its energy security, and macroeconomic reform. This study aims to partially fill this gap in the literature with new methodological approaches to the study of China's energy security and bring a new perspective to China's energy policy and security. To the best of my knowledge, there is no study that combines China's energy policy, energy security situation, and macroeconomic reform with the aim of developing a comprehensive and detailed understanding of China's energy security. In this sense, this study is eclectic and could be considered an original piece of research.

Energy security is a subject that is equally important to both security and economically-oriented researchers and policy makers. This study makes a significant contribution to the literature by focusing on a practical, necessary, and critical issue addressing policy and security. It fills the substantial gap between the quantitative analysis of energy security and qualitative policy relevance in the literature. The contribution of the quantitative methodology and analysis lies in two aspects. First, it provides a new method to quantify energy security in China. The quantification is not

only a picture depicting how energy security situation has evolved along a timeframe, but also a foundation for qualitative analysis of energy security in China. Second, it provides a very useful method and a valuable reference for energy security quantification in other countries. The contribution of the qualitative methodology is equally prominent. It provides a completely new perspective to analyze energy security in China: the macroeconomic reforms. Other perspectives, such as international relations, have been extensively discussed to explain energy security or insecurity in China. But they failed to 'locate' the key factor that determines energy policy and evolution of energy security in China. This study contributes to the literature with a very powerful instrument to explain and analyze why the energy security in China has evolved in the way it is quantified. More importantly, this new perspective is not only powerful for the China case, but also useful to explain energy security in other countries, especially those countries in economic transition. Besides, this study integrates the quantitative analysis of factors affecting energy security with the qualitative analysis of related policies. Such an integrated analysis is valuable not only because it provides policy makers with information on the performance of past policies, but also because a good understanding of such issues will help to improve policy making in the future.

1.5 Study framework

The 4-As framework is extensively used in this study. The framework incorporates four critical dimensions of energy security: availability of resources, applicability of technology, acceptability by society, and affordability of prices. Each dimension has five indicators for its measurement.

Availability of resources (AV) mainly deals with the amount of fossil fuel reserves that China has and the shortage relevant to demand; it also deals with alternative

resources, such as renewable energy, that China presently or potentially has. This factor shows how the Chinese government seeks to ensure that China has the energy resources needed for economic growth.

Applicability of technologies (AP) deals with the existing technologies China has and its capability for developing potential technologies that may be relevant to renewable resources, such as hydroelectric power, wind power, solar power, etc. To sum up, it refers to the exploration of potential resources and efficient use of the already-extracted resources.

Acceptability by society (AC) deals with environmental issues (e.g., emissions control) and measures people take (e.g., harnessing energy from alternative sources) to improve their physical environment. It also addresses the issue of whether local people accept resource exploitation in their area and to what degree they accept it. The extensive use of fossil fuels as the main energy resource in China had led to serious pollution problems that exceed the tolerance threshold of the general public. Health effects due to pollution might evolve into strong social critique and public protest. To sum up, acceptability by society addresses the general public's level of tolerance for the possible negative effects of energy exploration and/or use.

Affordability of prices (AF) refers to the purchasing ability of consumers for energy resources. Consumption behavior should be studied at the personal level and at the commercial level. Affordability should not only involve the 'affordable' factor but also the 'stable' factor of energy prices. Wildly swinging energy prices make it difficult for suppliers to invest prudently. Affordability should also relate to the quality of energy resources. Consumers need high quality energy with reasonable and stable prices.

Twenty measures or indicators that constitute the 4-As are identified. These measures and indicators cover the four dimensions of energy security: availability, applicability, acceptability, and affordability. Relevant data are collected for each indicator. The data are then converted into ordinal values for energy security status evaluation. For each period of China's energy policy evolution, a rhombus grid is developed. Under the ideal situation, energy security is in the perfect condition and the rhombus will be a perfect square with each 'A' hitting the highest value in its dimension. However, it is difficult to achieve 'perfect' energy security no matter which period the country is in. Therefore, different periods have different shapes and the areas of the different grids indicate the relevant energy security status in that period.

The mechanics of the 4-As framework is as follows. First, China's energy security indicators are identified. This study quantifies China's energy security status in terms of four dimensions. Therefore, it is important to first identify corresponding quantifiable indicators for each dimension. Second, ordinal values are assigned and computed for each indicator. Once the indicators for each dimension are identified, the next step is to assign a value to each indicator. All data collected for each indicator are translated into ordinal values. All of the ordinal values for each indicator are calculated, and then a final value is achieved for each dimension to facilitate the evaluation of the overall energy security status. Third, the comprehensive results are plotted. The last step is to map the quantitative results—the individual rhombus diagram for each analysis period. This step elicits the quantitative results needed to evaluate the energy security status in each period in terms of the availability of resources, applicability of technology, acceptability by society, and affordability of prices. The shape and area of the rhombuses indicate the level of China's energy security in each period. The framework makes it easy to

interpret the implications when data are collected and properly calibrated. Besides the 4-As framework, this study also uses an imbalance index to interpret whether the four dimensions of energy security in China have developed in a balanced way. Chapter 3 provides a detailed discussion of this methodology and an accurate description of China's energy security status in each period.

1.6 Analytical framework of the study

This study establishes the Macro Economy-driven Energy Security Mechanism, which is a very useful tool to analyze and explain the evolution of China's energy security. The Macro Economy-driven Energy Security Mechanism is elaborated as the following figure.

Figure 1-1: The Macro Economy-driven Energy Security Mechanism

1.6.1 Explanation of the analytical framework

The analytical framework identifies the key independent variable that functions in the evolution of China's energy security — macroeconomic reform. Energy security

in China is highly dependent on macroeconomic reform. In other words, it is the macroeconomic reform that frames the energy security situation in China. The concept of energy security, as defined in this study, incorporates four dimensions: availability of resources (AV), applicability of technologies (AP), acceptability by society (AC), and affordability of prices (AF). Macroeconomic reform, via its function in the energy sector (energy policies), improves or worsens each of the four dimensions of energy security. In such way, the causality between macroeconomic reform and energy security is established. The analytical framework does not deny potentially intervening variables, such as international relations, conflict of interest groups, or agencies/actors that improve or worsen energy security, but it picks out the key variable and provides a new perspective to analyze the energy security of a country, especially one in economic transition.

With regard to the Chinese case, from the very beginning of China's reform and opening up (1978), macroeconomic measures began to function as drivers of the dimensions of energy security. In the initial reform period, the central government decided to rectify the economic disorder left by the Cultural Revolution and other social chaos. This decision led to the adjustment of energy industry distribution. The coal industry was shifted to coal-rich areas and production efficiency was greatly increased (Section 5.2.1). Also in the initial period, the introduction of the Household Responsibility System (HRS) made an outlet for the fast development of town and village enterprises, which directly stimulated the spread of town and village coalmines that greatly contributed to coal production in China (Section 5.2.1). The two-tier pricing system, which typically reflected the Chinese government's cautiousness in introducing 'market force', also covered the energy sector. The in-quota and above-quota coal and oil prices lasted for nearly one decade until the two-tier system was revoked in China (Section 5.2.2).

Of the promulgation and implementation of the above macroeconomic measures and energy sector policies, some intervening variables, such as group interests, might also play a role. For example, the local governments, especially those at the village levels, were very efficient in facilitating the development of town and village coalmines, which were an important factor for promoting the local economy. The officials who profited from the two-tier pricing system by purchasing at low in-quota prices and selling at high above-quota prices made every possible effort to maintain the system and oppose its abolishment. However, these variables were not the key forces that drove energy policy making and energy security formation, although their functions cannot be annulled. It was the reform of the national economy and delegation of autonomy that made possible the emergence and development of town and village coalmines; it was the partial and very careful introduction of 'market forces' that made possible the emergence and development of two-tier pricing of coal and oil. Again, in the early 1990s when the economy was getting better, it was the relaxation of government control over production prices and reduction of the scope of prices administered by the government that finally eliminated the two-tier pricing system of coal and crude oil. Macroeconomic reform was a force too strong to be stopped or reversed. Once initiated, it operates like water rushing out of a floodgate with great energy. Macroeconomic reform thus made itself the key force driving energy policy and forming energy security in China. This key driving force washed away —or at least diminished— all other factors (intervening variables) that may have functioned in China's energy policy promulgation or implementation.

More examples from the 1990s can elaborate on this. For instance, it was the reform measure to salvage state-owned enterprises (SOEs) that discouraged the development of town and village coalmines. SOEs reform was one of the key reforms during the time. The aim was to promote the corporatization of large and medium-sized SOEs and clarify the property rights, which would facilitate the

establishment of a 'market economy'. During the process, the energy sector SOEs were subject to reform as well. In the coal sector, the long-term losses of state coalmines prompted the central government to shut down town and village coalmines nationwide, which competed with SOEs for resources and markets. As a result, coal production decreased at the turn of the 21st century. Many town and village coalmines, which had long contributed to the Chinese coal supply, were closed down under SOEs reform (Section 5.3.3). Once again, the force of macroeconomic reform dominated. The previous energy policy in the coal sector that had been favorable to the town and village coalmines and to the coal supply was changed in favor of state coalmines under the reform of SOEs. It is true that conflicts of interest existed and the closure was met with resistance at the local level, as the town and village coalmines provided an important source of employment and revenue from taxes and fees, but the closure had to be done to provide protection for state mines. At that time, it was SOEs reform that hindered the development of town and village coalmines. Once again, the 'flood' of macroeconomic reform diminished other (intervening) factors (variables) that might function in energy policy implementation.

Another example that reflects the typical domination of macroeconomic reform (SOEs reform) is power sector restructuring. In the 1980s, the central government stimulated investments in electricity generation by decentralizing the investment authority. Local governments, SOEs, and foreign companies were encouraged to finance and have their own power generation facilities. It is for certain that the introduction of new actors into the electricity sector only changed the Chinese electricity industry from a system exclusively owned and controlled by the central government to a system with dominant central planning and decentralized generation owned by various investors; it did not in any sense shift the underlying corporate governance or regulations in the electricity sector. However, it paved the way for liberalization in the Chinese electricity market. But, until the 1990s, further

liberalization was blocked by SOEs reform. Instead of injecting the market mechanism further into the electricity sector, reform in the 1990s resulted in the State Power Corporation of China (SPCC) monopolizing the sector. Small thermal power plants were shut down to protect state enterprises and the SPCC controlled most of the transmission and distribution assets and half of China's generation assets. SOEs reform in the power sector severely hindered the creation of a competitive electricity market in China (Section 5.3.3).

To the best knowledge of the author, there is no theory or framework in the relevant discipline that can explain the evolution of energy security in China. Most of the literature on China's energy security, as mentioned in Section 1.3, focuses on the international relations perspective, or targets a specific energy sector, without a pan-energy industry view. This literature cannot dynamically explain the 'evolution' of energy security in China along a timeframe. In contrast, the framework of the Macro Economy-driven Energy Security Mechanism provides a completely new perspective that incorporates both quantitative and qualitative analyses that can dynamically explain the 'evolution' of China's energy security along a timeline. This is where the significance of the study lies.

1.6.2 The scope of the analytical framework

The Macro Economy-driven Energy Security Mechanism is an efficient tool for analyzing the energy security evolution of a country, particularly countries undergoing economic transition. It incorporates both quantitative and qualitative methodologies that can be extended to other countries. The quantitative methodology is general, as it is based on well-established economic theories and studies, and is very flexible in selecting specific indicators for each dimension of energy security. Therefore, it could be generalized for evaluating the energy policy

and energy security of any country with expanded and/or modified indicators. As long as the key indicators for a country are identified, the energy security situation of that country could be evaluated. The qualitative methodology is also general as every country's macroeconomic policy must, in some way, dominate and manipulate the policies in its specific industrial sector, including the energy sector. This is the root source for the generalizability of the qualitative methodology: an analytical framework that is new and useful for analyzing the energy security of a country from a domestic perspective. The analytical framework is particularly useful for emerging economies in transition, since they make every effort to utilize reform measures to develop their economies. The macroeconomic reform measure will inevitably cover and affect the country's energy sector, and its energy policies must be subject to the promulgation and implementation of its macroeconomic policies. In this sense, the analytical framework can also be applied to analyze policies and explain the evolution of other industrial sectors besides the energy sector. This is the contribution of the Macro Economy-driven Energy Security Mechanism as well as the contribution of the study.

1.7 Research methodology

This study's research and findings are based on information collected from data, reports, journal articles, books, and other scientific works from institutions and think tanks. Additionally, policy documents, such as those issued by the International Energy Agency, China's State Council, and China's National Development and Reform Commission (NDRC), are used. A vast amount of data was collected for the research framework. To quantitatively explain China's past and current energy situation, empirical data were extracted from official reports such as the BP World Energy Review, the China Statistical Yearbook, the China Statistical Yearbook on Science and Technology, and the China Energy Statistical Yearbook, etc. Besides printed sources, relevant data were collected online through the websites of international and national institutions. These institutions include but are not limited to the National Bureau of Statistics of China, the Energy Information Administration (EIA) database,

and the International Energy Agency (IEA) energy statistics. For obvious practical reasons, all empirical data processed in this study are therefore secondary data. However, through different independent empirical sources, objectivity can be extracted for the reliability of these sources.

Extensive quantitative and qualitative research was conducted during the author's research visits to China in 2012 and 2013. The field research on China's energy security and policies started at Xiamen University in Xiamen, Fujian Province, where the author collected data, interviewed several professors, and completed most of the quantitative research. In addition, extensive documentary research was conducted at the National Library in Beijing and the Universities Service Centre for China Studies (USC) at the Chinese University of Hong Kong. Most of the qualitative part of this study was done at those two places. To describe it in one sentence, the research was conducted by 'digging into the facts' to better answer the proposed research questions.

1.8 Study structure

The structure of the study is as follows:

Chapter 2 reviews various works related to the concepts, measurements, and frameworks established to quantify energy security in conjunction with an analysis of their contributions to the existing quantitative study of energy security. Chapter 3 presents an account of the analytical framework — the 4-As model — followed by an introduction to the respective indicators it uses. It examines the rigor of the 4-As model and justifies the indicator selection with a discussion of data and measurement issues. Beyond the construction of the 4-As model, it introduces the data and time phases to examine China's energy security and evaluates the security level of each policy period. Chapter 4 explores China's energy policy evolution in detail. A subsection of policy examination from 1949 (founding of PRC) to 1978 (end

of Cultural Revolution) is discussed first. The following subsections within Chapter 4 discuss energy policies from 1981 to 2010 in every possible detail encompassing the sixth, seventh, eighth, ninth, tenth, and eleventh Five-Year Plans. The discussion involves an application of the 4-As framework and the quantitative results obtained for each period, which are presented in Chapter 3. The effectiveness of the energy policies in each period is evaluated and a comprehensive picture of China's energy security status throughout history is provided. Chapter 5 gives the reasons for the evolution of China's energy security status and energy policies. It analyzes the progress of China's macroeconomic reform during the administrations of Deng Xiaoping, Jiang Zemin, and Hu Jintao and answers the questions proposed at the beginning of the study. This chapter roots China's energy policies in its macroeconomic reform measures and identifies the key reason behind the evolution of China's energy policies and energy security status. Chapter 6 reviews the findings of the quantitative and qualitative analysis, highlights the argument and conclusion, and suggests new areas for future research.

Chapter 2 Energy Security: Concepts, Frameworks and Indicators

2.1 Introduction

This chapter reviews three aspects of current research on energy security: the concepts of energy policy and energy security; frameworks established to assess a country's energy security situation; and the indicators used to quantitatively evaluate a country's energy security. Section 2.2 focuses on existing research on the concept of energy policy and energy security. Energy security assessment frameworks in particular, are reviewed to establish the 4 As framework used in this study to analyze China's energy security situation. Section 2.3 explains the comprehensive concept of energy security which this study has constructed step-by-step. Section 2.4 reviews the energy security indicators, based on which China's energy security indicators are selected and constructed in chapter 3.

2.2 Views on energy policy and energy security

2.2.1 Energy Policy

The concept of 'policy' needs to be clarified before defining 'energy policy'. Policies are "what governments do or what governments say they do, manifesto commitments or post hoc rationalizations, specific initiatives or by-products of other actions" (McGowan, 1996, p. 132). Energy policy is concerned with energy resources, including renewable and non-renewable resources, and activities to reinforce the efficiency of energy supply and consumption. Energy policies can generally be categorized into official energy policies and unofficial energy policies. Official energy policies are 'clearly elaborated' and 'explicitly formulated' by the government. The official energy policies are normally presented in the form of commitments to particular choices and activity coordination in the energy sector. The unofficial energy policies are those policies that are not dedicated to the energy sector but exert a strong influence in the energy sector, intentionally or incidentally (McGowan, 1996).

Energy policies can also be differentiated by energy policy as a whole, and by specific intervention subsets under the general energy policy. Energy policy as a whole refers to a country's policy effort to meet its energy needs. A specific intervention subset, or a specific energy policy, refers to energy policies for an individual energy subsector (such as coal, oil, renewable, energy R&D, energy efficiency) and energy policies dealing with a specific subset such as the welfare of consumers, the environmental impact, safety and health, transportation requirements, employment implications, balance of payments concerns, and geopolitical stresses (Goode, 1980; Prontera, 2009).

2.2.2 Energy security

Security is an essential prerequisite for the existence and development of a society. The issue of security is a concern that could be extended from the individual to the state, and further to the international community. No matter whose concern it is, security is a sort of 'good' with its value to be protected (Rothschild, 1995). In the 21st century, new ways of thinking of security are sought to deal with new threats and new conditions faced by the individuals, states, and international communities. One reason for this is that the function of security has broadened from its military focus to a new perception that encompasses several aspects such as economic, political, environmental, and social ones. Among these aspects, "[e]nergy security is an important component of every country's national security" (Tatalović, 2008, p. 117). Energy insecurity will threaten the functioning of a country's economic, social, and environmental systems and it is necessary for the country to integrate energy security into its respective national security systems and also formulate energy policies that could guarantee energy security (Tatalović, 2008).

Yet the concept of energy security varies. Due to its polysemic nature, the concept of energy security is 'inherently slippery', hence attempts to clarify the concept of energy security have rarely been made (Chester, 2010). Many academic studies

produce definitions for energy security with different components.⁹ These definitions can be generally grouped into two categories --- the broad sense and the narrow sense. In the broad sense, the common definition for energy security is usually supply-oriented¹⁰ and it consists of three elements: reliable supply of energy, adequate supply of energy, and energy supply at reasonable prices. Existing works have attempted to give a systematic and comprehensive definition: the availability of stable and reliable energy supplies at all times in various forms, in sufficient quantities, and at reasonable and/or affordable prices (Yergin, 1988; Bielecki, 2002; Clingendael International Energy Programme, 2004; IEA, 2007a; Chang & Lee, 2008; Lin, 2009a).¹¹ However, no energy system, no matter in the short run or in the long run, can be entirely secure. Therefore, energy security can be seen as “a problem of risk management” which involves “reducing to an acceptable level the risks and consequences of disruptions and adverse long-term market trends” (IEA, 2007a, p. 161). In this regard, to promote energy security, three key pillars are put forward: energy efficiency, diversification of energy supplies, and minimizing energy price volatility (World Bank Group, 2005). Along this line of thought, the three key elements attributed to energy security mentioned above have emerged: adequacy, reliability, and a reasonable price. The meaning of adequacy and reliability is easy to understand. It is uninterrupted supply that fully meets the global demand. A reasonable price, however, is less easy to interpret. In general, a reasonable price should be determined by the market which is based on supply-demand balance (Bielecki, 2002). That is to say, a reasonable price is devoid of excessive market power and it does not adversely affect the economic performance of a country (APER, 2007; Chang & Lee, 2008). Following the three key elements, energy security,

⁹ Kruyt, van Vuuren, de Vries, and Groenenberg (2009) find that the definitions of energy security have widened over time. Traditionally focusing on physical definition of oil supply, energy security concept began to incorporate the price of energy when oil became a globally traded commodity amid price fluctuations in the world market. When disruptions frequently occurred in the supply chain, energy conversion and transport were mentioned in the concept. The ability to cope with extreme events, such as natural disasters or terrorist actions was sometimes addressed in energy security context. Finally, the political stability of energy supplying appeared in energy security discussions.

¹⁰ In fact, energy security concerns relate equally to energy supply and demand. But most public discussions concentrate on the supply side, especially the external supply sources over which the consuming countries have relatively less control than their domestic supply sources (Bielecki, 2002).

¹¹ Lin (2009a) highlights the reliable energy supplies as safe transport channels.

in a broad sense, is having an adequate and reliable supply of energy at a reasonable price.

In a narrow sense, energy security refers mainly to primary energy security or oil security which means that it is concerned with the security of primary energy resources, oil in particular (Fried & Trezise, 1993). This oil security focus directs a country's energy security attention to hedge against an 'oil supply crisis', aiming at reducing vulnerability to foreign supply disruption in order to minimize the economic and military costs once such a disruption occurs (Vivoda, 2010). Energy security in the narrow sense mainly covers the economic or national welfare aspect of the disruption of energy supply. It is "the loss of economic welfare that may occur as a result of a change in the price or availability of energy" (Bohi & Toman, 1996, p. 1). It is the ability of nations to secure supplies of fuels, primarily fossil fuels, especially crude oil and petroleum fuels at reasonable prices, and the capabilities to stave off oil crises (Nautilus Institute for Security and Sustainable Development, 1998). Some definitions, though not explicitly expressed, obviously presume oil as the focus of energy security. For example, energy security is to reduce the vulnerability to foreign threats/pressure of disruption of energy supply; prevent an energy supply crisis; and minimize the impact of the energy supply crisis once it occurs (Samuels, 1997).

Energy security issue involves time dimensions generally grouped into short-term energy security and long-term energy security. The short-term energy security deals with the risks of disruption to existing supplies, mainly due to technical problems or sudden political incidents. The long-term energy security covers the issue of investment for potential energy supplies to meet growing energy demand in the long run (Bielecki, 2002). Long term energy security in the narrow sense is "a proxy of the certainty level at which the population in a defined area has uninterrupted access to fossil fuels and fossil fuel-based energy carriers in the absence of undue exposure to supply-side market power over a period ahead of 10 years or longer" (Jansen & Seebregts, 2010, p. 1654), which means "the energy sector does not cause (major)

welfare-reducing frictions in the economy at national and global levels” (Loschel, Moslener, & Rubbelke, 2010, p. 1666). That is to say, long-term strategy for energy supply security must be geared to ensuring the well-being of a country’s citizens and the proper functioning of the country’s economy (European Commission, 2001).

Although not expressed as completely and explicitly as the broad definition, the narrow sense also includes three elements of energy security: reliability, adequacy, and reasonable price. Hedging against (oil) crisis and making national welfare intact amid the crisis serve as a country’s means for achieving energy adequacy, reliability, and reasonable price. These three elements cover several different dimensions.

The first dimension is the economic dimension, which could be depicted by the term availability and affordability. Availability is about energy supply. An implicit factor of availability entails the guaranteed supply and minimum dependence on foreign energy supply at the same time. High level of dependence on foreign energy supply is always a concern for policymakers who are responsible for making energy available to the country (Klare, 2007). Another related aspect of availability which could offset the negative effects of foreign dependency is diversification. To put it simply, this requires a country to diversify its energy sources, energy suppliers, and locations of energy facilities. Affordability is another important principle of energy security. Affordability is generally understood as a reasonable energy price. An important element implied in affordability is that the price should be reasonable to not only the rich people, but also the poor. This requires making access to energy services equitable for everyone. Affordability also requires stability of energy prices and consumers’ access to a broad range of high-quality energy services (Sovacool & Brown, 2010).

The second dimension deals with energy efficiency and technology. Energy efficiency, to put it simply, is to maximize production by minimizing the input of energy. The efficiency improvements could be realized by substituting fuels, or by changing the

consumption habits or patterns. This relates energy efficiency to demand-side management. It has been argued that demand-side management is a new factor to be added in the energy security concept. A conventional concept of energy security tends to be supply-oriented and carries the assumption that energy demand is given but demand-side risks are not less than the supply side. For example, either demand surges during prosperity or supply surpluses during recession puts pressure on a society's energy balance, hence demand-side management is also a key component of a comprehensive concept of energy security (von Hippel, Suzuki, Williams, Savage, & Hayes, 2009). A key implicit element under this dimension is technology innovation which comprises a set of processes that lead to new or improved energy technologies to amplify energy resources, enhance the quality of energy services, and reduce negative externalities related with energy supply and use (Gallagher, Holdren, & Sagar, 2006). As the world moves toward a technology-based energy society, the concept of energy security must address the various issues associated with technology application and innovation (von Hippel, Suzuki, Williams, Savage, & Hayes, 2009).

On the basis of these two dimensions, a new dimension---the environmental dimension---has been added to the energy security concept as environmental protection increasingly attracts public attention. During the combustion of fossil fuels, energy-related emissions of greenhouse gases have become the main source of environmental deterioration and climate change. To mitigate climate change, the emissions have to be reduced by changing the way energy is produced and utilized (IEA, 2007b). Climate change is a 'threat multiplier' for national security, which is inextricably linked to a country's energy security (CNA Military Advisory Board, 2007). If environmental problem such as climate change is to be solved, energy security policies must be reformulated. Mitigating climate change and protecting the environment are necessary to guarantee energy security (von Hippel, Suzuki, Williams, Savage, & Hayes, 2009). Definitions of energy security with the environmental factor interpret energy security as a country's ability to guarantee the

availability of energy resource supply in a sustainable manner, and at the same time, stressing that the energy price shall be reasonable (APEREC, 2007). The European Commission contends that the EU's long-term strategy for energy security is to ensure uninterrupted physical availability of energy products at an affordable price for both private and industrial consumers, and respect for environmental concerns and sustainable development (European Commission, 2000). The United Nations Development Programme defines energy security as "the availability of energy at all times in various forms, in sufficient quantities, and at affordable prices, without unacceptable or irreversible impact on the environment" (UNDP, 2004, p. 42).¹² All these definitions incorporate the factor of environmental sustainability in energy security concept.

Apart from these dimensions, some other factors are also identified as new challenges that shall be incorporated as dimensions in the concept of energy security. Social-cultural factors are among them. Not in my backyard (NIMBY) and other environmental justice concerns make it difficult and costly to site power plants and dispose wastes from energy production and utilization. Opposition to plant siting has forced the government to adjust or reformulate energy policies. Social and cultural factors must be recognised when decisions need to be made (Nautilus Institute for Security and Sustainable Development, 1998; von Hippel, Suzuki, Williams, Savage, & Hayes, 2009). International relations and foreign policies must be accounted for as a dimension of energy security. A country shall commit itself to international cooperation on energy-related issues. Although there is no impending threat of another world war, the threats of regional conflicts, nuclear terrorism and proliferation still exist. These issues need to be addressed by the concept of energy security (Alhajji, 2007; von Hippel, Suzuki, Williams, Savage, & Hayes, 2009; Vivoda, 2010). Human security has also been argued to be incorporated into the concept of energy security which means providing basic energy services such as making

¹² Acceptability to the environment and sustainability are used synonymously here when energy security is defined.

electricity accessible to the entire population. Energy security policy and regulation have even been argued as a new dimension: a country without a clearly-stated energy security policy may not have the capacity and/or commitment to ensure energy security (Vivoda, 2010). The country should also have legitimate and participatory modes of energy policymaking and its energy consumers should be well-informed of the policies (Sovacool & Mukherjee, 2011).

Besides the above academic discussion on energy security, there are many other conceptions of energy security derived from different points of views. Different energy stakeholders, such as consumers, producers, and policymakers, have different perspectives on energy security (Birol, 2006). For example, from the consumer point of view, energy security for them is simply reasonably priced energy services without disruption. In contrast, from the producer point of view, energy security is about their access to new reserves and the demand for their products. From the politician point of view, energy security is to secure energy resources and infrastructure against terrorism or war. Different national geology and geography may also lead to different conceptions of energy security (Sovacool & Brown, 2010). It appears that the perspectives on energy security vary depending on the beholder's position in the value chain (World Economic Forum, 2006).

It could be seen from the above that the notions of energy security can be either narrow or broad but drawbacks exist in both senses. The narrow concepts may neglect the comprehensiveness of energy challenges, while the broad concepts may lack precision and coherence. Energy security is an issue so complex that a holistic approach is needed to address it so as to "capture the complexity of the concept" (Sovacool & Mukherjee, 2011, p. 5346). A few attempts of 'holistic notions' have been put forward. One describes energy security as a situation where five characteristics dominate the whole energy system: surety, survivability, supply,

sufficiency and sustainability (the ‘five Ss’) (Kleber, 2009).¹³ Similar notions are addressed by several ‘As’: energy resource availability, accessibility barriers, environmental acceptability, and investment cost affordability (APEREC, 2007); or availability, adequacy of capacity, affordability and sustainability (Chester, 2008). Sovacool and Brown (2010) argue that “energy security should be based on the interconnected factors of availability, affordability, efficiency, and environmental stewardship” (p. 81). In a later work, a ‘regulation and governance’ dimension has been included so that energy security involves availability, affordability, technology and development efficiency, environmental and social sustainability, and regulation and governance (Sovacool & Mukherjee, 2011). To summarize, energy security is a concept of multiple dimensions that assumes different characteristics depending on the country, energy source, or time frame.

Based on the dimensions of energy security, frameworks could be established to assess a country’s energy security performance. The following sub-section discusses the frameworks constructed for the assessment.

2.2.3 Assessment Frameworks for Energy Security and Analyses

Frameworks for assessing energy security are a kind of new tool for energy security evaluation. These frameworks are created on the basis of the new comprehensive concepts of energy security that incorporate new dimensions.

(1) A 3-A framework

An early framework is suggested by Chang and Yong (2007). The framework is developed to analyze the perspectives of major oil firms including their perceptions of energy developments and projections of energy potentials. The analytical

¹³ By this description, surety is “[a] condition which provides access to energy and fuel sources”; survivability means “energy and fuel sources are resilient and durable in the face of potential damage”; supply suggests “[an] identified and available source of energy, whether it is traditional fossil fuels, alternative energy or renewable energy”; sufficiency means “an adequate quantity of power and fuel from a variety of sources”; and sustainability requires operating practices “be perpetuated by limiting demand, reducing waste and effectively utilizing alternative energy and renewable resources to the maximum extent possible” (Kleber, 2009).

framework is made up by three As dimensions: availability of resource (AV), applicability of technology (AP), and acceptability by society (AC). Although the framework is not directly used to assess a country's energy security situation, its reference meaning is obvious.

Among the three As, AV is about oil firms' resource exploration effort. This dimension could also be subsumed under the energy security concept as the resources available for a country include fossil fuels and renewable energies. AP is about the oil firms' perspectives on the possibility of a resource switch. This dimension could be subsumed under the energy security concept as technological advancement for harnessing more fossil fuels and new energy resources. AC is about the oil firms' attitude towards the balance between self-interested profit maximisation and desired benefits of using alternative fuels for environmental protection. This dimension could be subsumed under the energy security concept as public's environmental concerns and the government's concern about the pollution caused by fossil fuel utilization and the higher expenditure posed by the adoption of new technologies or new energy resources.

The three As constitute a 3-A triangle grid, with each A having three indicators under them. The 3-A triangle illustrates how the oil firms balance their stakes among the three As. Figure 2-1 shows the framework, whereby isolines represent ordinal values converted from the indicators under each A.

Figure 2-1: The 3-A triangle grid

Source: Chang and Yong (2007)

(2) Four dimensional framework

A four-dimensional grid of availability, adequacy of capacity, affordability and sustainability is proposed to assess the impact of Australia's existing and potential policies and government actions on its energy supply security (Chester, 2008).¹⁴ This approach supposes that all four dimensions contribute to energy security, rather than any one dimension as a primary determinant. Only when all dimensions are considered, then implications of such an approach for policymakers can become discernible. This approach is an attempt for "more holistic conceptualisations of energy security" (Chang & Lee, 2008, p. 110) so that a broader understanding of a country's energy security situation could be achieved.

By applying the four dimensional-grid, Chester (2008) examines Australia's existing and proposed policies that drive the country's energy security in terms of each of the four energy security dimensions. Specific definitions are given for the four dimensions and the impact of Australia's public policies on each of the four dimensions are assessed. The notion of energy security is thus directly and closely connected with a country's public policies that are related with energy. By this methodology, policy impact could be effectively assessed, future projections could

¹⁴ The four-dimensional approach has been reaffirmed by Chester (2010).

be predicted, and the development path to make a country energy secure could be identified. It is found that as Australia does not have a national strategy on energy security, its energy security is determined by 'default'. That is to say, Australia does not have explicit energy policies. The energy security status is determined by existing public policies that address objectives other than energy security. This interpretation is problematic as a country without an explicit energy security strategy does not necessarily mean the country does not have a strategy on energy security. Policies related with energy could all contribute to an implicit energy security strategy. Nevertheless, Chester (2008) used the four dimensional framework to evaluate Australia's energy security. The framework serves as a valuable reference for this study as it connects the notion of energy security with a country's (energy) policies.

This four-dimensional approach is a heuristic one for further research. It directly relates a country's public (energy) policy to the notion of energy security, and it assesses policy by the notion of energy security (the four dimensional grid), but it does not provide any indicators or quantification tools that can directly and explain how well a country has been doing on the development/improvement of any one dimension of energy security. The inherent weakness in detecting progress in any dimension has been improved by the methodologies proposed by subsequent researches on energy security assessment frameworks.

(3) Four dimensional framework: Extension and application

Based on the four dimensions of energy security established by APERC (2007), Kruyt, van Vuuren, de Vries, and Groenenberg (2009) classify energy security dimensions as follows: availability, accessibility, affordability and acceptability of energy.¹⁵ With these four dimensions, they classify indicators for energy security and incorporate these indicators in a model-based scenario analysis. An energy security spectrum has

¹⁵ The classification scheme of the four dimensions was first proposed by APERC (2007), which presents three fundamental elements of energy security: physical energy security, including the availability and accessibility of energy supply; economic energy security, mainly focusing on the affordability of resource acquisition, and environmental sustainability.

been created based on the different perspectives on globalisation versus regionalisation, and on economic efficiency versus environmental and societal targets, as well as the four dimensions of energy security, which offers a schematic framework for energy security discussion. Figure 2-2 depicts the spectrum of the framework.

Figure 2-2: The energy security spectrum

Source: Kruyt, van Vuuren, de Vries, and Groenenberg (2009)

Four different storylines are presented in the figure 2-2: A1 and B1 represent a situation where a high level of globalisation is expected: A1 focuses on economic efficiency whereas B1 focuses on environmental and societal targets. A2 and B2 represent a situation where a low level of globalisation is expected: A2 focusing on economic efficiency whereas B2 focuses on environmental and societal targets.

With the classified indicators for energy security, Kruyt, van Vuuren, de Vries, and Groenenberg (2009) apply a selection of these indicators to a model-based scenario analysis on energy security of Western Europe for the next few decades. The model

they use is the TIMER model, which is an energy-system simulation model that describes long-term developments of the world energy system. Since the authors' focus is to explore the applicability of different energy security indicators, they use a relatively simpler approach which analyses only two scenarios: an OECD baseline scenario and a stringent climate policy scenario. The OECD baseline scenario assumes medium economic growth, population expansion, and technology development. The stringent climate policy scenario assumes the stabilisation of greenhouse gas concentrations at 450ppm CO₂-eq by 2100. This scenario is implemented by the imposition of a carbon tax aimed at emissions reduction by means of energy efficiency improvement, fuel switch, and the application of carbon capture and storage technologies. They find that the energy security indicators in selection have clear limitations and assert that it would be better to use a wide range of indicators that cover the different relevant aspects when energy security trends are being assessed.

Their work is not to evaluate the past/current energy policy effectiveness or energy security situation, but to project future energy security situations. They use two scenarios for the future analysis rather than directly apply the four different storylines to evaluate energy policy. Their approach is suitable for analysing the future energy security situation and for exploring the applicability of energy security indicators. However, it cannot project an overall multi-faceted energy security situation on the basis of the four dimensional scheme when the notion of energy security is introduced. For this purpose, indicators have to be strictly positioned under individual dimensions so that a comprehensive and overall energy security status could be depicted.

(4) Frameworks with several more multiple dimensions

A conceptual framework of analyzing energy policy using six dimensions is applied to evaluate and measure global energy security (von Hippel, Suzuki, Williams, Savage, and Hayes, 2009). The framework is largely designed to identify the relative benefits

and costs of the future energy paths driven by energy policies. The six dimensions are: energy supply, economic, technological, environmental, socio-cultural, and military-security dimensions. Building on these dimensions, an energy security assessment instrument is established to evaluate energy security in the Asia-Pacific region (Vivoda, 2010). To make the instrument more robust and complete, five more dimensions were included in addition to the six created by von Hippel, Suzuki, Williams, Savage, and Hayes (2009).¹⁶ The five new dimensions are: demand management, efficiency, human security, international, and policy. The instrument is described as a 'systematic interrogative tool' which could be used to evaluate a country's energy security (Vivoda, 2010). It could also be used to assess a temporal change in a country's energy security.

The problem of over-disaggregation in the dimensions of energy security exists in both frameworks. The framework developed by Vivoda (2010) even has eleven dimensions. In fact, some dimensions are overlapping while some dimensions are not a direct energy security issue.¹⁷ Over-disaggregation only makes the concept of energy security less structured and more complicated. This is destructive not only for indicators selection but also for the formulation of quantitative tools to analyze a country's energy policies and their impact on energy security of the country. Both von Hippel et al and Vivoda frameworks have indicators to measure energy security, but over-disaggregation and the potential overlapping of the dimensions may lead to double-counting when indicators relevant to these dimensions are used to assess a country's energy security. Although both frameworks establish an energy security assessment instrument to analyse energy security of individual countries or regions, they are not applied in the assessment.

(5) Four dimensional framework: New Extension and Application

A practical application of dimensional framework with indicators and data to analyze

¹⁶ Policy issues included in the framework by von Hippel, Suzuki, Williams, Savage, and Hayes (2009), as the authors state, are 'by no means complete'.

¹⁷ This is discussed in section 3.

energy security performance of a number of countries have been done (see Sovacool and Brown, 2010, and Sovacool, Mukherjee, Drupady, and D'Agostino, 2011). This dimensional framework is based on four interconnected factors of availability, affordability, energy and economic efficiency, and environmental stewardship. A total of 10 indicators, which constitute an Energy Security Index, are developed to measure (the four dimensions of) energy security performance of 22 OECD countries from 1970 to 2007. Data are collected on these 10 indicators for the 22 countries. Then the relative energy security progress of each country according to each indicator is assessed. The conclusion is that most of the countries have fallen back in their effort to improve their energy security.

Although these 10 indicators, as the authors assert, are 'valid representations' of how well countries have performed with regards to energy security, the indicators "often do not highlight what is most significant or meaningful but merely what is measurable" (p. 87). With this kept in mind, the indicators incorporated in such dimensional framework shall not be too many, as this may complicate the concept and lead to double-counting as discussed; whereas the indicators shall not be too few, as this may omit some important aspects of the relevant dimension, such that the notion of the dimension cannot be fully reflected.

This raises the question as to how many indicators should be developed for each dimension. There is no common criterion for this, but it should be kept in mind that the indicators should reflect the notion of the dimension as completely as possible, while at the same time reduce complexity and avoid double-counting. The indicators selected by the Sovacool and Brown (2010)'s four dimensional framework may not be enough. For example, under the environmental stewardship dimension, only two indicators are selected: SO₂ emissions and CO₂ emissions. Other aspects such as soot emissions and wastes associated with the processing of nuclear fuel are not included. Such omissions make the indicators insufficient and incomplete. These omitted indicators are nonetheless also important energy-related ones as far as the

environmental dimension of energy security is concerned.

(6) A five dimensional framework

A framework encompassing five dimensions of energy security is suggested and the five dimensions are availability, affordability, technology development and efficiency, environmental and social sustainability, and regulation and governance (Sovacool and Mukherjee, 2011).¹⁸ They also suggest 320 detailed indicators and 52 aggregate indicators which could be used to measure a country's energy security performance. This framework synthesizes their earlier literature on energy security measurement and quantification into a condensable number of indicators looking at multiple dimensions simultaneously.

A four-phased methodological process is used to select the indicators: research interviews, a survey, a focused workshop, and a review of the academic literature. It presents a large set of indicators which could measure energy security within the dimensional framework. But the large set of indicators leads to a weakness of over-quantification as it involves a huge amount of data, making it difficult to find patterns in a country's energy security performance. This eventually leads to cost-ineffectiveness. Another weakness is the overlapping as many of the indicators are mutually non-exclusive, making it impractical for energy security measurement. It is not possible to collect data for all/most of the proposed energy security indicators (let alone some indicators are overlapping and redundant).

What was suggested in conceptual design of energy security has been finalized and presented (Sovacool, Mukherjee, Drupady, and D'Agostino, 2011). It contains five dimensions and 20 indicators in total. It tries to evaluate national energy security policies and performance of eighteen countries across the American, European, and Asian continents. To make the index (scoring of country performance) empirical and relative, all of the collected data points are transformed to a score between 0 and

¹⁸ This framework is actually an extension of the framework proposed by Sovacool and Brown (2010). The framework has been refined in a later work by Sovacool, Mukherjee, Drupady, and D'Agostino (2011).

100. Such indicators, however, are not totally suitable for the Chinese case. Several indirect indicators were included in the work while as many direct indicators as possible are not included. The indirect indicators here refer to the indicators that are not closely associated with the notion of energy security. For example, as far as environmental sustainability is concerned, forest cover is selected as an evaluating indicator. This indicator, which measures forest area as percent of land area, is not closely related with the direct result of energy production and consumption, which is, as the authors state, only “loosely connected to issues such as suburbanization, mining, and industrial development” (Sovacool, Mukherjee, Drupady, & D'Agostino, 2011, p. 5849). This study adheres to the principle that key direct indicators should first be selected, indirect indicators should supplement the list when direct indicators are not available. Therefore, some of their indicators are adopted whereas some are rejected.

(7) Frameworks evaluating China's energy security

Zhang (2007) and Chang (2010) use the Analytic Hierarchical Process (AHP) to establish evaluation frameworks incorporating indicators to assess China's energy security status. Chang (2010)'s framework is built up as figure 2-3. The first layer, layer A, reflects the framework's goal to evaluate China's energy security. The second layer, layer B, reflects different dimensions (or consisting of components) of China's energy security. The third layer, layer C, consists of energy security indicators. Zhang (2007)'s framework is similar, except for further categorization of layer B into two sub-layers, which is illustrated in figure 2-4.

Figure 2-3: A general framework evaluating energy security in China

Source: Chang (2010).

Figure 2-4: A detailed framework evaluating energy security in China

Source: Zhang (2007)

As illustrated in figure 2-4, Zhang (2007)'s concept of energy security consists of six factors including energy structure (Factor 1), utilization of renewable energy (Factor 2), energy consumption from foreign sources (Factor 3), international energy transportation (Factor 4), domestic energy reserves (Factor 5), and energy strategic reserves (Factor 6). Under these factors, eleven indicators are selected. They are: oil reserve to production ratio (D₀₁), share of oil out of total primary energy (D₀₂), share

of independent overseas energy exploitation out of total imports (D_{03}), share of renewable energy consumption (D_{04}), oil import dependence (D_{05}), total energy imports (D_{06}), import concentration (D_{07}), energy transportation capability (D_{08}), oil consumption per capita (D_{09}), energy reserves (D_{10}), and days of guaranteed energy reserves (oil) (D_{11}). The weight is averagely assigned to the six factors of energy security, which is 0.1667 ($1/6$) to each factor. Since different number of indicators is allocated to different factors, the weight of each indicator is not the same. D_{01} , D_{02} , and D_{03} are incorporated in the energy structure factor, hence the weight of 0.0556 ($0.1667/3$) is assigned to each of the three indicators. The utilization of renewable energy factor only has one indicator, D_{04} . Thus the weight assigned to D_{04} is 0.1667. The rest indicators are allocated weight in the same methodology. The factors and indicators indicate that Zhang (2007)'s framework is obviously constructed on a narrow concept of energy security, which only focuses on the energy supply adequacy.

Chang (2010)'s framework incorporates 24 indicators under six factors including energy reserves, energy imports, energy consumption, energy awareness, technology, and environment. The multiple dimensions indicate that his framework is based on a comprehensive concept of energy security. The problem is that several factors, such as energy awareness, are too subjective and cannot be normally treated as an energy security factor or dimension. The value of certain indicators such as 'national awareness of energy conservation' and 'national sense of social responsibility' could only be given very subjectively, which may be controversial and involve inaccuracies.

The AHP methodology has also been used to construct the framework to evaluate China's oil security. The framework consists of three layers. The first layer is oil security which comprehensively reflects China's oil security status. The second layer comprises four factors influencing oil security: resource, import, market, and other factors. The third layer has 12 indicators whereby three indicators are assigned to each factor. By assigning value and weight to each indicator, oil security index is

calculated. It is concluded that China's oil security has been worsening since 1991 (Zhang & Liu, 2005).

2.3 The concept of energy security---A need for a holistic approach

The above review on the concept of energy security and the frameworks established to evaluate the level of energy security shows that the notion of energy security has become multi-dimensional. It is noteworthy that different dimensions of energy security are frequently conflicting with each other. A policy which is effective for one dimension of energy security may erode other dimensions. For example, affordability may be competing with applicability and acceptability. Energy price controls which result in artificially low prices may dampen the users' interests in energy conservation and the producers' interests in developing clean energy technologies (Herring, 2006). Empirical examples could be found for dimension competition. The transnational energy projects within Thailand, Laos, and Myanmar, including the construction of a gas pipeline and various mega-dam projects enhanced the availability of energy supply. However, such projects benefited mostly the middle class and elite circles in the urban centers and proved to be environmentally destructive, thus contributing little to the overall energy security for the grassroots (Simpson, 2007). In the United States, a shift from coal to natural gas in the power sector would reduce greenhouse gas emissions, but this would increase its dependency on foreign sources of natural gas (Sovacool, 2008). Achievements in one dimension of energy security may impinge on other dimensions while different dimensions of energy security may reinforce each other as well. For example, new technologies and increased energy efficiency may actually lower the implicit price of energy and thus make energy more affordable (Herring, 2006). This may lead to higher energy consumption as well.

The multi-dimensions of energy security make a more comprehensive concept of energy security imperative, as well as a workable framework for energy policy

analysis.¹⁹ The comprehensive concept shall include these multiple dimensions, instead of highlighting only one or two aspects of energy security. The functional framework, established on the basis of the comprehensive concept, will be a useful tool for evaluation of a country's energy security performance in a realistic way. This means that achieving energy security in one dimension does not necessarily make a country 'energy secure' in a holistic sense. For example, a country may have enough energy available, but if the energy is not generally affordable, or harnessing or utilizing the energy seriously pollutes the environment, the country simply cannot be considered as more 'energy secure'. Therefore, traditional and narrow conceptualisation of energy security cannot help establish a workable framework for the analysis of energy security in a broader and more comprehensive sense (Vivoda, 2010). With this in mind, this research constructs a comprehensive energy security definition as a starting point to examine China's energy security policies. Only a comprehensive view can ensure that all key dimensions are factored into the successful pursuit of energy security. Also, a comprehensive view/framework facilitates prudent utilization of energy resources.

Section 2.2 has reviewed concepts of energy security and its dimensions. Although the literature on energy security definitions does not have a clear historical line, they exhibit, to some extent, a historical evolution of the concept. First, all definitions, broad or narrow and with whatever dimensions incorporated in the concept, stress the economic aspect of energy security. The supply of energy to a nation must be 'adequate' and 'reliable' and energy prices must be 'reasonable' or 'affordable' to the population. To interpret this alternatively, a country must hedge against the risk of inaccessibility to energy resources or fluctuation of energy prices. This is the emergence of the first dimension---the economic dimension---of energy security. Later on, rapid economic development and huge amount of energy consumption

¹⁹ With regard to the above-reviewed energy security concepts that are 'polysemic in nature' (Chester, 2010), it is not practical to seek a common definition of energy security, nor does this dissertation try to do so. This research proposes a comprehensive multi-dimensional definition which is suitable for the establishment of an analytical framework for assessing China's overall energy security situation.

require the efficient use of energy. Demand for more energy resources and energy efficiency improvement require technological innovation. Accordingly, the second dimension---the technological dimension---of energy security has been incorporated in the concept. When environmental deterioration began to threaten ecosystem and human health, energy harnessing and utilization had created a major source of environmental pollution. Therefore, environmental protection is taken into account by including the third dimension---the environmental dimension---in the concept of energy security. Nevertheless, it must be noted that these 'dimensions' are only implicitly expressed in the broad and narrow definitions. The notion of 'dimension' (or 'aspect', or 'theme') has only been recently introduced in the interpretation of the concept of energy security.²⁰

Along with the social development and change in domestic and international conditions, more dimensions are included in the concept: social factors, international relations, human security, and energy policy and regulations, and so on. Continually adding dimensions to the concept make energy security just "like a Rorschach inkblot test", and "you can see whatever you want to see in it" (Sovacool & Mukherjee, 2011, p. 5346). This research, as previously mentioned, constructs a comprehensive definition, but this research does not seek to incorporate as many dimensions that have arisen in the literature as possible but selects an absolutely minimum number of dimensions. As mentioned above, some dimensions or factors have been too 'disaggregated', which means that they are actually not necessarily to be listed as an individual dimension. For example, social factors have been suggested as a new dimension for the concept of energy security (von Hippel, Suzuki, Williams, Savage, & Hayes, 2009). It is argued that 'not in my backyard' (NIMBY) and other environmental justice concerns make it necessary for the government to take into account the social and cultural factors in energy policy decision-making. This is another mode of environmental concerns. These two dimensions are merged into one dimension in

²⁰ See APERC (2007), Chang and Yong (2007), Chester (2010), Chester (2008), Sovacool and Brown (2010), Sovacool and Mukherjee (2011), Sovacool, Mukherjee, Drupady, and D'Agostino (2011), Vivoda (2010), von Hippel, Suzuki, Williams, Savage, and Hayes (2009).

this research---acceptability by society, which will be discussed later in more detail. Some other dimensions, such as the international relations, energy policies and regulations are, by themselves, not issues in the concept of energy security. They are the 'tools' or 'means' to achieve energy security.

This research maintains that a comprehensive and holistic approach should be taken to define energy security. At the same time, the historical line along the evolution of energy security concept should also be respected. First, fossil fuels face the constraint of a declining rate of production. They will be used in the order of availability, the most cheaply available one is used first (Hotelling, 1931). This means that sometime before or at the ultimate depletion of a fossil fuel, other fossil fuel or renewable energy resources will replace the existing resource to ensure adequate supply of energy, which is the fundamental requirement to guarantee energy security. This is the first dimension incorporated in the concept of energy security by this research---availability of resources (AV).

Technology is required for harnessing and utilizing energy. A more advanced technology is required for harnessing resources which are not readily extractable. Technological advancement in the exploration and production of fossil fuels can expand the recoverable fossil resources base. It can also promote the utilization of new energy sources by continued research and development of renewable energy technology. Hence, technologies for finding and extracting fossil and renewable resources are also the determining factors for the availability of resources (Nordhaus, 1979; Doriana, Franssen, & Simbeck, 2006). For example, conversion of coal and biomass into liquids offer possible alternative sources of transportation fuel in the future (Chang & Yong, 2007). Applying (advanced) technologies in harnessing and utilizing energy resources guarantee (and enhance) the availability of energy resources. This is the second dimension of energy security---applicability of technologies (AP).

Third, energy and the environment are closely connected. While fossil fuels are considered a threat to the environment, especially through the greenhouse effect, using so-called environmentally clean energy resources can harm the environment as well. Utilization of hydropower will be detrimental to the local ecosystem and nuclear power plants will seriously damage the environment if nuclear and radiation accidents occur. Hence, a more ecological view of energy security is needed (Mulligan, 2010). When environmental protection has become a prominent issue for the international community, the latter will advocate using safer and cleaner energy resources and greener methods of energy production and consumption. Social and environmental concerns are an indispensable element of the contemporary energy regime. This is the third dimension of energy security---acceptability by society (AC).

Fourth and last, all the above dimensions, including objective conditions (availability of resources) and subjective effort (applicability of technologies and acceptability by society), have one common goal---to make energy resources affordable to the population. Affordability comprises three elements: reasonable and stable energy prices, equitable access to energy resources, and high quality of energy resources provided to consumers. This constitutes the fourth dimension of energy security---affordability of energy prices (AF).

Having said these, energy security is a comprehensive notion which encompasses four dimensions of AV, AP, AC, and AF. An 'energy secure' nation is a nation that has affordable energy resources with an adequate reserves of fossil fuels, nuclear energy, and renewable resources, advanced technologies applied to energy harnessing and utilization, and at the same time, addressing social and environmental concerns. On the basis of these four A-dimensions incorporated in the energy security concept, an analytical framework is established to examine China's energy security level and the effectiveness of its energy policies in achieving energy security. The framework provides a tool for energy policy evaluation from an interdisciplinary perspective: availability, applicability, acceptability, and affordability. It must be noted that though

the concept rests on multiple interconnected dimensions, it is more than the sum of these dimensions. The 4-As framework, established on the basis of the concept of energy security, is a dynamic framework whereby all the four dimensions interact with each other. The framework constitutes a comprehensive system akin to an ecosystem comprising individual species interacting with each other within the system (Sovacool & Mukherjee, 2011). To quantify energy security, each dimension incorporated in the dynamic framework needs to be elaborated by quantitative indicators, which shall reflect each dimension as accurately as possible. Existing literature on energy security indicators are heuristic, serving as a guide in identifying and formulating the indicators under each dimension. The next section discusses the energy security indicators.

2.4 The quantification of energy security: indicators identification

Indicators are an instrument that provides information on a specific measurement. Indicators selection could be generally grouped into two categories: identification and formulation. The identification stage involves brainstorming on all the possible or potential indicators. At the formulation stage, indicators are formulated. This section focuses on the identification stage and reviews the existing energy-related indicators.²¹ Indicators formulated to examine China's energy security will be addressed in chapter 3, which focuses on quantitative discussion about the evolution of China's energy security over thirty years' economic reform from 1980 till 2010.

Considering that energy security is closely related to energy policies, it is necessary to "study the energy security consequences of different development pathways" (Kruyt, van Vuuren, de Vries, & Groenenberg, 2009, p. 2166). To study the consequences/impact of energy policies, energy security indicators are needed to analyse the energy security performance of a country, which is the quantification of energy security. Energy security measure needs to be quantifiable for analytical

²¹ The review in this section does not include the indicators adopted by the analyzing frameworks reviewed in section 2.2: Views on energy security, but the framework indicators in section 2.2 also serve as important references during the identification stage of energy security indicators by this research.

purposes (DBERR, 2007). Quantification of policy measures is not a new thing. The 1992 Earth Summit has recognized the important role of indicators in helping countries to make informed decisions concerning sustainable development (Vera & Langlois, 2007). Indicators constitute a key tool and are primarily important for making policies and monitoring progress in policy implementation, and evaluating the effectiveness of the policies. The indicators are designed to answer the question: “How might I know objectively whether things are getting better or getting worse?” (Lawrence, 1997, p. 181). Specifically in this research, the indicators are the core element in assessing energy security. The indicators can assess policy effectiveness and indicate a desired state of energy security (Scheepers, Seebregts, de Jong, & Maters, 2006; Tönjes & de Jong, 2007). In addition, the indicators condense “large amounts of complex data into recognizable patterns” so that policy-makers and analysts could “find the best energy solutions”; the indicators could also help us “understand how dimensions of energy security improve or worsen over time” (Sovacool & Mukherjee, 2011, p. 5346).

Energy security indicators have been gathering momentum within the last two decades. There is plenty of literature on the measurement and indicators of energy security. Several institutions have constructed the quantitative measurement of energy security such as IEA,²² OECD,²³ UN,²⁴ IAEA, APERC, HELIO International,²⁵

²² The IEA has been developing energy indicators since the 1990s. The IEA’s first book on the subject is “Indicators of Energy Use and Efficiency: Understanding the link between energy and human activity” (IEA, 1997a). Later, in the book “The Link between Energy and Human Activity”, IEA (1997b) demonstrates how a system of relatively straightforward indicators of energy use has been developed. Indicators in this book describe the links between energy use and human activity in a detailed way. These are the early works IEA has endeavored to link the indicators of energy use and efficiency to carbon emissions.

²³ The OECD Group on the State of the Environment has developed indicators for the integration of environmental concerns into energy policies, which are called energy-environment indicators and are structured around three themes: sectoral trends of environmental significance, environmental impacts of the energy sector, and economic linkages between energy and the environment (OECD, 1993). These energy-environment indicators are further approved by OECD conference ‘Towards Sustainable Development: Indicators to Measure Progress’ held in Rome in 1999. This Rome conference shows that these energy-environment indicators that depict aspects of sustainable development have been widely used for policy purposes (OECD, 2000).

²⁴ In 1998, the Division of Sustainable Development of the United Nations Department of Economic and Social Affairs (DSD) established a set of indicators to measure changes in consumption and production patterns of key resources such as energy, materials, water, and land. In terms of energy, four key indicators are identified. They are: annual energy consumption per capita, which monitors energy consumption; intensity of energy use, which monitors energy use per unit of production/service; share of renewable energy in total energy consumption, which monitors the development of renewable energy sources; and energy prices, which monitor energy prices in relation to GDP and disposable income (DSD, 1998).

²⁵ HELIO International, an international non-governmental network, has undertaken to assess and monitor the

and the Clingendael International Energy Programme. Absolute quantification of energy security is still a very complex issue. Every approach to design energy security indicators faces the problem of subjective arbitrariness in defining the relative value of different components in the process of constructing energy security indicators. This section presents the key indicators in the development of energy security quantification. Some are simple indicators dealing with one aspect of energy security; others are aggregated indicators with the attempt to capture several relevant elements in a single indicator.

2.4.1 Simple energy security indicators

Simple indicators are frequently used to measure a particular aspect of energy security. In most cases, they are adopted by the analytical frameworks to assess a country's energy security. There are many such indicators and they take various forms. For example, Energy Import Dependency, a commonly used simple indicator, shows the extent to which a country relies on imports to meet its energy needs. Energy Intensity gives an indication of the effectiveness with which energy is being used to produce added value. Energy self-sufficiency rate deals with the degree that a country does not depend on energy imports. Energy Price Volatility reflects the impact of fluctuation of energy prices on energy security. A reserve to production ratio indicates the years of production left at current production levels. Energy price indicates the nature of the supply-demand relations and measures the economic impact of energy on energy security. Share of zero-carbon fuels measures a country's effort to switch away from a carbon intensive fuel portfolio (Kruyt, van Vuuren, de Vries, & Groenenberg, 2009). Some other energy security indicators,

contribution of energy policies. For this purpose, HELIO created the Sustainable Energy Watch (SEW) reports, which are based on a set of eight indicators to reflect four aspects of sustainability at the national level: economic, social, technological and environmental sustainability. According to HELIO, energy systems should be consistent with these four aspects to be conducive to eco-development. In practice, however, not all of these four aspects can be accommodated at the same time. It is important for the government to take into consideration all these aspects in policy making whereas at the same time trade off the benefits and costs among them. Therefore, indicators are to be designed to measure how these aspects are traded off in a country. Specifically, the SEW reports by HELIO can be used by governments to better promote sustainable development through energy policies and the set of indicators in the reports indicates a country's progress towards energy-related sustainability (HELIO International, 2005/2006). HELIO International indicators therefore constitute an important reference for the indicators selection in this dissertation.

though not simple, are used to measure security of specific sectors in the energy industry such as the oil sector and the power sector. Examples include the oil vulnerability index (Gupta, 2008), and indicators for adequacy of generation capacity, grid reliability and reasonable electricity price (Chang & Lee, 2008).

Oil vulnerability index (OVI) is an aggregated indicator based on seven simple indicators: the ratio of value of oil imports to GDP, oil consumption per unit of GDP, GDP per capita, oil share in total energy supply, ratio of domestic reserves to oil consumption, exposure to geopolitical oil market concentration risks as measured by net oil import dependence, diversification of supply sources, political risk in oil-supplying countries, and market liquidity. The composite indicator of OVI is a combined index of weighted average of the seven individual indicators. The weighting is derived on the basis of a multivariate technique of principal component analysis, which greatly increases the robustness of the results (Gupta, 2008). In the power sector, the indicators mainly measure the security of electricity supply. They are categorized into three groups: adequacy indicators, reliability indicators, and reasonable price indicators. Adequacy indicators measure the amount of spare generation capacity of the peak demand in a system and assess whether a market's peak day demand can be met without a generator in question (adequacy under emergency circumstances). Reliability indicators, measuring the average interruption duration experienced by customers served for a given period and the average number of times that a customer is interrupted during a given period, show how reliable a grid has been during a specific period. Reasonable price indicators measure market power---the extent to which the price exceeds marginal cost (price-cost mark-up) and specifically, the market power of the generator in question (Chang & Lee, 2008).

2.4.2 Aggregated energy security indicators

The most common aggregated energy security indicators are the diversity index and its derivative indicators. The diversity indicator is used to measure the number and

evenness of a target object. It is also seen as a basic indicator for energy security, which is frequently used to construct and develop the energy security evaluation index or system. By providing additional options for energy supply sources, diversity is believed to hedge against the risks of supply disruptions. Specifically, in an oil market subject to monopolistic exercises, diversity offers a means to mitigate unfair, disruptive, and other adverse actions. This diversity helps consumers to rely on a variety of mutually disparate options evenly and in a balanced way (Stirling, 1998; Stirling, 2010). One example of diversity index is the Shannon-Wiener diversity index,²⁶ an index originally used to measure ecological diversity, which has been modified to construct indicators of energy diversity (Jansen, van Arkel, & Boots, 2004).

The Shannon-Wiener index is extended to construct several other indicators and index systems to assess energy security. A multi-fossil-fuels approach with a set of two indicators to measure energy security, addresses price and physical availability respectively (IEA, 2007b). The two indicators are the Energy Security price indicator and the Energy Security physical availability indicator. The Energy Security price indicator (ESlprice) is a sum over the fuels weighted by the share of the respective fuel in the total primary energy supply (TPES).²⁷ The unique feature of ESlprices is that it takes account of political risk. Energy Security physical availability indicator (ESlvolume) is the share of the net imports of pipe-based gas (purchased through oil-indexed contracts) in a country's total energy demand.²⁸ Higher values of the IEA energy security indicators mean a lower level of a country's energy security. Although these measures have merits, the IEA energy security indicators have several major drawbacks. First, they only refer to international fossil fuel markets

²⁶ Shannon-Wiener diversity index is formulated as $I_1 = -\sum_i (c_i^1 p_i \ln p_i)$, where I_1 is energy supply security indicator no. 1; p_i represents the share of primary energy source i in total primary energy supply; c_i^1 represents the correction factor to p_i for indicator I_1 .

²⁷ ESI_{price} is formulated as $ESlprice = \sum_f \left[ESMC_{pol_f} \left(\frac{Cf}{TPES} \right) \right]$, where ESMC is Energy Security Market Concentration; $\frac{Cf}{TPES}$ is the share of fuel f in the fuel mix of the consumer country.

²⁸ ESI_{volume} is formulated as $ESlvolume = \text{Pipe Imp(gas)}_{oil-indexed} / TPES$, where $\text{Pipe Imp(gas)}_{oil-indexed}$ represents the pipe-based gas imports purchased through oil-indexed contracts.

while neglecting other energy sources in the energy consumption. Second, the indicators are complicated to some extent and cannot be readily interpreted by less informed policymakers and other users. Third, the mutual relationship of the two indicators in defining an overall energy security level may puzzle the users (Jansen & Seebregts, 2010, p. 1663).

Also based on the Shannon-Wiener diversity index, an index system with five energy supply indicators is applied to APEC countries in order to evaluate energy supply projections. The five indicators are: Diversification of Primary Energy Demand (DoPED), Net Energy Import Dependency (NEID), Non-Carbon based Fuel Portfolio (NCFP), Net Oil Import Dependency (NOID), and Middle East Oil Import Dependency (MEOID). They reflect the potential benefits/risks associated with the diversification of energy resources and import dependencies. DoPED and NEID measure the degree of diversification of a country's energy sources and the impact of both diversification and imports on energy supply security. NCFP, accounting for the share of clean energy in a country's energy demand, measures a country's efforts to switch away from a carbon intensive fuel portfolio. NOID, considering a country's oil imports and exports, measures the degree of a country's dependence on oil imports. MEOID measures how dependent a country is on the Middle East oil (APERC, 2007). This index system only addresses a country's energy availability. Some of the indicators are overlapping, such as the NOID and MEOID. This makes the energy security assessment complicated and confusing.

Apart from the five supply indicators, four composite diversity indices of long-term energy security have been constructed that are also based on Shannon-Wiener index. These indices are: diversification of energy sources in energy supply; diversification of imports with respect to imported energy sources; long-term political stability in regions of origin; and the fuel resource base in regions of origin, including the home region/country itself. Each subsequent index accounts for one more factor of energy security. Stepwise, additional aspects of long-term energy supply security are

incorporated into the diversity indices (Jansen, Arkel, & Boots, 2004). This approach treats all sources equal and thus has its weaknesses because certain sources are exhaustible while others are not. It does not cover any feedback on how demand/consumers respond to the disruptions in energy supply (Jansen & Seebregts, 2010, p. 1659). This weakness is overcome by the Supply/Demand Index (S/D Index), which integrates major underlying supply-side and demand-side factors, such as industry demand, residential demand, primary energy supply, and so forth, but the S/D Index still has drawbacks, which are discussed below.

2.4.3 Independent energy security measurement systems

Energy security assessment systems are independent systems that have their own features to describe and evaluate energy security situation. Three major energy security measurement systems are elaborated below.

(1) The Supply/Demand Index (S/D Index)

The S/D Index is a tree diagram integrating major underlying supply-side and demand-side factors with an attempt to cover energy supply and demand balances. It uses four types of inputs to evaluate a country's medium and long term energy security. They are: the *shares* of different supply and demand categories; the *values* characterizing efficiency, adequacy, and reliability in conversion and transport; the *weights* that determine the relative contribution of the different components in the S/D Index; and the *scoring rules* for determining various S/D Index values. In principle, it covers the entire energy system from demand to supply. The complicated system has several major drawbacks. First, the aggregation of various inputs has subjective value assignments. Second, the S/D Index tries to catch all possible demand-supply factors. The comprehensiveness of the Index means reduced simplicity, which makes the Index somewhat not readily interpreted. Third, this Index does not capture the geopolitical dimension very well (Scheepers, Seebregts, Jong, & Maters, 2006).

(2) The Crisis Capability Index (CC Index)

The CC Index combines Risk Assessment (RA) and Mitigation Assessment (MA) to reflect how well a country is prepared for the short-term energy security problems such as sudden supply interruptions. It deals more with short-term energy security problems by incorporating risk factors such as unforeseen shortfalls of power generation and sudden interruption over oil or gas transport routes. RA deals with the risks of a sudden and unforeseen supply disruption; MA deals with the country's capability to mitigate the negative impact of the sudden disruption on an economy. Both have checklists of factors for assessment. The CC Index could be calculated by assigning values to each factor of RA and MA and then comparing the MA sub-index to RA sub-index. MA sub-index is constituted by assessment factors of emergency stocks, demand restraint and rationing, fuel switch capabilities, reserve capability, and locked-in production. RA sub-index is constituted by assessment factors of domestic primary energy production, energy conversion, independent energy transport, and energy import. If RA sub-index is much higher than MA sub-index, then the country is vulnerable to short-term energy security risks (Scheepers, Seebregts, Jong, & Maters, 2006). But the CC Index cannot comprehensively reflect a country's energy security status. A very high MA sub-index does not necessarily mean desirable energy security situation. The costs to enhance a country's risk mitigation capability may be so high that they exceed the costs of sudden supply disruptions.

(3) The driving force-state-response (DSR) model

The DSR model is originally used to categorize sustainability indicators, which are driving force SIs, state SIs, and response SIs. Driving force SIs represents a process that influences state SIs.²⁹ State SIs describes the state of a specific variable. Response SIs gauges the progress in the response of relevant agents (e.g., the

²⁹ Driving force indicators are also referred to as control, process or pressure SIs. When the United Nations first developed its list of SIs, they use the term 'driving force' instead of 'pressure', since the impact of a factor on sustainable development could be positive or negative. 'Pressure' is regarded as implying negative, while 'driving force' can imply both negative and positive (Bell & Morse, 2008).

government) to achieve sustainable development. The DSR model is thus a cause-effect model with a causal link: driving force generates the state which requires the response (Bell & Morse, 2008). The DSR model, originally constructed to measure sustainability, has been modified to construct energy security evaluation systems. One derivative is an index system to measure a country's energy security system multi-dimensionally. This index system has six factors that have impact on energy security and three indices correspondent to these factors. The six factors are energy factor, political factor, economic factor, transport factor, military factor, and sustainable development factor respectively. These six factors are described and explained by the three indices: pressure index, state index, and response index respectively (Chi & Li, 2004).

Another derivative is the set of Indicators for Sustainable Energy Development (ISED) developed by the International Atomic Energy Agency (IAEA) and several other organizations in 1999.³⁰ The DSR model was applied and a set of 41 indicators within the model was constructed. The model and the indicators incorporated three aspects of sustainable development---social, economic, and environmental---together with institutional considerations (IAEA & IEA, 2001). The 41 indicators define the causal relationships among important energy-related factors and link these factors with a set of potentially appropriate policies for increasing energy sustainability. These indicators have also been used to help countries assess the effectiveness of their current energy policies towards sustainable development (Vera, Langlois, Rogner, Jalal, & Toth, 2005).

These 41 indicators were refined to a set of 31 energy indicators published in 2005 by the IAEA in a joint interagency report named 'Energy Indicators for Sustainable Development: Guidelines and Methodologies'. In this report, the original name 'Indicators for sustainable energy development (ISED)' was revised to 'energy

³⁰ The main collaborating organizations are the UN Committee on Sustainable Energy and the United Nations Work Programme on Indicators of Sustainable Development (WPISD).

indicators for sustainable development (EISD)'. This interagency report is "for specialists in energy and the environment, including statisticians, analysts, policy makers and academics—in particular those involved in the development of energy and environmental indicators relevant to sustainable development" (Vera, Langlois, Rogner, Jalal, & Toth, 2005, p. 280). This study uses the EISD set of indicators as one of its major references when formulating China's energy security indicators. The EISD indicators have already been applied to some developing countries such as Brazil, Cuba, Lithuania, Mexico, Slovakia, and Thailand. The application indicates the flexibility and versatility of the indicators. These indicators could be used to assess energy situations in countries with varied energy and economic conditions (United Nations/IAEA, 2007).

2.5 Chapter Summary

This chapter reviews various studies on energy security in the literature, including notions, assessment frameworks, and measurement indicators. Based on the literature review, this chapter presents the definition of energy security, which constitutes the foundation of the 4 As framework and the set of indicators to evaluate China's energy security in chapter 3. The framework, which reflects the comprehensive definition of energy security encompassing the dimensions of availability, applicability, acceptability, and affordability, evaluates the performance of China's energy policy in enhancing energy security in chapter 3.

Chapter 3 Quantitative Analysis of Energy Security in China

3.1 Introduction

This chapter is devoted to the discussion of the construction of the quantitative tools for assessing the impact of China's energy policies on its energy security status. It provides an insight into China's energy security trends starting from the early period of reform which coincides with the beginning of Deng Xiaoping administration in 1980 and ending with the late period of Hu Jintao administration in 2010. To identify changing policy priorities in China's Five-Year Plans (FYPs) of Economic and Social Development, the timeframe is divided into six periods according to the six FYPs: the sixth, seventh, eighth, ninth, tenth, and eleventh FYP that were drawn up during the administrations of Deng Xiaoping, Jiang Zemin, and Hu Jintao. The key energy policies implemented and their effects on China's energy security will be examined by using the 4-As evaluation framework.

The structure of this chapter is as follows: In Section 3.2, the method of constructing the indicators used for examining China's energy security is explained. In Section 3.3, an introduction to the data selection and China's data problem is provided. Section 3.4 contains an explanation of the method used in coding and converting the original cardinal data into ordinal values for analyzing the dynamic evolution of China's energy security situation. Section 3.5 contains a brief review of the energy policies that emerged during the six FYP periods and their consequences on China's energy security situation. The conclusion to the chapter is found in Section 3.6.

3.2 Formulation of indicators to examine energy security in China

Indicators developed in this chapter are scoped by two elements: spatial scale and time scale. The spatial scale refers to the entire country of China and the indicators are used to examine the energy security in China at a national level. The time scale for a study must be sufficiently long to validate the framework against historical data and to depict relevant trends to assist/inform future decision-making (Keirstead,

2007) so the indicators examine China's energy security over 30 years (or the three administrations of Deng Xiaoping, Jiang Zemin, and Hu Jintao). The period chosen is not only long enough to validate the 4-As framework constructed in chapter 2 but also representative enough to detect how and why the status of energy security in China has changed.

Sustainability indicators provide a theoretical background for the formulation and application of energy security indicators. The concept of sustainability has evolved from some vague abstraction to a somewhat coherent development framework since its appearance in the Brundtland Report. To tackle the sustainability problem, many indicators are required to address the excessively broad range of sustainability issues. The values of the indicators are gauged and the results are interpreted to assist policy assessment and policy making (Bell & Morse, 2008). Figure 3-1 presents a schematic framework of this mechanism.

Figure 3-1: The concept behind sustainability indicators (SI)

Source: Bell and Morse (2008)

Following this schematic framework, energy security indicators are constructed, their values are calculated and the results are interpreted for policy assessment and policy formulation purposes. The problem is that both sustainability indicators and energy security indicators have to face the ‘selection difficulty’, which is, to put it simply, “how many and which indicators to use” (Bell & Morse, 2008, p. 28).

The sustainability indicators reflect the complex processes in sustainability theory in several simple measurements. This means that sustainability could be analyzed by a reductionist approach which means breaking sustainability down into components and studying how they work jointly and individually. Clearly, sustainability indicators are quantification tools employing the reductionist approach and they do have limitations. However, it is not possible to deal with sustainability problems under the conditions of ‘real-world complexity’ (Bell & Morse, 2008). Thus, a minimum number of variables or indicators should be used if they are good enough to represent or replicate the reality. The same theory also applies to energy security indicators.

The problem lies in the difficulty in setting the acceptable limits of simplification. This involves the issue of indicator selection criteria. When selecting indicators, we should first define the evaluation criteria for the potential indicators. Three basic criteria are considered here: policy relevance and user utility, analytical robustness, and measurability. In terms of policy relevance, indicators should be representative, easy to understand, and provide a basis for comparison, either of different regions or time periods. In terms of analytical soundness, indicators should be constructed on the basis of scientific principles and international consensus to ensure their validity. In terms of measurability, data for the indicators should be readily available and frequently updated (OECD, 2003). To sum up, the criteria for constructing indicators ought to address the question: “Is it possible in practice to measure or judge how well an option performs on these criteria?” (Department for Communities and Local Government, 2009, p. 33). This study adheres to this set of criteria—easily understandable and limited in number—when formulating energy security indicators

in China. With this criteria, it is feasible to address the most important energy issues in China to capture as much of the complexity of energy security as possible. The challenge of data availability in China has been taken into account. In fact, many indicator projects are constrained by the availability of reliable data. Most indicators are constructed on the basis of the availability of raw data, which means that some possible 'ideal' indicators may be omitted (Moldan & Dahl, 2007).

Two types of indicators are distinguished in this research: direct indicators and indirect indicators. Direct indicators refer directly to the subject they have been developed for and directly pinpoint the subject of interest; indirect indicators only refer to the subject in an indirect way. In most cases, direct indicators are desirable for measuring the subjects. However, direct indicators may often not be used for two reasons. First, the subject of interest cannot be measured directly; second, even if the subject of interest can be measured directly, the scientifically reliable data may be unavailable or unfeasible to collect. In both cases, indirect indicators will be used, which may very well represent the balance between scientific measurement and data availability.

Given the comprehensive nature of the concept of energy security, this study advocates the construction of a wide range of indicators. These indicators provide a solid foundation for the quantitative description of the overall trend of the evolution of China's energy security situation. To depict the 'big picture' of China's energy security situation, these indicators are incorporated in the 4-As framework developed in chapter 2, a useful tool that is relevant for policymaking to boost China's energy security. Each indicator is tied to a particular dimension of the 4-As framework. The framework and its indicators make it easy to interpret China's energy security trends to date and its possible future directions, and examine whether the energy policies lift or lower each dimension of the 4-As framework. These indicators, with their relevant data, present a more complete and accurate picture of changes in China's energy security situation, monitor China's historical trends in energy

policymaking, and have implications for current policy decisions. Changes in the values of the indicator over time mark China's progress (or setback) on energy security. In most cases, all of the indicators are complementary. It is noteworthy that these indicators are more useful for dynamically depicting important trends in China's energy security situation, than for providing an absolute outcome of the energy security situation.

3.2.1 Availability indicators

The actual availability of energy sources is crucial for a country's energy security. The indicators for available resources should be used as direct indicators for the availability dimension of energy security.

AV-1: Coal reserve-to-production ratio (R/P)

The R/P ratio is an indicator widely used for assessing energy resources (Feygin & Satkin, 2004). It is the ratio of energy reserves remaining at the end of a year relative to the production of energy in that year assuming the production rate remains constant for a lifetime. It measures the availability of national energy reserves with respect to corresponding fuel production and estimates the number of years for which current level of production can be sustained by its reserves. It reflects the economic level during a time when the resources have been estimated as exploitable. Therefore, it truly reflects the energy resources available over time (IAEA, 2005).³¹ It is one of the EISD indicators (known as ECO4), and it is also used by Sovacool, Mukherjee, Drupady, and D'Agostino, (2011) to reflect the availability dimension of energy security. Coal is the dominant fossil fuel in China's energy production and consumption. Compared to the other two fossil fuels—oil and natural gas—coal R/P

³¹ Shortcomings of the reserves-to-production ratio indicator are argued as the ratio assumes constant future production rates and only reflects reserves proven at some point of time, while not taking into account fluctuations in energy prices or changes in energy demand. Neither does the ratio reveal anything about the quality of the fuels being produced (Feygin & Satkin, 2004). Nevertheless, the availability of energy supplies is a key aspect of energy security and this indicator can estimate the energy supplies in terms of the availability of energy reserves and the levels of production during a specific time period.

affects China's energy availability the most. It is hence selected as the first AV indicator to describe China's energy availability.

AV-2: Oil import dependence ratio

Besides R/P, the energy import dependence ratio is also used to measure the security level of energy supply (Zou, 2007). It is commonly used as an indicator to depict a country's energy security status in terms of energy availability (i.e., whether there is enough energy for the country). For example, oil dependency served as an important indicator to reflect oil availability and to measure oil security in the United States (Greene, 2010). This indicator is "a straightforward and insightful indicator that does not require specific expertise to comprehend" (Kruyt, van Vuuren, de Vries, & Groenenberg, 2009, p. 2169). The energy import dependence ratio expresses the level of exposure in terms of dependence on foreign energy supplies. It is "the ratio of net import to total primary energy supply (TPES) in a given year in total and by fuel type such as oil and petroleum products, gas, coal and electricity" (IAEA, 2005, p. 83). The EU defines energy import dependence ratio as the net fuel import as a percentage of gross consumption of the fuel.³² The EU definition is most suitable for this study because of the data/statistics available on China's energy consumption. In the pursuit of energy security, the core objective of energy policy is the guarantee of a stable supply of energy for the country. The importance of the physical availability of supplies highlights the policies and strategies to prevent the risks of interruptions to energy supply. The physical availability risk (quantity risk) is closely related to a country's extent of reliance on imported energy. The costs of reliance, such as the oil dependence costs, could be substantial. High import dependence may be a serious cause of economic vulnerability and also a constraint on a country's defense policy.

Import dependence ratio is commonly used in the energy supply security literature

³² See the European Environment Agency website:
<http://www.eea.europa.eu/data-and-maps/indicators/net-energy-import-dependency#toc-1>

(Bhattacharyya, 2009). For example, it is one of the EISD indicators (ECO15), which measures the extent of a country's reliance on imports to meet its energy requirements. It is also used by the European Environment Agency to address the issue of reducing the EU's dependency on imported fuel and diversifying its energy supply.³³ Sovacool and Mukherjee (2011) list the import dependence ratio separately by fuel type as the first of the three indicators of the dependency component of the availability dimension of energy security.³⁴

This study selects the oil import dependence ratio to describe China's energy import dependency. China's accelerating urbanization and emerging middle class in China requires more energy, particularly oil for the transportation sector. High economic growth and heavy industrialization make China's continued growth highly dependent on foreign oil (Kong, 2005). China's situation is unique. Within a short period of economic reform, China has transitioned from a net oil-exporting country into a net oil-importing country, and this is reflected by the oil import dependence ratio indicator. This indicator is useful for checking how dependent China is on foreign supplies of oil. A negative value (when China was a net exporter of oil) indicates the time when China did not rely too much on oil imports.

AV-3: Natural gas reserve-to-consumption ratio

The reserve-to-consumption ratio is a derivative of R/P ratio and a hybrid of R/P and the import dependency. Compared with the oil production, the natural gas production in China developed relatively slowly whereas its demand for natural gas is projected to increase substantially by 2030. The consumption of natural gas increases faster than any other fossil fuel over the projection period. The main

³³ For the details of this issue, see the European Environment Agency website:

<http://www.eea.europa.eu/data-and-maps/indicators/net-energy-import-dependency#toc-1>

³⁴ An alternative indicator to reflect import dependency of energy is self-sufficiency, which is "a useful proxy for evaluating how dependent a country is on foreign sources of fuel or energy imports" (Sovacool, Mukherjee, Drupady, & D'Agostino, 2011, p. 5849). Hence, self-sufficiency, an indicator used by Sovacool, Mukherjee, Drupady, and D'Agostino (2011) to reflect the availability dimension of energy security, is another interpretation for energy dependency.

reason for its growing consumption of natural gas is the need for ever more energy to fuel its economic growth and the desire for the diversification of China's energy mix (IEA, 2007a). As a result, the natural gas reserve-to-consumption ratio is more accurate than its R/P for understanding the availability of natural gas resource in China.

The above three indicators represent the availability of fossil fuels in China. Besides these indicators, another major form of energy—electricity—must also be included in the indicators to reflect how electricity is available to the population. Electricity supply is one of the essential inputs for economic activity. Electricity is the dominant form of modern energy for information technology, manufacturing and services. Top leaders need to take steps to ensure the reliability and sustainability of electrical supply as electricity is practically non-storable and the systems are often affected by fluctuations of the fossil fuel prices. Ensuring that electricity supply remains affordable and reliable is a major energy policy issue (Bhattacharyya, 2009). All these suggest the importance of an availability indicator for electricity. The availability factor, which is calculated as 'actual total generation in MWh/(total name plate capacity in MWh times 8,760 hours', just reflects the electricity availability very well. The electricity availability factor consists of two components: electricity generation and electricity installed capacity. The total amount of electricity generation has major implications for energy dependence, energy prices, and greenhouse gas emissions (IAEA, 2005). It is the maximum output that the generator produced for a specific time and it measures the extent of electricity that is available in a country. Electricity generation alone does not tell the whole story of electricity availability, since the possibility of more power being generated is not considered. This possibility needs to be shown by the total electricity installed capacity, which is the maximum potential that a country's power system could generate electricity. To represent the availability factor more precisely, it is better to distinguish it by the type of electricity. The two availability factors are hence constructed as:

AV-4: Availability factor of conventional thermal electricity

AV-5: Availability factor of non-thermal electricity (including nuclear and renewable)

3.2.2 Applicability indicators

Applicability indicators are the indicators that reflect China's current technology for harnessing fossil fuels and renewable resources, and improving the efficiency of energy utilization. They also reflect China's capacity for technological utilization and innovation. They could be interpreted as energy technology indicators measure that assess energy efficiency and technology development, and aid in the evaluation of related policies. Energy technology is "the means of locating, assessing, harvesting, transporting, processing, and transforming the primary energy forms found in nature (e.g., sunlight, biomass, crude petroleum, coal, uranium-bearing rocks) to yield either direct energy services (e.g., heat from fuel wood or coal) or secondary forms more convenient for human use (e.g., charcoal, gasoline, electricity)". They are also "the means of distributing secondary forms to their end-users and the means of converting these forms to energy services (e.g., electricity to light and refrigeration, electricity and gasoline to motive power)" (Gallagher, Holdren, & Sagar, 2006, p. 194). Applicability indicators should reflect the nature of such energy technology.

AP-1: Energy intensity-Total Primary Energy Consumption per Dollar of GDP

Several international conventions and agreements, such as the Johannesburg Plan of Implementation agreed at the 2002 World Summit on Sustainable Development, have proposed that sustainable energy development is largely affected by the application of advanced energy technologies. The success of the deployment or diffusion of energy technologies could be reflected by energy efficiency³⁵ or energy intensity. The extent of the deployment of energy efficiency technologies could be measured by the status of energy efficiency or energy intensity, which indicates the cumulative impact of all the energy efficiency technologies (Gallagher, Holdren, &

³⁵ Energy efficiency indicators are derivatives of initial data on industrial production and related energy consumption (APEREC, 2000).

Sagar, 2006).

Reductions in energy intensity reflect the genuine gains in energy efficiency (Lent & Conklin, 2007). Energy efficiency indicators can be constructed by numerous different formulations to analyze energy efficiency at different levels: from national energy efficiency in general to specific energy efficiency of individual operating units within a plant. The lower the level, the more indicators could be constructed (APERC, 2000). That is to say, energy efficiency indicators can be generated at different levels of aggregation in accordance with different analytical objectives.³⁶ In this chapter, energy efficiency is analyzed at the level of national economy. APERC (2000) defines the energy efficiency indicator as “energy consumption per unit of GDP” (p. 24), which is actually the concept of energy intensity.³⁷ The improvement of energy efficiency and energy cost-effective economic development are essential energy security objectives. Many studies use energy intensity as an index to reflect energy efficiency in relation with energy security, such as HELIO International (2005/2006), IAEA (2005), IEA (2009), Kemmler and Spreng (2007), Lent and Conklin (2007), and Sovacool, Mukherjee, Drupady, and D’Agostino (2011).

Energy intensity is categorized under the economic dimension of energy sustainability by IAEA (2005) while it is under the technological dimension of the energy indicators developed by HELIO International (2005/2006). It is interesting that the IAEA (2005) does not distinguish between the economic and technological dimensions of energy sustainability.³⁸ To evaluate the energy security status in China’s context, the energy intensity indicator should belong to the technological dimension.

³⁶ IAEA (2005) disaggregated the energy intensity indicator into indicators of energy intensities of several subsectors such as the industrial, agricultural, service/commercial, residential, and transport sectors, which correspond to ECO6, ECO7, ECO8, ECO9, ECO10 indicators in the EISD.

³⁷ Energy intensity of an economy is calculated by the ratio of energy consumption to GDP, which measures the quantity of energy required to perform an economic activity.

³⁸ Energy sustainability is synonymous with energy security (Sovacool, Mukherjee, Drupady, & D’Agostino, 2011).

The energy intensity changes at different rates in different sectors. According to studies on energy intensity in three major sectors of energy use—transport, residential, and manufacturing sectors—technological advancement is ranked as the largest contributor to the causality of energy intensity reduction. In the transport sector, many industrialized countries adopt the fuel-mileage as the measure of the efficiency of new car models. This undoubtedly encourages the car manufacturers to improve technology to develop new and more fuel-efficient models. In the residential sector, space heating has the largest share of energy use. The space heating indicator takes into account the approximate efficiencies of combustion equipment and measures a country's effort to reduce the energy intensity through new technology. This makes technology the key driver behind reducing energy intensity. In the manufacturing sector, the improvement of technology and a change in economic structure may cause energy intensity to decline (Schipper, Unander, & Marie-Lilliu, 2000). A decrease in aggregate energy intensity does not necessarily mean that energy technology has improved because a change within the economic structure can also contribute to the decrease in energy intensity. In China, the emphasis on energy efficiency has gained momentum along with its fast economic growth. There is a growing consensus among scholars that technology improvement has led to reduction in energy intensity.³⁹

To sum up, as technology is the key driver for the decline of energy intensity in China, it will be better to categorize it under the technological dimension of energy security. The energy intensity indicator provides useful information on the improvement in energy efficiency and it has been commonly treated as an essential measure of energy efficiency of China's energy security status. In this context, energy intensity serves as a reasonable proxy for energy efficiency, a component of the applicability dimension of energy security (APEREC, 2009).

³⁹ See Fisher-Vanden, Jefferson, Liu, and Tao (2004); Levine, Liu, and Sinton (1992); Lin and Polenske (1995); Sinton and Levine (1994); Sinton, Levine, and Wang (1998); and Zhang (2003a).

AP-2: Gross generation efficiency of fossil fuel-fired power plants

After selecting an indicator for evaluating overall energy technological advancement (energy intensity), the next step is to select indicators to depict the application of technology in a particular sector. The electricity generation sector is thus selected. Electricity is a key input to modern production and service industrial activities, modern telecommunication in particular. The shortage of electricity, for example, usually means limitations in lighting, telecommunications, and resources for industries (Vera & Langlois, 2007). That is why technological advancement related to electricity generation is always a major concern in the energy industry. The use of advanced technology could improve the efficiency of thermal power plants (IAEA, 2005). The generation efficiency of fossil fuel-fired power plants also depicts technological advancement in thermal power generation—a typical reflection of the applicability dimension. Therefore, the indicator of ‘Gross generation efficiency of fossil fuel-fired power plants’ is adopted. It comes from one of the comprising parts of the indicator ‘Efficiency of energy conversion and distribution’ (ECO3) of the EISD. The efficiency of energy conversion is also one of the key energy indicators adopted by the National Bureau of Statistics of China. It refers to the ratio of the total output of energy products after processing and conversion to the total input of energy for processing and conversion. It shows the conditions of energy processing and conversion equipment and production technology (NBS, 2002). For the power generation sector, the indicator ‘generation efficiency of fossil fuel-fired power plants’ is “gross production of electricity (including own use of electricity by power plants) from fossil fuel power plants relative to fossil fuel inputs” (IAEA, 2005, p. 46). A similar indicator, ‘average thermal efficiency of power plants’, is also used by Sovacool and Mukherjee (2011) as a technology indicator for energy security evaluation. In short, ‘generation efficiency of fossil fuel-fired power plants’ represents technology advancement in thermal power generation sector.

Besides evaluating the particular sector of thermal power generation, applicability indicators also need to directly measure the technologies that enable China to

harness another key energy resource: crude oil. 'Crude Oil Distillation Capacity', as a direct indicator, is a good candidate for this purpose.

AP-3: Crude Oil Distillation Capacity (Thousand Barrels Per Day)

"[T]he real technical genius of the oil industry has been to maximize the yield of useful products from a given amount of crude petroleum" (Crabbe, 2003, p. 245). Crude oil cannot be used directly by the consumers. It must be refined via a process of fractionation defined as the separation of the various constituent parts of crude oil by distillation into oil fractions. This is the basis of oil refining. A good indicator to describe this technology is the crude oil distillation capacity.⁴⁰ Therefore, it is adopted to reflect the technology of crude oil harnessing.

AP-1 to AP3 refer to applicability indicators related to the overall energy technological advancement, application in the thermal power generation sector, and the harnessing of crude oil. The status in energy technological improvement may also be measured by the supply of human resources---the number of scientists and engineers engaged in the energy sector. But a major drawback is that this indicator does not take the efficiency or work quality into account. The work quality may be poor even though a large number of people are engaged in activities related to energy technological innovation (Gallagher, Holdren, & Sagar, 2006). The indicators related to human resources in the energy sector are hence not adopted.⁴¹ Energy technological innovation could also be further measured by patents of energy technology.

⁴⁰ Crude oil distillation is an oil refining technology to "separate the hydrocarbons in crude oil into fractions based on their boiling points. The separation is done in a large tower that is operated at atmospheric pressure. The tower contains a number of trays where hydrocarbon gases and liquids interact. The liquids flow down the tower and the gases rise up. The lighter materials such as butane and naphtha are removed in the upper section of the tower and the heavier materials such as distillate and residual fuel oil are withdrawn from the lower section" (http://www.petrostrategies.org/Learning_Center/refining.htm).

⁴¹ Sovacool and Mukherjee (2011) had selected human resources indicators such as 'Direct employment in the energy sector', 'Indirect employment in the energy sector', 'Induced employment in the energy sector', 'Technical expertise (number of engineers or energy employees)', and 'Unemployment in the energy sector (%)' to evaluate 'technology development and efficiency' dimension of energy security. But in a follow-up work, all these indicators have been dropped (Sovacool, Mukherjee, Drupady, & D'Agostino, 2011).

AP-4: Patents owned by LME (State-owned) in coal mining and dressing and petroleum and natural gas extraction industries

Patent is a special type of technology document that provides information on technological innovations (Huang, et al., 2003). Since patent license is a form of property rights included in technology transfer (Lewis & Wiser, 2007), patents indicate technological innovation and also reflect the pace of technology. Therefore, this indicator shows the technological progress in the fossil fuel industries. Although the patent is not a perfect measure of technological progress, patent counts are still the best available source of data on technological innovation (Johnstone, Hascic, & Popp, 2010).

Patterns of U.S. energy technology patents have been used to examine its R&D spending on energy technology. The conclusion is that they are highly correlated (Margolis & Kammen, 1999; Nemet & Kammen, 2007). The cutbacks in energy R&D, together with the declining number of energy patents, will probably reduce the capacity of the energy sector to innovate and reduce the pace of energy technological improvement (Margolis & Kammen, 1999). Patents are used to assess the effectiveness of the U.S. R&D investment in emerging energy technologies (Nemet & Kammen, 2007). Patent counts are also used as evidence of the impact of environmental policies on technological innovation in the renewable energy sector. Analysis using patent data on a panel of 25 countries reveals that policy instruments have affected the technological progress of renewable energy sources (Johnstone, Hascic, & Popp, 2010).⁴² With this backdrop, patents are used as an indicator to evaluate the applicability dimension of China's energy security.

AP-5: Energy industry technical updating & transformation investment/Investment in fixed assets of state-owned units in energy industry

Besides patents, investment in energy technological innovation is essential to enable

⁴² Besides the energy sector, use of patents for academic research could also be found in Lee and Sorenson (2001) research on invention and technology; Huang, et al. (2003) research on nanotechnology performance; and so on.

a country to respond to its changing economic and environmental needs. Inadequate investment in energy technological innovation at a national level will have negative effects on the energy sectors and the national economy and environment in the long run. A commonly-used indicator of status of energy technological innovation is the investments by government and/or the private sector in the energy technology innovation—assuming that there is a strong positive relationship between investment in energy and energy technological innovation (Dooley, 1998; Margolis & Kammen, 1999). When applying this indicator in the case of China, it must be kept in mind that in China, the government budget is only used as a supplementary instrument to boost the development of the energy sector, which is still highly dominated by large SOEs. Under this condition, the energy investments of China's SOEs should be taken as a substitute for the investments by government (Pan & Zhu, 2005/2006). In China Energy Statistical Yearbook, investments in fixed assets of state-owned units in energy industry include capital investment as well as upgrading and renovation investment (Pan & Zhu, 2005/2006). AP-5 depicts the share of upgrading and renovation investments in the fixed assets investment of state-owned units in the energy industry. It indirectly reflects the technological advancement in China's energy sector.

3.2.3 Acceptability indicators

Energy has a great impact on the environment and is a key element in the study of sustainable development. Fuel combustion is one of the main sources of air pollution. Other energy-related activities such as energy production also have caused water pollution and other environmental problems. The energy-environment relationship has been closely intertwined and indicators are needed to reflect whether such relationship is acknowledged and how well it is reflected in decision-making. For example, air pollutant emissions (ENV3: Air pollutant emissions from energy systems) is used by the IAEA (2005) as one of the environmental dimension indicators of the EISD to track the release of air pollutants into the atmosphere from energy-related activities in order to assess energy sustainability.

Coal will continue to dominate China's energy system in the foreseeable future. Two-thirds of the country's total energy supply comes from coal and 80% of its electricity is generated by coal. By 2020, coal will still account for about 60% of China's total energy consumption (Kong, 2005). The use of coal is a major source of air pollution in China. Consequently, the air pollution indicators that directly reflect the impact of the combustion of coal on the environment are selected. These indicators include 'Share of China's CO₂ emissions out of global CO₂ emissions', 'China's SO₂ emissions' and 'the volume of soot emission'. The CO₂ and SO₂ emission levels indicate how far a country has progressed in alleviating air pollution from greenhouse gas emissions and acid rain (Sovacool & Brown, 2010). Soot emissions are commonly used by Chinese scholars as an indicator to depict air pollution in China.⁴³

AC-1: Share of China's CO₂ emissions out of global CO₂ emissions

This indicator measures China's share of the world's total emissions of CO₂ from energy production and consumption. It also provides information on the rising or declining trend of the carbonization of China's energy system. Fossil-fuel burning produces CO₂, a greenhouse gas associated with climate change. During the twentieth century, the amount of CO₂ has increased by more than 30% largely due to the burning of fossil fuels (IAEA, 2005). Consequently, the global environmental impact is conventionally measured by CO₂ emissions (HELIO International, 2005/2006). Typical examples could be found in HELIO International (2005/2006), IAEA (2005), OECD (1993), Pan and Zhu (2005/2006), and Sovacool, Mukherjee, Drupady, and D'Agostino (2011). The IAEA (2005), in particular, uses this indicator as one of the environmental dimension indicators (ENV1) of EISD to assess energy sustainability. The OECD (1993) measures the levels of CO₂ emissions to assess the environmental impact of energy use to reflect the role of energy and environmental policies in achieving sustainable economic development. This indicator is one of Pan and Zhu (2005/2006)'s environmental sustainability indicators to evaluate China's sustainability and environmental performance. This is also one of the environmental

⁴³ I thank Dr. Sun Chuanwang at Xiamen University for this point.

sustainability dimension indicators used by Sovacool, Mukherjee, Drupady, and D'Agostino (2011) to assess a country's energy security. To explain the environmental impact of energy utilization, Schipper and Haas (1997) have established a quantitative link between energy consumption patterns and CO₂ emissions.

China's high reliance on coal combustion produces huge amounts of CO₂. Its contributions to global CO₂ emissions are already increasingly high because of its fast industrial development and economic growth. The Chinese government has been striving to reduce its carbon intensity⁴⁴ and its share of the world's emission of CO₂. In 2007, China released its First National Climate Change Assessment which sets the goal of reducing China's carbon intensity by 40% by 2020, and 80% by 2050 (Herzog, 2007). By the end of 2009, as a participant in the Copenhagen Accord, China committed to reduce its carbon intensity by 40% to 45% by 2020 compared to 2005 levels (Cohen-Tanugi, 2010, p. 1). In order to achieve the long-term goal, the twelfth FYP (2011-2015) sets the target to reduce carbon intensity by 17%. Reflecting the above elaboration, the indicator 'Share of China's CO₂ emissions out of global CO₂ emissions' is selected to demonstrate the historical evolution of one environmental aspect of the country's energy system: the CO₂ emissions.

AC-2: China's SO₂ emissions

An increase in the pollutants from the burning of coal also causes acid rain that harms ecological systems. Therefore, SO₂ emissions, the source of acid rain, are selected to evaluate the impact of air pollution on the environmental sustainability dimension of a country's energy security (Sovacool, Mukherjee, Drupady, and D'Agostino, 2011). The level of SO₂ emissions is adopted by OECD (1993) to measure environmental effects of energy use to reflect energy and environmental policies designed for economic sustainability. The combination of the concentration of particulates in an urban area with the SO₂ concentrations is the most significant energy-related local pollutant(s) selected for China by HELIO International

⁴⁴ Carbon intensity is the ratio of carbon emissions to GDP.

(2005/2006). As the SO₂ is more region-specific, its absolute amount (rather than a global share) of emissions is selected.

Given China's heavy reliance on coal and particularly its direct use of coal, it is no surprise that coal burning contributes more than 85% of SO₂ in China. The correlation coefficient between coal consumption and increased SO₂ level is above 95% (He, Huo, & Zhang, 2002, p. 410). Therefore, the emission of SO₂ is a key indicator of China's air pollution.

AC-3: the volume of soot emissions

The burning of coal releases soot and smoke to the atmosphere. Soot emissions are a major source of pollution from the energy industry (especially coal in China) and cause significant health risks. Besides CO₂ and SO₂ emissions, soot emissions are also identified as one of the main pollutants in the air (Heymann, 2006). The empirical study on China's air pollution often includes three air pollutants: SO₂, industrial soot emissions, and dust emissions (Shi, 2009). The indicator of soot volume is used to evaluate both the air pollution situation and the air pollution control in China (Chen & Xu, 2010; Hu & Jiang, 2007).⁴⁵ 'The volume of soot emissions' is hence selected, together with CO₂ and SO₂, as one of the acceptability indicators.

In addition to air pollution indicators, there are some indicators that indirectly measure the effects of energy production and consumption on the acceptability dimension of energy security. For example, the share of zero-carbon fuels in energy mix is used as an indicator of the acceptability (environmental) dimension of energy security (APEREC, 2007; Sovacool & Mukherjee, 2011). Formulated as the share of renewables and nuclear in total primary energy supply, this indicator measures the extent/status of a country's effort to move away from a carbon-intensive fuel portfolio (Kruyt, van Vuuren, de Vries, & Groenenberg, 2009). It quantifies a

⁴⁵ Another commonly-used indicator for air quality evaluation is the suspended particular matter concentration level: PM₁₀ emissions, mainly the result of industrial process, of which coal mining and burning constitutes a major source. Data on PM₁₀ emissions in China, however, are not readily available.

country's progress in utilizing alternative fuel sources by increasing the share of clean energy resources to meet their energy demand.

A fuel mix in electricity generation is the most critical contributor to the variation in the carbon factor.⁴⁶ Since nuclear and hydro energy resources have little carbon emissions, a country with a high share of these energies in electricity generation will naturally have a low carbon factor (Ang, 1999). China has been working hard to increase the share of electricity use in end-use sectors. The expansion of electricity use makes Chinese electricity generation a global-scale industry. Large power stations (including coal-fired power plants, hydroelectric facilities, and nuclear power stations) have been constructed. Electricity generation itself is, however, a polluting industry in China, since coal contributes more than half of the sources of electricity generation. To alleviate environmental pollution, China must expand the construction of nuclear power stations and also the renewables power generation facilities in order to raise the share of nuclear energy and renewables in electricity generation.

A share of renewable energy, no matter in energy consumption or energy supply, reflects a type of energy mix. This percentage gives information on renewable resources exploitation as well as the status of market penetration of various alternative energy sources and reveals consumer preferences for different energy sources. Both the indicator of 'renewable energy deployment' of HELIO International Indicators (2005/2006) and the indicator of 'Renewable energy share in energy and electricity' (ECO13) of the EISD highlight the status of the renewable share in environmental improvement.⁴⁷ Besides the renewable energy resources, the use of

⁴⁶ The carbon factor, also referred to as the carbonization index, is the energy-related carbon emissions per unit of energy consumption (Ang, 1999).

⁴⁷ Actually, the percentage of renewable energy in total primary energy supply (TPES) is a good indicator to reflect the level of harnessing renewable energy. Renewable energy is normally used to generate electricity or produce biofuels. However, biofuel consumption and production make up only a very small share of China's total renewable energy consumption or supply. Consumption and production of biofuel started only in 2001. According to the EIA database, China produced (and consumed) 45,000 barrels of biofuel per day in 2009. Since 1 barrel of crude oil/day=50 tons of crude oil/year, this means that in 2009, China produced (and consumed) 2250,000 tons of biofuel, which is a very small number compared not only to the number of China's TPES but also to the size of China's renewable energy supply. Therefore, the contribution of biofuel in the renewable energy supply is omitted.

other new energy resources (such as substituting fossil fuels with nuclear energy) may lead to negative environmental effects which are markedly different from the air pollution caused by fossil fuel utilization. Therefore, how the population accepts nuclear energy in their community needs to be reflected. Accordingly, two specific indicators to depict China's non-carbon shares in energy mix are adopted in this research:

AC-4: Share of renewable energy out of total electricity generation

AC-5: Share of nuclear energy out of total electricity generation

3.2.4 Affordability indicators

Energy pricing is a key driving factor in energy consumption. It also measures the economic impact and reflects the scarcity of energy resources as well. For example, as a dominant energy carrier, oil pricing is considered a crucial energy security indicator (Kruyt, van Vuuren, de Vries, & Groenenberg, 2009). Energy pricing must reflect whether and how the population can afford to pay for energy consumption. For this purpose, the growth rate of ex-factory price index for coal, petroleum, and electricity prices are adopted. The growth rate is calculated over a five-year period on the basis of ex-factory price index with the previous year's equal to 100.

Coal is the dominant fossil fuel in China's energy mix and its consumption is still growing rapidly. It is mostly a locally available resource and readily available. Eighty percent of China's electricity is generated by coal. The majority of rural residents in China still use coal as a fuel for daily activities such as cooking and heating (Gan & Yu, 2008). Therefore, changes in coal pricing affect the energy costs of large numbers of industries and consumers in China.

The indicator 'Share of renewable energy out of total electricity generation' is used as a proxy of 'percentage of renewable energy in total primary energy supply (TPES)'.

Besides using coal, China is now the world's second-largest oil consumer following the United States. Its oil demand will grow as its disposable income rises and as more households opt for cars and oil-based household appliances. The pricing of oil indirectly affects the consumers' ability to own cars and home appliances. In an emerging economy like China, sustained economic growth requires an expanding electrical power sector to support industries and commercial activities as well as to raise the people's living standards (Andrews-Speed, 2004). Electricity prices are thus critical to people's daily life and to the nation as a whole. In China, the electricity prices are highly subsidized and set below the average total costs to support industrial growth. Low electricity prices have caused power shortages. (Lam, 2004). The Chinese government has tried to solve the problem by linking coal and electricity prices, but the linkage cannot fundamentally solve the problems. The electricity pricing is also significant to many Chinese households which use electricity for air conditioning in summer. In view of these, the following three AF price indicators are selected:⁴⁸

AF-1: Growth rate of ex-factory price index (previous year=100) for coal (over five-year period)

AF-2: Growth rate of ex-factory price index (previous year=100) for petroleum (over five-year period)

AF-3: Growth rate of ex-factory price index (previous year=100) for electricity (over five-year period)

⁴⁸ Sovacool and Brown (2010) use two indicators to measure affordability: retail electricity prices, and retail gasoline/petrol prices. In a refined later work, Sovacool, Mukherjee, Drupady, and D'Agostino (2011) use only the retail price of gasoline/petrol as a direct price indicator to measure affordability. The electricity pricing indicator is adjusted as 'Percentage that retail electricity prices have changed every five years' to measure the stability of electricity prices. This study uses three direct price indicators. Coal price is included in addition to electricity and prices of petroleum products. This is because coal is a major source of China's energy mix. The gas price is not included in the AF indicators. Although the piped gas supply has a long history in China, its development was slow until the early 21st century when large hikes in oil prices caused many enterprises to switch their production fuel to natural gas, which drove up international LNG prices to a level that China could not afford (Wong, 2010). Percentage of total Chinese urban population using gas is small, from less than 10% in the early 1980s to up to one third in mid-1990s (LBNL, 2008), not to mention the rural population. Hence, this dissertation does not use gas price as an AF indicator.

AF-4: Volatility of coal prices

The volatility of coal prices measures how the ex-factory price index (previous year=100) for coal has changed every five years. The volatility component of the affordability dimension can be measured by the 'stability of electricity prices' (Sovacool, Mukherjee, Drupady, & D'Agostino, 2011). In this study, the 'volatility of coal prices' is used as a proxy to measure energy price stability in China. This is because electricity pricing is still kept artificially low, and thus relatively stable by the authorities in China. In contrast, the coal sector has been fully liberalized in China and its pricing is subject to the forces of demand-supply. Therefore, the volatility of coal prices (instead of the volatility of electricity prices) is selected for study.⁴⁹

AF-5: Energy consumption per capita: Non Productive Use

Affordability indicators need to reflect the energy consumers' sensitivity to price changes. The energy consumption per capita can indirectly reflect the affordability of energy to the population. It measures the level of energy consumption on a per capita basis and reflects the changing patterns of a country's energy consumption over time. By using a global level of average consumption as a benchmark, the higher the level, the more people can afford to pay for more energy consumption; the lower the level, the fewer people can afford to sustain a decent level of energy consumption. In the developing countries where the per capita consumption of energy is much lower than that of the developed countries, having lower energy consumption than what is required to sustain a decent level poses a serious constraint on economic development. This refers to consumption in the end-use sectors, thus excluding energy consumed, or losses incurred, in the conversion, transformation and distribution of energy resources (IAEA, 2005).

It is noteworthy that the indicators constructed to evaluate China's energy security could also be used to measure that of other countries. Given that the selection of

⁴⁹ The stability of electricity prices refers to the percentage that retail electricity prices have changed every five years (Sovacool, Mukherjee, Drupady, & D'Agostino, 2011). Following this definition, this study selects five years as the time interval measure for the 'stability of coal prices' indicator.

indicators in this chapter is subject to data availability in China, one could alternate or tweak some of the indicators to evaluate the energy security of other countries. The indicators listed in this chapter are not exhaustive but they are the best and most suitable key indicators, considering the limited data available to evaluate China's energy policy and security. These energy security indicators can be further developed for any other country by adding or reducing the listed indicators.

3.3 Data

This section contains an explanation of the method of data collection and extrapolation for the indicators for the period 1980-2010 in five-year increments. The energy databases used in this study primarily include: National Bureau of Statistics of China (NBS), China Statistical Yearbook (CSY), China Energy Statistical Yearbook, the US Energy Information Administration (EIA), the US Lawrence Berkeley National Laboratory (LBNL), and the BP Statistical Review (BP).

3.3.1 The AV data

This section explains how the data for the indicators are chosen, collected and calculated. As above illustrated, there are five AV indicators:

AV-1: Coal reserve-to-production ratio

AV-2: Oil import dependence ratio

AV-3: Natural gas reserve-to-consumption ratio

AV-4: Availability factor of conventional thermal electricity

AV-5: Availability factor of non-thermal electricity (including nuclear and renewable)

China's coal reserves

It is noteworthy that even though the CSY has extensive data for coal reserves and production, the statistical coverage has changed since 2002. Before 2002, the data indicated 'ensured reserves' (*Baoyou Chuliang*) as stipulated. Since 2002, the CSY

indicated ‘basic reserves’ (*Jichu Chuliang*). There is a big increase of the coal reserves figure from 2001 to 2002, with 1,003,300 million tons in 2001 and 331,800 million tons in 2002. In fact, there is no consensus on the precise reserves of China’s coal resources. Estimates vary among the international and Chinese sources (Aden, Fridley, & Zheng, 2009).

With a series of extensive national resource surveys, China reported to the World Energy Council (WEC) that their coal reserve totalled 114,500 million tons in 1992. This coal reserve estimate was often cited in subsequent years and in other references such as the annual BP Statistical Review of World Energy (Aden, Fridley, & Zheng, 2009).⁵⁰ This could be verified in their recently published reports. The WEC, in its *2010 Survey of Energy Resources*, reported that China’s proved recoverable coal reserves at the end of 2008 was 114,500 million tons and its coal production was 2,782 million tons (World Energy Council, 2010, p. 16), with the R/P ratio of coal 41 years in 2008. The BP has the same figure, i.e., 41 years in 2008. Therefore, when extrapolating China’s coal R/P ratio, the author uses the WEC estimate of coal reserve, i.e., 114,500 million tons. The following table shows China’s coal R/P ratio.

Table 3-1: China’s coal reserve (Mt), coal production (Mt), and coal R/P ratio (years)

Year	1980	1985	1990	1995	2000	2005	2010
Coal Reserve	114,500	114,500	114,500	114,500	114,500	114,500	114,500
Coal Production	620.1	872.3	1079.9	1360.7	1384.2	2349.5	3240.0
AV-1	185	131	106	84	83	49	35

The coal production data are sourced from *BP Statistical Review of World Energy June 2011*. Since the *BP Statistical Review of World Energy* began to record coal production from 1981, the 1980 data on coal production, 620.1 Mt, is retrieved from the EIA. The EIA figures of coal production are very similar to those of the BP in the other years. It is noteworthy that the *BP Statistical Review of World Energy June 2006*

⁵⁰ The reason why the WEC’s coal reserve estimate is frozen is that coal resource has been converted into reserve at a rate equal to annual consumption (Aden, Fridley, & Zheng, 2009).

cites China's coal production hit 2190.0 million tons, and thus the R/P ratio of 52 years for 2005. But in its 2011 report, the production figure is revised as 2349.5 million tons. This study uses the data from the latest BP Statistical Review, i.e., *BP Statistical Review of World Energy June 2011*. The same logic applies to other BP data in this study when discrepancy exists in its statistical reviews.

Table 3-2: AV data for each ending year of the FYP periods

Year	1980	1985	1990	1995	2000	2005	2010
AV-1	185	131	106	84	83	49	35
AV-2	-0.1406	-0.3158	-0.1791	-0.0076	0.2824	0.3947	0.5473
AV-3	49.3	67.4	65.5	94.1	55.8	32.8	25.7
AV-4	0.571	0.563	0.521	0.531	0.500	0.561	0.495
AV-5	0.324	0.395	0.396	0.416	0.331	0.401	0.361

Data of AV-2 are retrieved from the NBS, AV-3 from the *BP Statistical Review of World Energy June 2011*, and AV-4 and AV-5 from the EIA. AV-4 and AV-5, the availability factor, are calculated as 'actual total generation in MWh/(total installed capacity in MWh times 8,760 hours)'.

3.3.2 The AP data

This section explains how the data for AP indicators are chosen, collected and calculated. As above illustrated, the AP indicators include the following:

AP-1: Energy intensity-Total Primary Energy Consumption per Dollar of GDP (Btu per Year 2005 US Dollars (Purchasing Power Parities))

AP-2: Gross generation efficiency of fossil fuel-fired power plants

AP-3: Crude Oil Distillation Capacity (Thousand Barrels Per Day)

AP-4: Patents owned by LME (State-owned) in coal mining and dressing and petroleum and natural gas extraction industries

AP-5: Energy industry technical updating & transformation investment/Investment in

fixed assets of state-owned units in energy industry

Table 3-3: AP data for each ending year of the FYP periods

Year	1980	1985	1990	1995	2000	2005	2010
AP-1	33161.7	25364.3	21310.4	15385.0	10644.3	12546.7	10150.3
AP-2	0.298	0.309	0.314	0.325	0.339	0.359	0.373
AP-3	1600	2150	2200	2867	4346.8	4649.6	6806
AP-4	0	0	0	314	199	828	808
AP-5	0.330	0.153	0.152	0.223	0.322	0.357	0.290

For AP-1, the data are retrieved from the EIA. The EIA only has data on China's energy intensity until 2008. The 2010 figure is calculated on the basis of the 2005 figure and the actual energy intensity reduction. In its eleventh FYP, the Chinese government set the target of reducing energy intensity by 2010 by 20% from 2005. From 2005, China's energy intensity began to decrease after a steady three-year rise. The Climate Group (2011) claimed that China achieved a reduction of 19.1% in 2010. With the 2005 energy intensity of 12546.7 Btu/GDP, and the real reduction figure at 19.1%, the 2010 energy intensity is calculated as 10150.3 Btu/GDP.

For AP-2, the data are sourced from the LBNL. The LBNL only has the data of China's gross generation efficiency of fossil fuel-fired power plants until 2006. The 2010 figure, 0.373, is extrapolated on the basis of the average annual increasing rate of gross generation efficiency of fossil fuel-fired power plants over the latest period based on data available from 2002 till 2006.

For AP-3, the data are sourced from the EIA.

For AP-4, the data are sourced from the *China Statistical Yearbook on Science and Technology* of various years. This yearbook has records on patents owned by the LME (State-owned) from the year 1996 until 2008. The 1980, 1985, and 1990 data are thus taken as zero. From 2009, there is a change of statistical coverage. The statistics previously recorded as 'patents owned' by LME was changed to 'patents in force' by

LME. As a result, the data from 2009 onwards are not used. There is no regular change in the number of patents owned by LME. In general, patents owned by LME since 2004 are more than those in the period before 2004. This study uses the 1996 figure to represent the 1995 figure, and the 2008 figure to represent the 2010 figure.

For AP-5, the data are sourced from LBNL and the China Energy Statistical Yearbook. The LBNL only has data on the 'energy industry technical updating & transformation investment' until 2003. The China Energy Statistical Yearbook has this data recorded until 2002. The China Energy Statistical Yearbook has the data of 'investment in fixed assets of state-owned units in energy industry' until 2010. The LBNL has the data on 'energy industry technical updating & transformation investment' as from 1981. In fact, the China Statistical Yearbook (*Zhongguo Tongji Nianjian*) was first published in 1982, which marked the beginning of the regular release of official statistical data in China. The first one is the 1981 issue, which covers only 1981 data. The second one is the 1983 issue, from which the most recent data in each issue are on the previous year (Holz & Lin, 2001). This study uses the data of 1981, i.e., 0.330, to represent the 1980 data. The 2005 figure is extrapolated on the basis of the average annual increasing rate of the technical updating & transformation investment of energy industry over the years from 1999 till 2003. The 2010 figure is also extrapolated on the basis of the data over the years from 1999 to 2003.

3.3.3 The AC data

The AC indicators include the following five. This section explains how the data for these AC indicators are chosen, collected and calculated.

AC-1: Share of China's CO₂ emissions out of global CO₂ emissions

AC-2: China's SO₂ emissions (10,000 tons)

AC-3: The volume of soot emissions (10,000 tons)

AC-4: Share of renewable energy out of total electricity generation

AC-5: Share of nuclear energy out of total electricity generation

Table 3-4: AC data for each ending year of the FYP periods

Year	1980	1985	1990	1995	2000	2005	2010
AC-1	0.078	0.093	0.109	0.139	0.143	0.199	0.251
AC-2	1325	1325	1494	1891	1995.1	2549.4	2185.1
AC-3	1324	1324	1324	1478	1165.4	1182.5	829.1
AC-4	0.202	0.234	0.212	0.196	0.174	0.168	0.193
AC-5	0	0	0	0.0129	0.0124	0.0212	0.0177

AC-1 data are sourced from the *BP Statistical Review of World Energy June 2011*. AC-2 data are sourced from the *China Statistical Yearbook*. The data include emissions by the industry and emissions by daily consumption. The *China Statistical Yearbook* began to record SO₂ emissions from 1985. The 1980 figure is taken as the same with that of 1985. The AC-3 data come from two sources. From 1995 onwards, the data are sourced from the *China Statistical Yearbook* of various years. China began to keep records of soot discharges from 1992. The *China Environment Yearbook* began to keep data of soot discharges in 1990. The 1980 and 1985 data are taken as the same as the 1990 data. Both AC-4 and AC-5 data are sourced from the EIA. China began to generate nuclear power in 1992.

3.3.4 The AF data

This section explains how the data for AF indicators are chosen, collected and calculated. The AF indicators include:

AF-1: Growth rate of ex-factory price index (previous year=100) for coal (over five-year period)

AF-2: Growth rate of ex-factory price index (previous year=100) for petroleum (over five-year period)

AF-3: Growth rate of ex-factory price index (previous year=100) for electricity (over five-year period)

AF-4: Volatility of coal prices (measured by new formula)

AF-5: Energy consumption per capita: Non Productive Use (SCE Kg)

Table 3-5: AF data for each ending year of the FYP periods

Year	1980	1985	1990	1995	2000	2005	2010
AF-1	0	5.24%	5.72%	20.48%	2.24%	11.84%	10.4%
AF-2	0	5.06%	6.18%	35.06%	11.78%	9.3%	10%
AF-3	0	2.32%	4.1%	22.12%	7.18%	2.12%	2.22%
AF-4	0	122.95	160.53	338.27	541.29	696.55	1202.99
AF-5	112.26	126.71	139.18	130.68	123.66	194.1	258.34

Data AF-1, AF-2, AF-3, and AF-4 are all sourced from the *China Statistical Yearbook* of various years. To account for changing relative energy prices, the relative energy price indices of ex-factory prices for coal, petroleum, and electricity are adopted. These relative ex-factory price indices are calculated on the basis of the previous year figure equal to 100. The growth rate is calculated over a five-year period. There is no data about energy price index available in the 1970s. It was in the early 1980s that a two-tier pricing system (the beginning of price liberalization) was adopted. Prior to that (i.e., 1976-1980), the energy pricing was under the strict control of the government and also damaged by the Cultural Revolution. Therefore, the period 1976-1980 is taken as no price growth and volatility. The 1980 figure is thus zero. The AF-5 data are sourced from the National Bureau of Statistics. Coal price volatility is calculated by the following standard deviation model:

$$\sigma = \sqrt{\frac{1}{n-1} \sum_{t=1}^n (r_t - \mu)^2}$$

Where r_t is the logarithmic return: $r_t = \ln \frac{P_t}{P_{t-1}}$

μ is expected return given by:

$$\mu = \frac{1}{n} \sum_{t=1}^n P_t$$

P_t is the yearly price index and n is five.

3.4 Data coding and the performance scoring

3.4.1 Data coding

To make the gathered data comparable, the data are coded and normalized on a scale of ordinal values. This section contains an explanation for the coding of the raw data (i.e., conversion of the raw data into ordinal values). It is noteworthy that when coding data, the indicators are made unidirectional, which means that higher values correspond to better energy security performance. The scores are not designed to reflect the dichotomy between energy insecurity and energy security. Instead, the scoring for the specific years just reflects a dynamic change of China's energy security status (i.e., whether the situation has improved or deteriorated). The scoring range is scaled from 1 to 10. The higher score, the better the energy security situation.⁵¹ The following table 3-6 presents the scoring scale of data and table 3-7 presents the ordinal values of each indicator.

⁵¹ This is a second best methodology to depict the energy security situation. The ideal methodology would be identifying the absolute highest and lowest possible values for each indicator. If such values are identified, absolute ranges for the indicators can be constructed.

Table 3-6: Scoring scale for data converted into ordinal values

Indicator	Ordinal value									
	1	2	3	4	5	6	7	8	9	10
AV-1	30-46	46-62	62-78	78-94	94-110	110-126	126-142	142-158	158-174	174-190
AV-2	0.5-0.6	0.4-0.5	0.3-0.4	0.2-0.3	0.1-0.2	0-0.1	(-0.1)-0	(-0.2)-(-0.1)	(-0.3)-(-0.2)	(-0.4)-(-0.3)
AV-3	25-32	32-39	39-46	46-53	53-60	60-67	67-74	74-81	81-88	88-95
AV-4	0.495-0.503	0.503-0.511	0.511-0.519	0.519-0.527	0.527-0.535	0.535-0.543	0.543-0.551	0.551-0.559	0.559-0.567	0.567-0.575
AV-5	0.32-0.33	0.33-0.34	0.34-0.35	0.35-0.36	0.36-0.37	0.37-0.38	0.38-0.39	0.39-0.40	0.40-0.41	0.41-0.42
AP-1	31600-34000	29200-31600	26800-29200	24400-26800	22000-24400	19600-22000	17200-19600	14800-17200	12400-14800	10000-12400
AP-2	0.290-0.299	0.299-0.308	0.308-0.317	0.317-0.326	0.326-0.335	0.335-0.344	0.344-0.353	0.353-0.362	0.362-0.371	0.371-0.380
AP-3	1600-2130	2130-2660	2660-3190	3190-3720	3720-4250	4250-4780	4780-5310	5310-5840	5840-6370	6370-6900
AP-4	0-84	84-168	168-252	252-336	336-420	420-504	504-588	588-672	672-756	756-840
AP-5	0.150-0.171	0.171-0.192	0.192-0.213	0.213-0.234	0.234-0.255	0.255-0.276	0.276-0.297	0.297-0.318	0.318-0.339	0.339-0.360
AC-1	0.241-0.260	0.222-0.241	0.203-0.222	0.184-0.203	0.165-0.184	0.146-0.165	0.127-0.146	0.108-0.127	0.089-0.108	0.070-0.089
AC-2	2470-2600	2340-2470	2210-2340	2080-2210	1950-2080	1820-1950	1690-1820	1560-1690	1430-1560	1300-1430
AC-3	1432-1500	1364-1432	1296-1364	1228-1296	1160-1228	1092-1160	1024-1092	956-1024	888-956	820-888
AC-4	0.160-0.168	0.168-0.176	0.176-0.184	0.184-0.192	0.192-0.200	0.200-0.208	0.208-0.216	0.216-0.224	0.224-0.232	0.232-0.240
AC-5	0-0.0022	0.0022-0.0044	0.0044-0.0066	0.0066-0.0088	0.0088-0.0110	0.0110-0.0132	0.0132-0.0154	0.0154-0.0176	0.0176-0.0198	0.0198-0.0220
AF-1	18.9%-21%	16.8%-18.9%	14.7%-16.8%	12.6%-14.7%	10.5%-12.6%	8.4%-10.5%	6.3%-8.4%	4.2%-6.3%	2.1%-4.2%	0-2.1%
AF-2	32.4%-36.0%	28.8%-32.4%	25.2%-28.8%	21.6%-25.2%	18.0%-21.6%	14.4%-18.0%	10.8%-14.4%	7.2%-10.8%	3.6%-7.2%	0-3.6%
AF-3	20.7%-23.0%	18.4%-20.7%	16.1%-18.4%	13.8%-16.1%	11.5%-13.8%	9.2%-11.5%	6.9%-9.2%	4.6%-6.9%	2.3%-4.6%	0-2.3%
AF-4	1125-1250	1000-1125	875-1000	750-875	625-750	500-625	375-500	250-375	125-250	0-125
AF-5	110-125	125-140	140-155	155-170	170-185	185-200	200-215	215-230	230-245	245-260

Table 3-7: The 4 As Indicators in Ordinal Values

Indicators	Years						
	1980	1985	1990	1995	2000	2005	2010
AV-1	10	7	5	4	4	2	1
AV-2	8	10	8	7	4	3	1
AV-3	4	7	6	10	5	2	1
AV-4	10	9	4	5	1	9	1
AV-5	1	8	8	10	2	9	5
Average value	6.6	8.2	6.2	7.2	3.2	5.0	1.8
AP-1	1	4	6	8	10	9	10
AP-2	1	3	3	4	6	8	10
AP-3	1	2	2	3	6	6	10
AP-4	1	1	1	4	3	10	10
AP-5	9	1	1	4	9	10	7
Average value	2.6	2.2	2.6	4.6	6.8	8.6	9.4
AC-1	10	9	8	7	7	4	1
AC-2	10	10	9	6	5	1	4
AC-3	3	3	3	1	5	5	10
AC-4	6	10	7	5	2	1	5
AC-5	1	1	1	6	6	10	9
Average value	6.0	6.6	5.6	5.0	5.0	4.2	5.8
AF-1	10	8	8	1	9	5	6
AF-2	10	9	9	1	7	8	8
AF-3	10	9	9	1	7	10	10
AF-4	10	10	9	8	6	5	1
AF-5	1	2	2	2	1	6	10
Average value	8.2	7.6	7.4	2.6	6.0	6.8	7.0

3.4.2 Performance scoring-Area of rhombus

This section depicts China's energy security status in each FYP period. Seven rhombuses are drawn to represent the status. The following figures 3-2 to 3-8 illustrate the rhombuses and their relevant energy security situation. Figure 3-2 is the energy security situation in 1980, the original situation and also the benchmark for analysis. Figures 3-3 to 3-8 show the energy security situation of the ending year of each FYP period. Table 3-8 lists total area of the rhombus of each period.

Figure 3-2: Energy security status of 1980 (benchmark for this study): 68.04 sq. units.

Figure 3-3: Energy security status of 1985 (the ending year of the sixth FYP period): 72.52 sq. units.

Figure 3-4: Energy security status of 1990 (the ending year of the seventh FYP period):
59 sq. units.

Figure 3-5: Energy security status of 1995 (the ending year of the eighth FYP period):
43.92 sq. units.

Figure 3-6: Energy security status of 2000 (the ending year of the ninth FYP period):
52.48 sq. units.

Figure 3-7: Energy security status of 2005 (the ending year of the tenth FYP period):
70.84 sq. units.

Figure 3-8: Energy security status of 2010 (the ending year of the eleventh FYP period): 62.32 sq. units.

Table 3-8: Total rhombus area of ending year of FYP

Year	1980	1985	1990	1995	2000	2005	2010
Area (sq. units)	68.04	72.52	59	43.92	52.48	70.84	62.32

Besides the total rhombus area, the energy security performance of each period is depicted by an imbalance index as well, which is defined as (area of a diamond taking the highest A score – actual total area)/area of a diamond taking the highest A score. The lower the index, the more balanced the four dimensions of each period. Table 3-9 indicates the imbalance index of the ending year of FYP.

Table 3-9: Imbalance index of ending year of FYP

Year	1980	1985	1990	1995	2000	2005	2010
Imbalance index	0.49	0.46	0.46	0.58	0.43	0.52	0.65

3.5 Evolution of the 4-As

3.5.1 An overview

China's energy security evolution is studied in terms of its Five-Year Plans (FYPs), as

the analytical framework is based on the study of energy policy decisions according to specific time periods to assess the entire energy security evolution. This study presents seven timing points to mark the ending year of the FYP over 30 years to reveal significant trends in China's energy security situation. A total of six Five-Year Plans are covered—from the sixth FYP till the eleventh FYP—which also coincides with the period of China's early economic reform to its transition to market liberalization. The 1980 rhombus marks the beginning of the period under study, which is also the beginning of economic reform and China's recovery from the 'Cultural Revolution'. The lagging economy and low level energy demand made China a net energy export country. Besides, its underdeveloped electricity generation capacity was accompanied by low levels of technology, environmental pollution, and energy pricing (under strict government control). The AV, AC, and AF scored high in 1980 whereas the AP score was pretty low. The 1980 rhombus covers 68.04 sq. units, which is also a relatively high score among the seven rhombuses. This shows that at the very beginning of China's economic reform, its energy security status was favorable compared to that of subsequent years.

The target of the country's economic plan was to speed up growth in its industries that were damaged during the 'Cultural Revolution'. During the sixth FYP period (1981-1985), energy shortage was the key obstacle to the nation's economic development. To fuel the economy, the sixth FYP highlighted the expansion of energy supply. It specified the targets for coal, oil, and electricity production. Considering the scale of the national economic development goal, the government forged ahead to promote the development of renewable energy, hydropower in particular, and called for energy conservation to compensate for restrictions caused by the low level of energy technology. All energy policies during this period showed an obvious emphasis on the availability dimension.

The energy security situation improved a little during the seventh FYP period. The 1985 rhombus covers 72.52 sq. units, which is the biggest area among the seven

rhombuses. The 1985 rhombus shows that the negative impact of the low level of technology on the status of energy security of China was offset by relatively low volatility in energy prices and by the cleaner environment. Taking into account the imbalance index, which is the second lowest among the seven years in calculation, the sixth FYP period shows a relatively good energy security situation. More energy reserves, cleaner environment, and stable prices contributed to relatively balanced development of the four dimensions of energy security in China.

Since the industrial production growth was much faster than originally planned, the development of the energy industry was clearly defined during the seventh FYP period (1986-1990). The government emphasized supply expansion to meet the expected surging demand for energy. The planned annual growth in total primary energy production was targeted at 3.4% (NDRC, 1986, p. 18). The power industry was highlighted as the most critical sector to be developed. It was clearly stipulated in the suggestions on the seventh FYP that power industry should be the center of energy industry development: China shall 'actively develop thermal power' and 'vigorously develop hydropower' (NDRC, 1985). But the energy security situation did not improve. The 1990 rhombus covers 59 sq. units, indicating a deteriorating situation.

China's energy security continued to deteriorate in the 1990s, a period characterized by 'deepening reform and broadening opening up', resulting in its drastic economic transformation and an insatiable hunger for energy. The 1995 rhombus is the smallest and its relevant imbalance index, 0.58, is the second highest among the years in calculation, suggesting an obvious imbalanced development of the four dimensions of energy security. This period was marked by expanding energy production, fluctuating energy prices, and deteriorating environmental conditions.

The ninth FYP (1996-2000) continued to rank power as the center of energy development. Its annual growth in production was targeted at 7% over the Plan period. The coal industry was selected as the key sector for development. Its

development principle was to stabilize the production in eastern areas, and accelerate development in northwestern regions. Energy technologies—the clean coal technology, long distance power transmission technology—were highlighted in the Plan. The state coalmines were expected to improve their production efficiency and raise profits by making technological progress. Nevertheless, the drastic economic reform measures and the untiringly pursuit of the economic goal only worsened the overall of energy security situation. The 1995 and 2000 rhombuses cover 43.92 and 52.48 sq. units respectively, indicating a relatively negative energy security status in the 1990s.

The tenth FYP (2001-2005) specified that the energy sector had to continue to undergo marketization. The AP and AF dimensions began to attract increasing attention and improved to some extent. The 2005 rhombus covers 70.84 sq. units, an area much larger than the 2000 rhombus of 52.48 sq. units, indicating an improved energy security situation. However, during the eleventh FYP (2006-2010), the energy availability reached its worst situation in all the years under study. The 2010 rhombus covers 62.32 sq. units. Taking the panoramic view of China's 30 years of economic reform, the sixth FYP period had the best energy security situation and it coincided with the early reform period (the first FYP period of the economic reform). Although the overall situation was better in the first decade of the new millennium than in the 1990s, it did not catch up with the sixth FYP period. Figure 3-9 shows the evolving trend timeline for area of the rhombuses.

Figure 3-9: Evolving trend timeline for area of the rhombuses

3.5.2 The AV Trend

The average ordinal value peaks in 1985 at 8.2 and hits the lowest in 2010 at 1.8.

Figure 3-10 shows a downward trend of the availability dimension.

Figure 3-10: Trend illustration of average value for AV

China's economic development, accelerated by a series of economic reforms, required high levels of energy production. Since 1980, the expansion of energy

supply has been vital to China's energy policy. The policies changes were evidently relative to energy supply as the nature/roles of policies swing between two extremes: policies gave incentives to push for energy production during times of shortages of energy; policies imposed harsh restrictions when the economy was overheated. Since the early 1980s, the government began to encourage the development of township and village coal mines (TVCMs) to alleviate energy shortages even though some TVCMs were shut down in the late 1990s due to the pressure to enhance environmental protection and to protect the state-owned coalmines. The steady growth of coal production led to a decreased coal R/P ratio. Similarly, the growth rate of natural gas consumption increased faster than that of its proved reserves. The natural gas reserves-to-consumption ratio began to decrease in the mid-1990s. China was a net exporter of energy resources. The oil import dependence ratio was -31.58% in 1985, which was the decisive factor that made the AV dimension the highest ordinal value in 1985. The huge demand for energy, along with a fast pace of economic development, made China a net importer of oil in 1993, a net importer of natural gas in 2007, and a net importer of coal in 2009.

The power sector is vital to China's energy security due to its key role in both industry and daily life. It was stipulated in the seventh FYP that the power industry should be the center of the country's energy industry development. Since then, the electricity generation and the installed capacity of generation had grown steadily. Reforms in the power sector accelerated the expansion. The first stage of the power sector reform was initiated in 1986. The reform partially decentralized the investment authority in the generation sector. Various investors, including local governments, SOEs, and private and foreign companies were invited to build new power plants to supplement power generation to meet the increasing demand for electricity. Since Deng Xiaoping's 1992 Southern Tour, China accelerated its transformation to the market economy. This gave birth to the second stage of the power sector reform beginning in 1997. This wave of reform aimed at separating the government administration from the business operations of the power plants and power grids

(Zhang & Heller, 2004). Market competition was gradually injected into the power sector to hasten the pace of economic expansion of both electricity generation and installed capacity of China's power industry. The pace of the expansion of the power industry was so fast that by the end of the eleventh FYP in 2010, China generated about 4,000 billion kWh of electricity with a total installed capacity of about 1,000 million kilowatts, at least a tenfold increase compared to the early reform period. In general, the installed capacity in the conventional thermal electricity sector expanded faster than the actual generation, especially in 2000 and 2010, when the government rushed to shut down small and inefficient thermal plants to protect state-owned ones in a concerted effort to improve the environment. This makes the ordinal value of the availability factor of conventional thermal electricity the lowest in 2000 and 2010. The availability factor of 1985, 1995, and 2005 scores relatively high, which drives up the average AV ordinal value in these three years respectively.

3.5.3 The AP Trend

China's energy-related technology generally improved over time. Figure 3-11 shows that there is a general upward trend of the ordinal value during the 30 years of economic reform except for the slight outlier in 1985. But since then, the trend takes an upward turn until 2010. The ordinal value hits the highest at 9.4 in 2010 and the lowest at 2.2 in 1985.

Figure 3-11: Trend illustration of average value for AP

Well-aware of the need to reduce its energy intensity and improve energy efficiency since the beginning of the economic reform, its energy intensity decreased steadily and consistently between the 1980s and 1990s. Since 2001, fast economic growth and huge consumption of energy triggered the rise levels of energy intensity. In response to the surge in energy demand during the tenth FYP period, the government set the goal to reduce the country's energy intensity by 20% during the eleventh FYP period, and made structural adjustments to move the economy away from energy-intensive production (IEA, 2007b). Consequently, by the end of 2010, China "saw a last-minute rush to meet targets" amid social and economic disruption including blackouts, forced factory closures, and the disrupted residential heating (The Climate Group, 2011, p. 8). With much awkwardness, China managed to achieve its goal of energy intensity reduction. The relevant ordinal value increases from 9 in 2005 to 10 in 2010.

The increase of generation efficiency of thermal power plants reflected China's success in improving its power generation technology. This helped to push up the AP ordinal value particularly since 1990, the starting year of the steady rise of the AP ordinal value. Coal is the dominant fossil fuel for electricity generation. China has

been actively researching and developing various forms of advanced coal-burning technologies including supercritical and ultra-supercritical systems, circulating fluidized beds, and flue gas desulfurization to improve economic and environmental efficiencies (Wu, Pineau, & Caporossi, 2010). Although the development of supercritical and ultra-supercritical systems in China started relatively late, it made rapid progress. The first application of supercritical boilers, imported from Switzerland and the United States, was at the Shanghai Shidongkou Second Power Plant, operated by the China Huaneng Group in 1992. During the eleventh FYP period, there were two more power plants using ultra-supercritical pressure boilers: China Huaneng Group's Yuhuan power plant in Zhejiang Province and China Huadian Corporation's Zouxian power plant in Shandong Province. Both had high-efficiency dust removal and desulphurization equipment that could meet international standards. By 2010, supercritical and ultra-supercritical units accounted for more than 40% of the newly built thermal power generating units (Chen and Xu, 2010, p. 2126). These units greatly helped to reduce the energy consumption per kWh electricity supply. Other advanced power generation technologies such as supercritical and ultra-supercritical systems, circulating fluidized beds and flue gas desulphurization were rapidly developed during this period. The generation efficiency of thermal power plants grew very fast, with its ordinal value going up from 4 in 1995 to 8 in 2005, and 10 in 2010.

In the oil sector, the introduction of foreign technology and capital along with the opening up of China's offshore oilfields to international oil companies during the sixth FYP period sped up China's oil harnessing technology. International oil companies were also allowed to be involved in China's onshore oilfields in the coastal provinces in July 1985. The modernization and maintenance of onshore oilfields accelerated oil technological advancement and oil production (Locatelli, 1989). China's oil distillation capacity increased steadily from 1,600 thousand barrels per day in 1980 to 6,806 thousand barrels per day in 2010. This contributes to the steady rise of the AP ordinal values since 1985.

Patents owned by coal mining and dressing and petroleum and natural gas extraction industries grew very fast during the tenth and eleventh FYP periods. These industries focused on technological advancement, which contributes the most to the fast and steady increase of AP ordinal values since 2000. To boost the development of the energy industry, the government implemented a series of measures to attract domestic and foreign investments since 1990. From then on, energy investments had expanded. The increasing sources of investment and the focus on technological advancement had improved the share of energy industry technical updating and transformation investment in total investment in fixed assets of state-owned units in energy industry consistently rising, from 15.2% in 1990 to 35.7% in 2005. The milestone of investment in Chinese energy industry was in 2004. The State Council issued the '*Decision about Investment Regime Reform*', which specified the principle that "whomever makes the investment shall be the decision-maker, the beneficiary, and the risk undertaker of the investment" (Pan and Zhu, 2005/2006, p. 45). The *Decision* prospered technical updating and transformation investment in the energy industry.

3.5.4 The AC Trend

Figure 3-12 shows that there is a steady declining trend in the AC ordinal values from 1985 to 2005. The ordinal value declines from 6.6 in 1985, the ending year of the sixth FYP, to 4.2 in 2005, the ending year of the tenth FYP. The worsening situation took a turn for the better during the eleventh FYP period, when the ordinal value rebounded to 5.8.

Figure 3-12: Trend illustration of average value for AC

Fossil fuels are the key sources of CO₂ and SO₂ emissions, with coal alone accounting for a major part. Continued growth in energy production and consumption led to steady increases in the CO₂ and SO₂ emissions in China. China had been addressing the air pollution problems since the 1980s. Starting in 1982, the government ordered the industries to pay a 0.04 Yuan for every 10 m³ of SO₂ emitted in excess of standards. However, most enterprises preferred to pay the charges instead of reducing emissions, due to the high cost of emissions abatement (Yun, 1998). Environmental problems had been serious in China since the 1990s. Although environmental protection began to exert its full presence on China's political agenda during this period, the enforcement was at odds. The CO₂ emissions rose steadily and peaked at 2861.68 million Mt in 1995 and only decreased slightly to 2849.75 million Mt at the end of the ninth FYP period in 2000. However, it soared to 8375.89 million Mt in 2010. China's share of global total increased from 7.8% in 1980 to 25.1% in 2010. The government's effort in controlling SO₂ emissions was effective in the eleventh FYP period. The SO₂ emissions rose steadily and reached a peak of 25494 thousand tons at the end of the tenth FYP period in 2005, before falling back to 21851 thousand tons in 2010—partly as a result of the requirement of installing

more desulphurisation equipment at thermal power plants. The total volume of soot discharges decreased from 11825 thousand tons in 2005 to 8291 thousand tons in 2010, which proved to be the most effective soot discharge control over 30 years of economic reform. The promotion of environmental protection proved fruitful during the eleventh FYP and contributed to the climbing up of the AC ordinal value in 2010.

China has a long history of renewable energy usage. Since 1992, China had shown strong willingness to support the deployment of renewable energy when the *China's Agenda 21* was issued. Several policies on renewable energy technological development were made. In 1994, the State Planning Commission (SPC) formulated the 'Brightness Program and Ride the Wind Program'. In 1996, the State Economic and Trade Commission (SETC) advanced the 'Ninth Five-Year Plan of Industrialization of New and Renewable Energy'. In 2001, the SETC proposed the '*Tenth Five-Year Plan for New and Renewable Energy Commercialization Development*'. In 2003, the '*Renewable Energy Promotion Law*' was promulgated (National Renewable Energy Laboratory, 2004). All these policies promoted the renewable energy technological development in China, but the development pace lagged behind the enlarging appetite for energy. Although the electricity generated by renewable energy resources increased on a yearly basis, the share of renewable energy out of total electricity generation decreased steadily from 23.4% in 1985 to 16.8% in 2005. Several economic, political and social barriers delayed the progress of renewable energy development. First, the high cost of renewable energy, compared to coal-fired generation, posed a formidable barrier. Promoting renewable energy development is dwarfed by the government's motivation to keep electricity prices low in support of GDP growth. Second, the electricity price that was fixed by the government did not reflect the cost of production, so grid companies were often unwilling to connect renewable generation plants to the grid, and this deterred potential investors and limited the growth of the renewable energy industry. Third, there was a lack of domestic and international investment mechanisms, and a shortage of capital for the renewable energy sector. The renewable energy industry underwent a process of

cautious liberalization as the government maintained strict control over renewable resources. The overall uncertainty about the future structure of the renewable energy industry would deter the investors (Cherni & Kentish, 2007).

The pace of Chinese development of renewable energy cannot offset the negative impact on environment brought by the increasing fossil fuel consumption in China. To alleviate the environmental pollution, several programs were set up during the eleventh FYP to promote renewable energy development in China. '*Renewable Energy Law*' and '*Circular Economy Law*' took effect in 2006 and in 2007. According to the '*Renewable Energy Law*', the NDRC announced '*Plans on Medium- and Long-term Development of Renewable Energy Resources*' in 2007 (NDRC, 2007b). The Plans quantified the specific goals of developing renewable energy resources. It was planned that by 2020, China would have 300 million kilowatts installed capacity of hydropower, 30 million kilowatts installed capacity of biomass power, 30 million kilowatts installed capacity of wind power, and 1.8 million kilowatts installed capacity of solar power. All these measures contributed to the small rebound of the renewable energy resources share in total electricity generation from 16.8% in 2005 to 19.3% in 2010. The exploitation and development of renewable energy became more effective during the eleventh FYP period.

A favorable factor that may have helped in the development of nuclear energy in China was the willingness of the Chinese people to embrace the role that nuclear technologies will play in the country's continued economic development. Public opposition had often been a major impediment to nuclear development in the West. However, the Chinese people are often informed of nuclear decisions only after they were made, due to China's centralized government and government-driven economy (Zhou, 2010). Since 1992, nuclear power has been utilized and generally, it has an increasing share of total electricity generation despite slight decreases in some years. In 2005, the nuclear share peaked at 2.12% in China's total net electricity generation. Over the eleventh FYP period, the increase rate of nuclear share went down, but the

share still remained at 1.77%, much higher than in the 1990s. The Chinese people’s acceptability of nuclear power dilutes the declining trend of AC ordinal values.

3.5.5 The AF Trend

Figure 3-13 shows that there is a slight dip of AF ordinal values with the year 1995 as an outstanding outlier. The highest ordinal value 8.2 is in 1980, showing the best affordability situation in China. The outlier 1995 only has the ordinal value of 2.6, the lowest one among the seven years in calculation, due to the high growth rate of coal, oil, and electricity prices in that year.

Figure 3-13: Trend illustration of average value for AF

Before the economic reform, China’s energy industry operated within the planned economy system. Energy prices were decided by the central government, which intentionally kept the prices low to fuel the economy. The low and stable prices led to a relatively favorable situation that enhanced affordability in the country. Little progress was made in liberalizing energy pricing in the 1980s except the introduction of a two-tier pricing system in the coal sector.

Since 1984, local state mines were allowed to sell coal output in excess of their

official quotas at a premium and all non-state mines were allowed to sell their products at market prices. In 1986, the central state mines were also allowed similar concessions for their over-quota output (Wright, 1996). The coal sector was the sector with the earliest pricing liberalization, albeit not in a full scale. China's explicit target to establish a socialist market economic system after Deng Xiaoping's 1992 Southern Tour accelerated the deregulation of coal pricing. Since then, the market mechanism had been gradually injected into energy pricing. In 2002, the 'supervised prices' imposed on thermal coal consumed by power plants was revoked. The liberalization of coal pricing was finally complete in the coal sector in 2009, when the NDRC approved of direct negotiation between coal enterprises and power plants on thermal coal contracts (Tu, 2011). The liberalization of coal pricing during the eleventh FYP period led to the highest volatility of coal prices in 2010.

The power pricing reform preceded the oil pricing reform and progressed rapidly. In the power sector, electricity tariffs were allowed to fluctuate according to the prices of primary energy and other production materials in the early 1990s (Yang & Yu, 1996). Relevant pricing policies made the electricity tariffs very complex. In 2002, the separation between the enterprises of power generation and the enterprises of power grid stimulated the electricity tariff reform. The pricing system was designed to be more market-oriented, with three categories: the generation price based on generator status; the transmission and distribution price set by the central government; and the end-user price determined by the central government. Although controlled by the government, these prices are set to reflect costs and to manage electricity demand (APERC, 2008). The control over oil pricing generally lasted until a new oil price regime was established in 1998. In June 1998, China reformed the oil pricing system to peg its domestic oil price to Singapore prices, with a one-month lag built in. Since then, the domestic oil prices had been based on Singapore export prices and were adjusted monthly (Anonymous, 1998; Hang & Tu, 2007). In November 2001, the domestic oil prices were adjusted to peg to the package price—prices of New York, Rotterdam, and Singapore markets. The market

mechanism had begun to play a fundamental role in oil pricing.

Pricing liberalization was gradually introduced into the energy sector. During this process, China experienced mounting pressures of the excessively high growth rate of energy prices in 1995 and the worst affordability situation. Only in the later periods when the market mechanism in energy pricing gradually became relatively mature did the situation began to improve, which is reflected in the upward trend during the ninth FYP, and the flat and smooth slope shown in the tenth and eleventh FYP periods. The 1995 high energy price growth rate is inextricable from Deng's 1992 Southern Tour and the central government's goal to establish a socialist market economy. Driven by Deng's tour and the reform to construct a socialist market economy, China's national economy grew very fast between 1992 and 1993. At the same time, excessive price increases and inflation pressures rose again (Peng and Chen, 2011b). The overheated economy during the eighth FYP period made the rise in energy prices steep in 1995. After that, the sustained transition to marketization brought about a relatively mature pricing mechanism in the energy sector. The AF dimension had gradually improved since 1995.

3.6 Chapter Summary

In this chapter, the author uses the comprehensive concept of energy security and the indicators within the 4-As framework to measure China's energy security over 30 years of economic reform. The energy policies are reviewed to analyze the extent of their impact on energy security.

The 4-As framework is constructed by four dimensions—the availability of energy resources, the applicability of technology, the societal acceptability and the affordability of energy resources. Unlike other existing quantitative frameworks and measurements of energy security, the 4-As framework uses the least number of indicators but is comprehensive enough to accurately represent the nature of energy security. Ordinal values are converted from the statistical data of 20 indicators under

the 4-As for seven years in calculation: 1980, 1985, 1990, 1995, 2000, 2005, and 2010. They are then plotted into seven rhombuses respectively to illustrate the energy security situation by measuring the area of these rhombuses. A bigger area indicates that a higher level of energy security is brought about by the energy policies that were implemented in a particular FYP. The analysis shows that China's overall energy security situation had not improved since its reform in 1980. The status of energy security appears to be the best in 1985 and the worst in 1995. Since then, the situation improved until 2005, but still fell short of its peak in 1985. From 2005 to 2010, the situation deteriorated. The emphasis on the energy development plan had affected the status of energy security directly and deeply. In the early reform period, the Chinese economy was still directly under government control and prices were still stable. The energy resources were not extensively exploited so the environment was relatively not so polluted. However, the reform package introduced in 1994 had an immediate adverse impact on the 1995 energy security status. Amid the expanding energy production, deteriorating environment, and fluctuating energy prices, the energy security situation in China hit the bottom in 1995, as depicted by the smallest rhombus in the study.

China's insatiable hunger for energy resources caused the quantitative value of the availability dimension to decline while the environmental (acceptability) dimension deteriorated along with the energy utilization. However, there were signs of slight improvement in recent years. The affordability dimension improved after it hit the worst status in 1995. China's technology progressed steadily but the applicability dimension did not make sufficient progress to make the overall energy security status reach the early reform period level. In 2010, the deteriorating energy security status was accompanied by the worst availability. Along with the injection of the market force into the energy industry in China, the sectors of coal, oil, and electricity experienced reforms that either improve or diminish the relevant 'A' dimension, and affect the overall energy security in China. The next chapter provides a detailed review on the impact of the energy policies on the energy security situation in China.

Chapter 5 provides an analysis to suggest reasons for the lack of continuous improvement in China's energy security situation during the 30 years of economic reform.

Chapter 4 Energy Policy in China since Its Reform and Opening up

The conventional wisdom is that China does not have an energy policy because there is no unified energy ministry in China and no explicit 'energy policies'. However, this is simply not true. China's energy policies are a diversified mix of government mandates, industry stipulations, and company activities. This chapter contains a discussion of these policies and an analysis of their impact on China's energy security situation (discussed in chapter 3).

4.1 Energy policies from 1949 (founding of PRC) to 1976 (end of Cultural Revolution)

4.1.1 Energy policies from 1949 (founding of PRC) to 1957 (end of the first Five-Year Plan)

In the early days after the founding of PRC, the first task of the energy industry was to restore the normal production of the existing coalmines, oil fields, and power plants. To do this, the Ministry of Fuel Industry was established in October 1949 to manage the Coal Mine Bureau, the Oil Bureau and the Electrical Industry Bureau (Yu, 2010). Acting as China's energy industry power authority, the Ministry of Fuel Industry was to take the lead to develop the coal industry, power industry, and oil industry in order to meet domestic demand. It developed the energy production plan, and interfered with the individual enterprises' production and management matters such as production planning, technology, and even workers' wages. The establishment of the Ministry of Fuel Industry fully reflected the role of the planned economy of that time (CASS, 1996).

Immediately after the founding of PRC, the Ministry of Fuel Industry held three national professional meetings to address the management of coal, electricity, and oil. The meeting on coal management was the most important as it established the key aim for the coal industry in China at that time. The aim was to recover the coal

production and at the same time, build several new mines with new technology and equipment in order to guarantee supply for future industrial development (Chi, 2005). In 1949, the central government established and exercised control over new institutions to stabilize the prices of key resources such as coal. By 1952, due to the threat of the Korean War, the central government further improved the allocation of important materials, 12 (including coal) of which were under direct central control (Chen, 1992). The existing energy industry was taken over by the central government. The foreign investment and bureaucratic capital left behind by the KMT government were confiscated to form a large part of China's energy industry (Su, 1999).

Investment

In 1951, the first National Industrial Conference set out a plan for industrial production. The total investment in coal, electricity, and petroleum industries represented 18 percent of the total national infrastructure investment (Li, 1992, p. 306). The investment in the energy industry made up a relatively high proportion of the country's total investment in infrastructure. During the first FYP (1953-1957), the industrial projects were randomly distributed. Key projects were scattered across the country, and were mostly concentrated around the cities. Most of the coal and power industries were located in coal-rich regions of Northeast and North China. The industrial investment in these two regions accounted for 70% of the national total between 1953 and 1955. In 1954 and 1955, the output of coal and electricity of these two regions accounted for 84.4% and 66% of country's total output respectively (Liu, 1995, p. 8). During the five years, the fuel industry⁵² accounted for 25.5% of the national industrial infrastructure investment. This is higher than the heavy industry (24.4%) and only slightly lower than the machinery industry (26%) (CCP Central Committee's Literature Research Center, 1993a, p. 416). In contrast, the investment in coal still kept a high proportion. Within five years, 31 coal enterprises

⁵² In the early days of China's energy production and consumption pattern, coal was the major one. Exploration of oil and gas was very low. This situation lasted for more than a decade until the exploitation of Daqing and other oil fields which greatly improved the structure of energy production and consumption. This means that in the early days of China's national economic plan, fuel industry mainly refers to the coal sector.

were constructed and accounted for more than one million tons of coal per annum (Li, 1993). The central government realized that energy development must remain top priority for the smooth development of other industries. However, during the first FYP period, the unexpected rapid heavy industrial development resulted in a shortage of energy supply. To meet the demand for coal, measures such as inventory reduction, sales control and energy conservation were adopted (CCP Central Committee's Literature Research Center, 1993b).

Reform of energy enterprises

Both coal and power sectors had to undergo reform during this period. The coal industry experienced three types of reforms: production, management and technology. The coal industry followed the former Soviet Union production model. The cadres at all levels in the Party, the government officials, and the workers were required to cooperate under the leadership of the Party committee. Both coal mining and transportation adopted mechanization. The reform of the coal sector helped to reduce accidents and casualties, save resources, and improve productivity. The reform of the power industry upgraded its technology to the Soviet model to solve practical problems. It focused on the workers' use of innovative tools. Plenty of suggestions and proposals were submitted by workers to increase efficiency. In the meantime, the heavy equipment maintenance technology improved significantly. The safety of power supply was enhanced. The management system of the power industry, which played an important role in saving manpower and resources, also improved (CASS, 1996). The coal and power sectors were reformed in a planned and systematic manner under the centralized planned system.

Policy effects

From 1950 to 1952, China saw the restoration of its coal, power and petroleum industries. The recovery of the power industry was the most remarkable. Years of war had ravaged the power industry. After the restoration of the existing old equipment, the growth rate of the power industry became impressive. In 1952, the

total power production was 7.3 billion Kwh. The growth rate of power production was 26.3% (Woodard, 1980, p. 462). Production efficiency rose. During the recovery period, China had largely restored the war-torn energy industry, and upgraded the technology of the energy industry. During the first FYP period, the production of energy industry increased but still lagged far behind the soaring demand for coal. This demand-supply gap also existed in the oil and electricity sectors (Chen, 1993; CASS, 1998).

4.1.2 Energy Policies during the 'Great Leap Forward'

China's attempt to a quick transition to heavy industrialization forced it to develop heavy industries promptly, even though its energy and raw material industries were not mature enough. Focusing on heavy industry made China rapidly establish its energy industry but at the same time undermined the development of other sectors such as the agricultural development. This phenomenon was especially prominent during the 'Great Leap Forward', a period marked by the rampant practice of incorrect economic development guidelines (Zhao, 2010). As China's heavy industry development (mainly the iron and steel industry) was essential for national industrialization and economic development (Shi, 1996), it became the key focus of its energy production plan.

In 1957, the Chinese leaders had unprecedented confidence in pursuing rapid economic development because they achieved the target of their first FYP ahead of schedule. In 1958, the 'Great Leap Forward' was introduced to strengthen China's industrial power via increasing steel and iron production. However, the movement disrupted the national economy and wasted resources. The mass steel and iron smelting campaign had a direct negative impact on the energy production and consumption. The campaign was also the major reference for the government energy policymaking. The following subsections have a discussion in detail.

'Great Leap Forward' of coal industry

In 1958, the second FYP set its target to turn China into a socialist country by modernizing its industry, agriculture, and science and culture. Therefore, the central government highlighted the importance of steel production and ordered that industrial production meet the needs of the mass steel and iron smelting campaign. The expected target, by the end of the second FYP, was as follows: by 1962, if the production of steel was 80 million tons, then the corresponding key energy indicators would include 300 billion kWh of power generation, 900 million tons of raw coal, and 50 million tons of crude oil (CCP Central Committee's Literature Research Center, 1995, p. 432). Subsequent modifications to the energy production plan were subject to the adjustment of the steel and iron production plan. In order to meet the needs of the national mass steel and iron smelting campaign, the Ministry of Coal Industry proposed the slogan of 'Whole Nation Put Great Effort to Build Coalmines'. The Ministry of Coal Industry changed the production plan's target to 380 million tons in 1959 and 520 million tons in 1962 (Editorial Board of 'Contemporary China', 1988, p. 44). As the production plan departed from the coal mining production capacity, the coal production was seriously affected. Since May 1960, the national coal production continued to fall significantly (Editorial Board of 'Contemporary China', 1988). It was estimated that China's raw coal production was around 280 to 425 million metric tons in 1960. But in 1962, this figure fell in the range of 180 to 254 million metric tons (Woodard, 1980, pp. 408-409). It is difficult to make estimates for the 'Great Leap Forward' period due to the over-reporting at that time. One thing that was certain was that in the early 1960s, China's coal industry was sluggish. New mines were not constructed, and the output of the existing mines remained at low levels (Woodard, 1980).

'Great Leap Forward' of power and oil industries

Soon after the 'Great Leap Forward' began, the development of the steel and iron industry led to a huge demand for power, creating a severe shortage of electricity. One reason was the severe shortage of power generation equipment. Therefore,

under the 'Great Leap Forward', the central government ordered all power generation equipment to be installed immediately. It also ordered factories to do everything possible to manufacture more power generation equipment. However, the shortage of large castings caused the delay of most of the equipment-producing projects (State Economic and Trade Commission, 2000).

Besides, it was stipulated in the *Report on Draft of 1958 National Economic Plan* that "the future development of the power industry should resolutely implement the Central Committee's proposal--- dominated by hydropower while supplemented by thermal power. Central authorities should help the local governments build small hydropower stations" (Bo, 1958). Consequently, the central government handed some power plants to the local governments. The Ministries of Electric Power and Hydro Conservancy were merged to form the Ministry of Hydro Conservancy and Electric Power (Yu, 2010). This 'hydropower-based' development approach, which did not take into account the local realities, damaged the power industry. Hydropower-based development needed water-rich terrain and thus not suitable for all parts of the country. For example, Northeast and North China did not have much water resources for the hydropower development. This approach impaired the development of the power industry in these areas (State Economic and Trade Commission, 2000).

At the beginning of the second FYP, Deng Xiaoping pointed out that their oil exploration effort should primarily concentrate on regions such as Songliao, North China, East China, Sichuan, and Ordos. Since then, the focus on oil exploration shifted from the west to the east (Wang & Zhang, 1997). By that time, China had increased the production of the oil industry equipment according to the Soviet model. The Soviet Union had also provided extensive aid in carrying out seismic surveys, which had led to the identification of some important oilfields including the Daqing oilfield (Congress of the United States, 1979). The eastward industrial shift and the discovery of the Daqing oilfield helped to ease the oil crisis in China after the

Sino-Soviet relations worsened.

Impact of 'Great Leap Forward' on energy industry

During the 'Great Leap Forward' (1958-1960), governments at all levels, from the central to the local, invested heavily in the construction of the energy industry. The production of energy, including coal, oil, and electricity, had risen. However, the disadvantages outweighed the advantages. The negative impact of the 'Great Leap Forward' on China's energy industry can be categorized into three aspects. First, energy production was increased at the expense of massive resource wastage. For example, in the coal industry, most of the coal produced were of inferior quality, and wasted in the campaign of steel and iron smelting in the families' or communities' 'backyard' furnaces (Smil, 2010). The construction for power-generating equipment was blindly carried out, resulting in great wastage and long-term shortage of energy supply in subsequent years. Second, the mass steel and iron smelting campaign resulted in low efficiency in energy production and utilization. Third, huge investments in the energy industry yielded far less return. The coal industry proposed the slogan of 'Whole Nation Put Great Effort to Build Coalmines'. In addition to the coalmine construction in the coal-rich regions of East China and Northeast China, new coalmines were also constructed in the northwest, southwest and middle-south regions. In 1961, the coalmine construction scale of these three regions was 68.59 million tons, exceeding the total of North and Northeast China's 54.69 million tons (CCP Central Committee's Literature Research Center, 1997, p. 264). In short, the hydropower-based development approach regardless of the local differences in the actual situation throughout the country resulted in severe power shortage and massive wastage of resources in the northern region.

4.1.3 Energy Policies after the 'Great Leap Forward' (from 1961 to 1966)

After the end of the 'Great Leap Forward', the central government attempted to adjust energy policies to get the economy back on track. Its energy policies focused on three aspects: the adjustment of the energy investments, adjustment of the

energy industry management system, and construction of the Third Front.

Adjustment of investments in energy industry

The ratio of the industrial sector investment was adjusted. Investments in coal, wood, non-ferrous metals, and oil accounted for 30.6% of the total heavy industry investment in 1960, 45.5% in 1961, and 58.8% in 1962 (Li, 1997, p. 494). Specifically, it was mentioned in Li Fuchun's *Report on the Adjustment and Implementation of the Last Two Years of the Second Five-Year Plan* that "it is absolutely necessary to largely reduce infrastructure investments and projects" (Li, 1997, p. 494). It could be seen that the central government reduced its investments in the heavy industry but increased its investments in the energy industry. In the past, the increased investments in the energy industry infrastructure were used to expand production scale. Later, it was used to provide equipment for the enterprises. As a result, between 1961 and 1962, there was a positive increase in production. The installed capacity (for power generation) increased 1.13 million kilowatts; natural oil output increased 3.15 million tons; and coal output increased thirteen million tons (Li, 1997, p. 495).

Adjustment of management system in energy industry

Adjustments to the management system were carried out in the energy industry. These involved reforms in the reinforcement of financial management, corporate affiliation, and concentration of financial power. During the 'Great Leap Forward', mass movement led to the formation of many small and medium-sized enterprises (SMEs), which had inefficient operations and produced wastage of resources. A total of 92,800 inefficient SMEs closed down or merged with large enterprises between 1961 and 1965 (Yang & Dong, 2000, p. 7).

In addition to the phenomenon of downsizing and merging SMEs, the energy industry was restructured according to the principles of 'specialization and cooperation'. With the improvement of the organizational structure of the energy

enterprises, the level of efficiency increased. For example, in 1964, the East China Coal Industry Company was established in Xuzhou, where coal and labor were abundant. The company was in charge of the coal industries in several provinces such as Jiangsu, Shandong, Anhui, Jiangxi, Zhejiang and Fujian. It was efficient and performed well in resource development and decision-making (Shi, 1995). By reforming its management system and improving its technology, the company was ready to handle large-scale production. After four consecutive years of losses, it made a profit of RMB 5 million Yuan in the first quarter of 1965 (Wang & Dong, 1995, p. 161).

Energy policies for the Third Front construction

In 1964, Chinese government made massive investments in the military-industrial development of inland provinces in the western region of China, known as the 'Third Front' of China's industrial distribution. The construction of Third Front was the result of the geopolitical confrontation going on at that time. After the split from Soviet Union and the threat of American aggression in Vietnam, China decided to create 'self-sufficient' bases to fortify defense in the remote regions. The Third Front construction was a "large-scale, centrally-directed program of development" to prepare China for "a perceived external threat" (Naughton, 1988, p. 351). The program was "large; hastily prepared; military-related; and constructed in a highly dispersed pattern" (Naughton, 1988, p. 356). It would give China an alternative industrial base to continue normal production in case of an attack on its east urban centers (Naughton, 1988). This program dominated China's economic agenda until 1971 and lasted until the late 1970s.

The construction of the Third Front began with mining and energy production. Based on the third Five-Year Plan (1966-1970), projected investments in coal, oil, and power industries was targeted to hit RMB 5 billion Yuan, 3.5 billion Yuan, and 9 billion Yuan respectively (CCP Central Committee's Literature Research Center, 1998). The coal mining construction scale of West China exceeded that of Northeast and East China.

Oil exploitation effort was concentrated in North China, Sichuan, and Daqing. A total of RMB 960 million Yuan was invested in Sichuan's oil and gas exploitation. Exploitation of hydro-power resource was greatly accelerated, including the construction of an enormous dam at Liujiaxia, west to Lanzhou (CCP Central Committee's Literature Research Center, 1998). The new factories and projects, however, were scattered in remote and sparsely populated areas. New railways had to be built at vast expense through mountains to create transport networks for these factories to ferry resources. It was wasteful and economically unsound to put large investments into the Third Front areas (Fairbank & Goldman, 1998). The decentralization of these energy industries resulted in the loss of the benefit of regional labor division. In general, energy policies under the Third Front program had a lasting negative impact on the national economy.

4.1.4 Energy policies during the Cultural Revolution (from 1966 to 1976)

Between 1967 and 1968, the early stage of the Cultural Revolution, the State Planning Commission and State Economic Commission almost stopped working. The 1968 national economic planning was even cancelled. For two years, China's industrial production was in chaos and impeded the energy industry. For example, at the end of 1967, the country's electricity generating capacity was only equivalent to 65% of the normal capacity (Cong & Zhang, 1999, p. 399). Many regions had to take measures to limit power use. With reference to the production of raw coal and crude oil, only 76.35% and 81.6% of the year plan had been completed (Cong & Zhang, 1999, p. 400). In face of the chaotic industrial production, the government tried to reverse the situation by building some large enterprises such as Liupanshui mining district in Guizhou and the Dukou mining district in Sichuan.

However, amid mass movement and revolution, the government's operations were poorly coordinated and economically unsound. For example, according to the fourth FYP, there was a decentralization of industrial management (*gezi weizhan*). Small-scale local industries were established as 'self-reliance' was the dominating

propaganda for the establishment. The aim was to make full use of local resources to establish the local energy industry, the mechanical industry and the fertilizer industry to support the local agricultural industry (Yang & Dong, 2000). The local governments were expected to set up their small-scale industries outside of central planning. However, the results were disappointing. Compared to large-scale plants in the heavy and energy industries, these local small-scale plants were costly and inefficient. Many of them were started without adequate local supplies (Fairbank & Goldman, 1998). At the same time, they had to overcome the difficulties left behind by the Third Front construction. Some projects under construction had expanded beyond the scheduled time frame and could not be completed. In the early 1970s, it was common to see 'large-scale construction' (*daguimo jianshe*) struggling with many separate projects initiated at one time. Since budgets and completion periods were seriously underestimated, and the investments were not forthcoming, the situation got out of control when design errors emerged in many Third Front projects, such as the Gezhouba project, which was suspended in 1972 (Naughton, 1988). In fact, it was impossible to complete some of the projects. In 1972, about 150 Third Front projects out of 1,600 were suspended due to problems related to inefficiency (Fairbank & Goldman, 1998, p. 398).

Irrational energy industry construction was also reflected in the coal mining construction. At the beginning of the fourth Five-Year Plan, nine provinces in the southern China, regardless of their small coal reserves and complex geological conditions, proposed to 'reverse the situation of transporting coal from north to south'. Since then, nearly half of China's coal infrastructure investment benefited southern China. About 300 small to medium coalmines were built. The construction was high in investment but low in efficiency. The coal mining attempt in southern China delayed the coalmine construction in the coal-rich regions of Northeast, North and East China. The latter regions were more suitable for large-scale coal mining development (National Electric Power Corporation, 2001).

The energy policy during the Cultural Revolution was a continuation and intensification of the energy policy developed during the 'Great Leap Forward' and 'Third Front' construction. The construction of both small-scale local energy industry and coalmines in southern China was typically influenced by the political ideology of the 'Great Leap Forward'. Energy production, important for producing war weaponry, was given high priority during the Cultural Revolution. This was clearly affected by the 'Third Front' construction strategy. To sum up, regardless of China's actual energy resources and construction capabilities, these energy policies resulted in high costs and low rewards.

Despite the chaos and destruction brought about by the Cultural Revolution, the Chinese government persevered in its five-year plan and reaped some achievements that promoted the future development strategy for the country. Heavy investments led industrial growth to average 13.5% nationally between 1969 and 1976 (Fairbank & Goldman, 1998, p. 400). Investments in the energy industry in the 'Third Front' area had developed energy resources in the western parts of China, especially coal resource. This made the western parts of China the main source of coal production. The development of the Daqing oilfield was a major breakthrough in China's oil exploration which formed the base for rapid development in the energy industry in the following years. The sections below discuss China's energy policies undergoing the reform from 1979. The discussion is categorized according to the 4 As framework presented in chapter 2 and 3 and offers a timeline for various energy policies in relation to the 4 As during the reform period.

A variety of new energy policies have been introduced since 1979. The energy policy in China is primarily guided by the successive FYPs for China's macroeconomic and social development. The guiding principle is that the energy sector should not impinge on overall economic growth. In general, the energy policy in China recognized the importance of expanding energy supply and simultaneously, prioritizing energy efficiency and energy conservation across the country (Asian

Development Bank, 2009). China's energy policies from 1979 to 2010 in terms of the FYPs under the administrations of Deng Xiaoping, Jiang Zemin, and Hu Jintao will be discussed in the following sections.⁵³

4.2 Energy policies of the AV dimension

4.2.1 Coal production during the reform period

Adjustment of coal industry distribution and development of coal production

Attention has always been given to the production of coal, the richest energy resource in China. With intensive production during the reform period, the coal reserve-to-production ratio steadily decreased from 185 years in 1980 to 35 years in 2010. The sixth FYP had a chapter on 'energy', which mainly focused on energy supply. In the coal sector, the planned annual growth in production was 2.5%. The main measures to expand production included expanding the productivity in existing mines through mechanization and development of new mines in coal-rich areas such as Shanxi and Hebei. The development of the new mines materialized through adjusting the distribution of the energy industry. Before the reform and opening up, energy industries were developed and distributed in a 'balanced' way. The construction of the 'Third Front' and local small coalmines had intensified the decentralization of the distribution of the energy industry. The development of coalmines in southern China had further reinforced this trend. This development strategy greatly undermined the economic efficiency and violated the comparative advantage principle.

Therefore, since the reform and opening up in the late 1970s, the central government changed the strategy of economic development. Preferential development strategy was implemented to make full use of comparative advantages

⁵³ China's Five-Year Plans establish the overall development framework for the national economy. As these Plans provide macroeconomic guidance for detailed policy making, these documents are valuable in understanding China's energy development trends and its energy security status.

of local resources. This policy shift also affected the distribution of the energy industry, which was typically reflected by the coal industry distribution. To address the chaotic management of the coal industry, coal production was adjusted at the beginning of the sixth FYP. The production was shifted to the coal-rich areas especially Shanxi, Hebei, and eastern Inner Mongolia. Energy infrastructure was also constructed accordingly. For example, the railway construction focused on enhancing its coal transporting capacity. In order to develop the coalmines in Shanxi and Inner Mongolia, the sixth FYP enhanced railway construction around these areas (NDRC, 1982). The intensive development of coalmines rapidly increased coal production and improved the energy supply system in China.

With the adjustment to the coalmines, coal production increased rapidly and met the sixth FYP target in 1983, two years ahead of schedule. In 1984, the upward trend continued. In 1985, the coal production increased drastically to 872.3 Mt.⁵⁴ The AV-1 ordinal value decreased from 10 in 1980 to 7 in 1985. Besides the adjustment of the coal industry distribution, the government support for the Town and Village Coal Mines (TVCMS) development also contributed to the fast increase in coal production (the decrease in AV-1). In the wake of the liberalization of the coal sector, coal was permitted to be transacted in the market and transported freely throughout the country since the mid-1980s. In 1985, the central government implemented the 'General Contract Program'. The program set specific targets for coal production which was directly related to the economic benefits of the relevant coal production department. By 1990, coal production reached 1079.9 Mt.

In the eighth FYP period from 1991 to 1995, the government stressed the construction of key state-owned coalmines and the promotion of transformation and improvement of local mines, and mines operated by townships (NDRC, 1991). The rural coalmines experienced initial reform and consolidation. A total of 13,000 small coalmines without certification were closed down (Chen & Chen, 2007, p. 2041). In

⁵⁴ Coal production data are sourced from *BP Statistical Review of World Energy June 2011*, as in chapter 3.

1995, the marketing balance between supply and demand began to replace the conventional state-fixed-yields policy that had dominated the coal industry. At the end of the eighth FYP in 1995, the coal production increased to 1360.7 Mt. The coal production stabilized during the ninth FYP period from 1996 to 2000, as reflected by the same AV-1 ordinal values of 4 both in 1995 and 2000. In 1998, 94 key state coalmines were transferred to the local governments. Since then, no production plans or breakeven indices prescribed by the State Coal Industry Bureau were needed any more. In the same year, the TVCMs closure campaign resulted in a reduction in production by the TVCMs in the subsequent years until 2001. In 1999, the '14.40 Project' helped to adjust the basic structure of the coal industry. There were 14 coal enterprises that went bankrupt and 40 inferior and resource-depleted coalmines closed down. At the end of the ninth FYP, the coal industry was rectified by the government. The macro-control policies and the rectification of coal extraction and processing, together with the decontrolling of coal pricing in the 1990s, contributed the coal enterprises' rising profits. The rise in international oil prices also accounted for the increase in the production and profits of the coal enterprises (Lin B. , 2010). Since 2000, coal production increased very fast. During the tenth FYP from 2001 to 2005, the coal industry focused on improving efficiency and productivity of large state coalmines. Coal supply and demand was more balanced, and coal production rebounded to 2349.5 Mt in 2005.

During the eleventh FYP from 2006 to 2010, China's economy developed very fast. This raised the production and consumption of coal. To guarantee the efficient exploration and rational use of coal resources, the Ministry of Land and Resources issued a series of policies: the '*Notice on Further Strengthening the Management of Coal Resource Prospecting and Mining*' (24 January 2006),⁵⁵ the '*Notice on Strengthening the Management of Mineral Resources and the Collection of*

⁵⁵ For the details, see the website of the Ministry of Land and Resources:
http://www.mlr.gov.cn/pub/mlr/documents/t20060126_72358.htm

Compensation Fees to Improve Coal Recovery Rates' (28 April 2006),⁵⁶ and the *'Notice on Strengthening the Management of Comprehensive Exploitation of Coal and CBM Resources*' (17 April 2007).⁵⁷ More large modern coalmines were constructed. Coal production rocketed to 3240.0 Mt in 2010. The AV-1 ordinal value finally decreased from 2 in 2005 to 1 in 2010.

Contribution of China's Town and Village Coalmines (TVCMs) to coal production

The economic reform provided the opportunity for small-scale coalmines to flourish by meeting the demand where the large state-owned coalmines could not do so. In China, the small-scale coalmines were normally the TVCMs. In the early 1980s, several measures were designed to promote such coalmines. In 1981, the Ministry of Coal Industry formulated new policies to provide subsidies for small-scale coalmines and funds for their maintenance (Andrews-Speed, 2004).

In March 1983, the *'Eight Measures on Accelerating the Development of Township and Village Coal Mines*' document was issued by the State Council. It stated that the government would bear responsibility for the strategy, while the people (enterprises) would bear responsibility for the operation of the coalmines. In January 1985, the state developed a new coal industry development strategy, which required both the state and the individuals to engage themselves not only in the large coalmines, but also in the medium and small ones (*guojia, jiti, geren yiqishang; dazhongxiaoxing meikuang yiqigao*) (Pan, Pu, & Xiang, 2002). In 1987, Vice Premier Li Peng reaffirmed this strategy in the national coal work conference to raise output (People's Daily, 1987). These measures are successful in increasing China's domestic energy production to sustain China's fast economic development.⁵⁸ Figure 4-1 shows the comparison of the growth of raw coal production between centrally-administered

⁵⁶ For the details, see the website of Ministry of Land and Resources:
http://www.mlr.gov.cn/pub/mlr/documents/t20050316_74203.htm

⁵⁷ For the details, see the website of Ministry of Land and Resources:
http://www.mlr.gov.cn/tdzt/zxgz/zdhgfkczykfzx/xgwj/200806/t20080627_676997.htm

⁵⁸ Most literature on China's small-scale coal mining has been focused on the costs of environmental damages, health and safety problems, and so forth. Despite the negative impact, small-scale coal mining still reaped large-scale benefits.

state-owned coalmines and TVCMs in China. The comparison presents the large-scale benefits of reforms on TVCMs.

Figure 4-1: Raw coal production by administered state-owned coalmines and TVCMs from 1980 to 2005 (Mt)

Source: China Energy Databook v. 7.0, October 2008 (LBNL)

While these policy measures were dramatically raising the output of domestic coal, the coal sector evolved to a sector which was so diverse and dispersed that it was difficult to manage. On 20 March 1990, at the third meeting of the Seventh National People's Congress, Prime Minister Li Peng drew attention to the government work report '*Struggle for Further Stabilization of China's Political, Economic and Social Development*'. He highlighted the government's determination to manage the chaos in the coal market.⁵⁹ Since the early 1990s, a series of measures, regulations, and laws were issued to manage the TVCM sector, such as '*Administrative Measures for the Coal Production License*' (meitan shengchan xukezheng guanli banfa) effective from 20 December 1994, and '*Management Regulations of Township and Village Coal Mines*' (xiangzhen meikuang guanli tiaoli), effective from 20 December 1994. These two documents were taken as the legal basis for rectifying and regulating the

⁵⁹ For the details of the report, see *Struggle for further stabilization of China's political, economic and social development: the government work report at the third meeting of the Seventh National People's Congress on 20 March 1990*, published by People's Publishing House in 1990.

TVCMs. However, these measures, regulations, and laws were uncoordinated and hence ineffective. Small coalmines were still exploited within the key state coalmines. Some owners even declared that their ancestors had been mining in the region since the Ming Dynasty. Some coalmine management departments arbitrarily issued licenses regardless of losses incurred by the key state mines (Zheng, 1995). The situation began to improve in 1998, which marked a turning point for China's coal industry for two reasons. First, the government carried out a package of reforms for restructuring institutions and industries, including the coal sector. The Ministry of Coal Industry was abolished and state coalmines were transferred to local governments. The production plan was no longer needed. Second, the drop in demand for coal during the 1997 Asian Financial Crisis continued, resulting in substantial oversupply (Andrews-Speed, 2004).

China in the early 1990s witnessed major changes in its energy institutions, among other institutions, to develop a socialist market economy. Under the context of deepening economic reform, various institutions, enterprises, and other agencies had to change their roles, responsibilities and behavior. Most changes occurred in 1998, when the Chinese government announced a wide-ranging package of reforms to reconstruct most of the industrial sectors of the Chinese economy, including the energy sector. Also in 1998, during the Asian Financial Crisis, the expansion of the energy capacity resulted in a substantial surplus of coal. This posed a threat to the large state coalmines which held huge amounts of government investments. As the TVCMs had sold coal at prices below the costs of the state coalmines, the government had to close TVCMs to protect the large state coal mines.

All these factors led to the TVCM closure campaign in 1998 to shut down illegal and hazardous TVCMs and to rationalize the structure of coal production (Andrews-Speed, 2004).⁶⁰ Many TVCMs were shut down between 1998 and 2002. In 1998 alone, 25,000 small, non-state coalmines and 40 state-owned mines,

⁶⁰ For the details of the TVCM closure policy, see the 1998 State Council Document No. 43 '*Notice Concerning the Closure of Illegal and Irrationally Distributed Coal Mines*'.

accounting for about 250 Mt of annual output, were shut down (Sinton & Fridley, 2000, p. 674). The 1998 TVCM closure campaign was seen as “the first systematic attempt by central government to bring order to a chaotic sector across the whole country” (Andrews-Speed, 2004, p. 96). The campaign was effective in shutting down the TVCMs and in controlling coal production. As discussed in chapter 3, the indicator AV-1 in 2000 maintained the same ordinal value as in 1995, which indicated little expansion of coal production in 2000 compared to 1995.

China in the early 21st century saw its economy enter a fast track after its recovery from the Asian Financial Crisis. Pushed by the increasing energy demand in the energy-consuming industrial sectors, the coal production increased dramatically. By 2006, the total raw coal production was about 2,332 million tons. Of the output, the share contributed by TVCMs increased very quickly. From 2001 to 2006, the output by TVCMs increased by 271% while the centrally-administered state-owned mines increased only by 81%. In 2006, the output of TVCMs peaked at 1,023 million tons, amounting to 44% of total output in China.⁶¹ Figure 4-2 presents the comparison of output increase by the centrally-administered state-owned mines and TVCMs from 2001 to 2006.

The leading role of key state-owned coalmines had been strengthened through the TVCMs closure campaign beginning in 1998, but the system of regulations and laws made it hard to maintain this favorable condition. For example, the Coal Law of the People’s Republic of China, which came into effect in December 1996, explicitly states that “[t]he state shall implement a policy of support, transformation, consolidation, combination and improvement with regard to township coalmines in order to safeguard their standardized and rational exploitation and orderly development” (Article 6).⁶² The Coal Law of China generally legitimates the survival of TVCMs without specifying the requirements for operation or management. The

⁶¹ Data source: China Energy Databook of LBNL, 2008.

⁶² Coal Law of the People’s Republic of China, website: <http://policy.mofcom.gov.cn/english/claw!fetch.action?id=e01567>.

governmental system within the energy sector was so weak that it could not coordinate the interests of state mines, TVCMs, and local governments and other parties. In the absence of a system of regulations and laws (that establish a rational relationship between the state mines and TVCMs), and without efficient institutional administration, the central government's effort to guarantee the healthy development of state-owned coalmines was largely reversed by the booming local government-backed TVCMs in subsequent years (Andrews-Speed, 2004).

Figure 4-2: Output increase by the centrally-administered state-owned mines and TVCMs from 2001 to 2006 (Mt)

Source: China Energy Databook of LBNL (2008)

4.2.2 China's oil and gas industry

China's oil balance

During the sixth FYP, the government established a rationing system and stabilized the level of crude oil production at above 100 million tons, in which 94.5% was unified-planned (Chen & Chen, 2007, p. 2043). The Ministry of Petroleum Industry contracted with the state to produce 100 million tons of crude oil. The surplus output over the lump sum was 'overcapacity crude oil', which was permitted to be

exported or sold at higher domestic prices (SETC, 2000). This also led to an increase in the amount of crude oil exports. In 1985, the oil import dependence ratio was -31.58%, indicating a higher independence of oil supply in China compared to 1980's ratio of -14.06%. The AV-2 ordinal value hit 10 in 1985, the highest among the years in calculation.

Since 1985, the AV-2 indicator deteriorated steadily. Oil independence disappeared quickly due to China's growing appetite for oil to sustain its fast economic growth. China's proven oil reserves were estimated at 16 billion barrels, which was only about 1.3 % of the world's total.⁶³ Most of the oil basins in China were well-explored. The oldest and largest oil fields in northeastern China, which provided the bulk of China's domestic oil supply, were experiencing a decline in production due to insufficient oil exploration investment and storage capacity. China's upstream oil industry had to face the challenge of declining output (Wang, 1999; Chen & Chen, 2007). In 1993, China became a net importer of oil products. In 1996, it became a net importer of crude oil. Facing the domestic supply-demand gap, the Chinese government had endeavored to reduce its dependence on foreign oil. It tried to stabilize the eastern oilfields output and explore and develop the western oilfields while at the same time, make rational use of international resources (NDRC, 1991). In 1998, the oil industry was restructured. The formation of three national oil companies strengthened the capability of Chinese oil companies to invest in international resources. However, the formation of the companies was initiated by the government, not caused by the processes of capital accumulation and market competition (Shao, 1999).⁶⁴ The 1990s policies did not reduce the country's dependence on foreign oil. The oil import dependence ratio increased from -17.91% in 1990 to 28.24% in 2000.

During the tenth FYP from 2001 to 2005, the concept of 'energy security' was

⁶³ Energy Information Administration, United States. *International Energy Annual 2006*, available at: <http://www.eia.doe.gov/iea/res.html>.

⁶⁴ The restructuring of the oil sector in 1998 is discussed in chapter 5.

officially introduced in official documents as the government began to place great strategic importance on the oil industry. The government took all possible measures to accelerate oil exploration and exploitation, and make effective use of overseas resources. In 2003, the Chinese government released the policy of '*Twenty-First Century Oil Strategy*', a key theme in China's tenth FYP. This policy allocated US\$100 billion for a 'futuristic strategic oil system' in China (Miller, 2006, p. 39). In June 2004, the State Council adopted the '*Medium and Long-term Energy Development Program*' from 2004 to 2020, which emphasized the diversification of oil supply, the building of a strategic oil reserve, and regional cooperation of energy production. The first phase of the national strategic oil reserves was ready for use by 2009. The storage sites of the first phase included Zhenhai, Daishan, Huangdao, and Dalian. The second phase is under construction and is expected to satisfy 100 days of imports upon completion. The storage sites of the third phase are also in selection.⁶⁵ With regards to energy cooperation, the Chinese government was already actively conducting 'energy diplomacy' since 2000 to facilitate regional energy cooperation to guarantee the country of reliable access to oil imports (Kong, 2005). These policies, again, did not stop China's increasing dependence on foreign oil. Since 2000, the country's oil import dependence increased even more sharply.

Development of natural gas in China

China's first natural gas reservoir started operating in Daqing in 1980. Although the seventh FYP put the natural gas development on the agenda to optimize the energy consumption and production structure (NDRC, 1986), the progress of natural gas exploitation and development was very slow until 1995. Few investments and heavy taxes hindered the development of natural gas consumption and production. The combined mechanism of market regulation and government planning within the natural gas industry also impeded its development. The raw materials for the natural gas industry were regulated by the market, while the gas production was decided by

⁶⁵ Shen, R., Li, X., & Liu, X. (2010). *The second phase of strategic oil reserves is launched* (Dierpi Shiyou Zhanlue Chubei Gongcheng Luxu Kaigong). Economic Information Daily, 29 March 2010, available at: http://jjckb.xinhuanet.com/cjxw/2010-03/29/content_214283.htm.

the government. Financial losses made it impossible for the natural gas industry to develop rapidly.

There was a turning point during the eighth FYP period (1991-1995) when marketization was accelerated and new gas fields were discovered. The new gas fields included Shaanxi–Gansu–Ningxia with $2.28 \times 10^{11} \text{ m}^3$ reserves, Eastern Sichuan with $2.0 \times 10^{11} \text{ m}^3$ reserves, and Xinjiang with $1.87 \times 10^{11} \text{ m}^3$ reserves (Chen & Chen, 2007, p. 2045). This caused AV-3 in 1995 to hit 94.1, the highest among the years in calculation. With the discovery of new reserves, the ninth FYP led to the accelerated exploration of natural gas resources in order to maintain a steady increase in natural gas production and consumption. Offshore development of oil and gas took priority. It was also planned to construct oil and gas pipelines (NDRC, 1996). Since the late 1990s, China's city gas industry developed rapidly and increased its consumption level (Wong, 2010). Domestic pipelines were under construction. The first LNG terminal was constructed in Guangdong Province, and received its first shipload of LNG in May 2006. The need for more energy to fuel its economic growth and the desire for the diversification of China's energy mix spurred China's demand for natural gas (IEA, 2007a). The rapid growth of natural gas consumption resulted in an ever-decreasing AV-3 value since 1995.

4.2.3 China's electricity generation

During the sixth FYP, the government increased the installed capacity by constructing mine-mouth thermal generation plants in coal-rich areas, and large and medium-sized hydropower stations in water-rich regions. At the end of the sixth FYP period, the gap widened between power supply and demand. Power shortage expanded from the coastal areas to the west and seriously constrained agricultural and industrial production (National Electric Power Corporation, 2001). Compared to developed countries, primary energy had been converted into electricity at a lower level in China. The share of electricity in China's energy production and

consumption was small. The proportion of electricity in the total energy consumption was regarded an important symbol of a country's technological and economic development and its people's living standards (Ma, 1988). Therefore, during the seventh FYP, the power industry was singled out as the most critical sector for development to meet the soaring demand for energy. It was clearly stipulated in the suggestions on the seventh FYP that the power industry should be the center of energy industry development: China should 'actively develop thermal power' and 'vigorously develop hydropower' and construct nuclear power plants step-by-step (NDRC, 1985). The power industry-centered energy policy was proposed. To develop power industry, the central government planned to build many thermal power plants in the major coal-producing areas and coastal areas. Large-scale hydropower plants were to be built in the region adjacent to the Yellow River and the Yangtze River (NDRC, 1986). However, these policies increased the installed capacity without simultaneous growth of thermal power generation. As discussed in chapter 3, the availability factor of conventional thermal electricity (AV-4) decreased from 0.571 in 1980 to 0.521 in 1990. A direct reason was the dramatic increase in the demand for coal for non-power generation. The coal for power generation was not supplied as scheduled. In 1988, the coal 'arrival rate' for power generation was only 92.6%. The accumulated shortage of coal supply for power generation exceeded 8 million tons. Without enough coal to generate electricity, many generators were forced to shut down (People's Daily, 1989).

During the 1990s, the Chinese government developed thermal power and hydropower progressively. Thermal power plants were planned to be constructed especially at the mine-mouth, in coastal areas, and along railroads. When constructing hydropower, particular attention was given to areas with abundant hydropower resources. Nuclear power was expected to undergo proper development (NDRC, 1991). The ninth FYP still regarded power as the center of energy development. Development of thermal and hydropower continued to be emphasized. The Plan also called for the further development of mine-mouth power

stations in order to alleviate the pressure of coal transport (NDRC, 1996). In the 1990s, two key legal documents served as the foundation to guarantee adequate electricity supply. One was the '*Electrical Power Law of the People's Republic of China*' (effective from 1 April 1996); the other is the '*Regulations on Electric Power Supply and Consumption*' (effective from 1 September 1996). The '*Electrical Power Law*', as a series of policy expressions, required the power supplier to supply qualified electricity to consumers in its operational area, so did the '*Regulations*' (Andrews-Speed, 2004). Both installed capacity and electricity generation increased.

There was a turning point in 1999, when the central government decided to advance the restructuring of SOES. The decision was to shut down inferior and technologically-backward, polluting and resource-wasting small enterprises involved in coal mining, oil refining, and thermal power generating (People's Daily, 1999). Although small thermal power enterprises were explicitly restricted by the central government since 1995, many provinces continued to construct them. During the ninth FYP period, about three million kilowatts of small thermal power plants were built each year. An important reason was that these projects were subject to approval of the local planning department, rather than the central government (People's Daily, 2001). The policy priority to expand energy supply encouraged investment expansion not only in small thermal power plants but also in the state energy enterprises. However, during the Asian Financial Crisis, growing investment resulted in an inevitable surplus of electricity supply. Consequently, the investment in large-scale power stations was banned between 1999 and 2002 (Meidan, Andrews-Speed, & Ma, 2009). The closure of the small thermal power plants and the prohibition of investment in large-scale power stations drove the availability factor of electricity very low. The ordinal value of indicator AV-4 and AV-5 only scored 1 and 2 respectively in 2000, which were fairly low values among the seven years in calculation.

The late 1990s energy supply surplus came to an end in 2002, when fuel shortages

and blackouts became widespread. The enlarging supply-demand gap was a serious threat to China's economy. Since 2002, China's energy consumption grew at a faster rate than its GDP growth, due to high economic growth driven by the demand for energy-intensive materials to support the development of the industrial sector (Research Centre for Sustainable Development, Chinese Academy of Social Sciences, 2005). Therefore, China saw the growth of large-scale mine-mouth thermal power plants during the tenth FYP. Generation and grid were gradually separated. The long-term build-up of installed capacity resulted in China adding power plants faster than it had use of them. The AV-4 indicated the lowest ordinal value '1' again in 2010.

The shortage of power supply also forced the government to develop the renewable resources. In February 2005, the Renewable Energy Law was passed to give legal backing for China's renewable energy development. For the first time, the central government legalized renewable electricity generation and connection to the grid. The government drafted the long-term renewable energy development strategy as well. Both the *'Medium and Long-term Renewable Energy Development Plan'* released in 2007 and the *'Eleventh Five-Year Plan of Renewable Energy Development'* issued in 2008 set mandatory targets for renewable energy development in the national supply of energy. The share of renewable energies was expected to amount to 10% of the national total energy consumption by 2010 and 15% by 2020 (Chai & Zhang, 2010, p. 4000; NDRC, 2008). The Chinese government made heavy investments in renewable energy resources during the eleventh FYP period. In 2010, China's investment of USD 54.4 billion in the renewable industry made it the biggest investor in clean energy resources. Until 2010, China had the highest installed hydro capacity and the largest installed wind power capacity in the world (Betz, 2013, p. 16).⁶⁶ In addition to renewable resources, China also sped up its nuclear power construction to expand utilization. By 2005, China had a total installed nuclear capacity of 6.958 million kilowatts, which made up 1.34% of the total installed power

⁶⁶ A significant amount of wind capacity lay idle due to inadequate transmission infrastructure.

generation capacity in the country.⁶⁷ The Chinese government planned to greatly speed up its nuclear power construction in the next 15 years (from 2005), to achieve a total nuclear power capacity of 36 million kilowatts by 2020 (People's Daily Online, 2004). The AV-5 indicator hit '5' in 2010, a moderate one of the years in calculation.

4.3 Energy policies of the AP dimension

4.3.1 Energy conservation and energy intensity

China has a long history of pursuing energy conservation to support its economic development. In the late 1970s, the Chinese government had listed energy conservation as an important part of domestic energy policy as the potential for energy saving was enormous (Smil, 1981). The Chinese government incorporated energy conservation into its sixth FYP and issued numerous supporting regulations and policies to encourage energy conservation. The regulations and policies include both administrative measures as well as financial incentives. During the 1980s, systematic policy measures such as the establishment of energy conservation technology centers, low interest loans and tax credits for investment in energy conservation were adopted to improve energy efficiency (Andrews-Speed, 2009). However, deepening marketization and emergence of market forces in more sections of the economy since the 1990s had not improved energy conservation as effectively as in the 1980s.

Throughout the 1980s, the government reinforced their energy conservation measures and policies. In January 1980, the National Economic Commission held a special meeting to carry out energy conservation throughout the year. The target savings set for 1980 included 23 million tons of coal, 3 million tons of gasoline and diesel, 1.5 million tons of fuel oil, 1.5 million tons of coke, and 70 million kWh of

⁶⁷ The data is sourced from EIA website and calculated by the author. Data source is available at: <http://www.eia.gov/>

electricity. Energy production enterprises were expected to focus on saving energy consumption and reducing energy loss (People's Daily, 1980). It was explicitly stated in the sixth FYP that the total production of national primary energy was expected to grow at an average annual rate of 1.4%. While during this period, the average annual industrial production growth rate was targeted at 4%, which had to be achieved mainly by energy conservation. During the sixth FYP period, the Chinese government initiated an investment plan for the energy-saving programs. These cost-effective investments were estimated to reduce the annual energy consumption growth by 3% by 1985 (Levine, Liu, & Sinton, 1992, p. 427). Several projects were identified by the government for energy conservation, and an amount of RMB 10 billion Yuan was allocated to these projects (Levine, Liu, & Sinton, 1992, p. 428). This was the first time that the Chinese government devoted specific funds to energy conservation.

During the seventh FYP period, the central government was very active in promoting energy conservation. It planned to save energy resources equivalent to 100 million tons of standard coal (NDRC, 1985). To do so, it issued numerous new efficiency policies to limit energy consumption in industrial production. In 1986, the State Council released the *'Provisional Regulations Regarding Energy Conservation Management'* to regulate energy consumption in the industrial and residential sectors. Regulations on efficient technology development were also included in the document. This energy conservation policy expanded the scope of the government's role to promote energy conservation. It established an energy-saving management system, which required that all key enterprises that consumed energy above 10,000 tce to have a person responsible for the energy conservation work. The amount of energy savings was also a criterion for evaluating the work of an enterprise's manager (State Council, 1986a). Later in the same year, the State Council passed the specified requirements of the enterprise evaluating system in the *'State Council Decisions Regarding Problems in Strengthening Management of Industrial Enterprises'*. The evaluation was based on product quality and materials consumption, and in particular, the energy consumption of the enterprise. Thus,

energy conservation was linked to the overall performance of enterprises and became an indispensable part of successful management (State Council, 1986b).⁶⁸ In 1987, the State Council approved the '*Several Regulations Regarding Further Strengthening Electricity Savings*'. This document required departments in charge of enterprises and electricity distribution to set electricity-consumption quotas for the enterprises and to implement the award and penalty system to encourage electricity savings. Enterprises consuming electricity below the quota would be awarded while the enterprises with electricity consumed in excess of the quota would be subject to electricity price 5 to 10 times of the regular price for the part of excessive electricity consumption (State Council, 1987).

To guarantee that actual work be done for energy conservation, a variety of meetings were held to issue general guidelines for energy conservation and to monitor and promote energy-saving activities (Levine, Liu, & Sinton, 1992). In general, the energy conservation policies during the 1980s were successful in reducing energy intensity. Substantial savings were achieved. It is estimated that during the sixth and seventh FYP, about 280 million tons of coal equivalent was achieved as a result of energy conservation policies (Byrne, Shen, & Li, 1996, p. 459). As the administrative measures were very effective for energy conservation, the ordinal value of AP-1 increased from 1 in 1980 to 6 in 1990.

Facing rapid energy demand growth, the eighth FYP specified that "(the country shall) adhere to the principle of both energy development and energy conservation, but give prominence to conservation". Since the annual growth of total primary energy supply was targeted at 2.4% whereas the annual economic growth rate was targeted at 6%, energy conservation continued to be a heavy task (NDRC, 1991). The ninth FYP made energy conservation top priority and highlighted the principle of conserving and developing energy simultaneously. The ordinal value of AP-1

⁶⁸ This evaluating system was later considered as an awkward and expensive way to manage energy use and was dismantled in 1992 by State Economic and Trade Commission (Liu, Sinton, Yang, Levine, & Ting, 1994).

continued to increase from 6 in 1990 to 10 in 2000.

It is noteworthy that even though the energy intensity kept on decreasing (continuous increasing in AP-1), the central government had the tendency to overlook energy conservation. In 1996, China's total investment in energy conservation projects dropped considerably for the first time in the reform period, and remained low until 1999, when the investment was restored to the 1995 level.⁶⁹ The ratio of energy conservation investment to the energy supply investment dropped from about 7% in 1995 to about 3% in 1996. The ratio remained low throughout the entire ninth FYP period. Energy conservation investment as a percentage of the total energy investment declined in importance (Lin, 2007, p. 920). This was largely because of the changes in investment vehicles. The financing program managed by the China Energy Conservation Investment Corporation (CECIC) that offered preferential loans for energy conservation and promoted investments in energy efficiency was phased out during government restructuring in the 1990s. The deepening of the reform and the development of a socialist market economy during this period forced the gradual abolition of the state-managed process. Instead, market-oriented financing mechanisms through commercial banks emerged. Consequently, the former preferential loan interests were not available for energy-efficiency investments. As China was in transition to a more market-based economy, policies to support energy conservation investments weakened. The reforms "stipulated the wholesale scrapping of older sets of codes and regulations, including measures intended to stimulate efficiency investment" (Sinton, Levine, & Wang, 1998, p. 827).

China's transition to market economy affected technical service and training centers as well. Throughout the ministerial systems, energy-efficiency technical service and training centers were established in all major cities in China. These centers provided

⁶⁹ During the 1980s, the central government made direct investments in many energy conservation projects, including the installation of efficient equipment and the support of research and development.

aid in technical matters. However, the market reform package during the 1990s weakened China's bureaucratic energy management apparatus severely. These energy-efficiency technical service and training centers gradually lost their government funding. Therefore, the capacity of the institutions to enhance energy efficiency and the investments in energy conservation rapidly diminished (Lin, 2007). Therefore, energy conservation in the 1990s was mainly conducted via international assistance. International cooperation had to be reinforced. Announcements on energy-efficiency standards for international cooperation were made for refrigerators, ballasts for fluorescent lamps, and air conditioners. For example, the China Green Lights Program (CGLP), launched in 1996, benefited from the U.S. and other international aid. This program contributed significantly to the widespread application of energy-efficient lighting technologies in China. Another internationally-funded program was the CFC-Free Energy-Efficient Refrigerator Project, which aimed to improve the energy-efficiency of the Chinese refrigerators (Sinton, Levine, Fridley, Yang, & Lin, 1999, p. 6). However, the energy-efficiency gains were largely offset by the rapid growth in the energy-intensive sectors during the tenth FYP period, a result of industrial policies at that time. The policies paid little attention to structural adjustments across industrial sectors and there had been a structural shift towards energy-intensive sectors. The rapid development in the energy-intensive industrial sectors became the most important driver behind China's energy-intensity increase (Andrews-Speed, 2009; Zhao, Ma, & Hong, 2010). Ordinal value of AP-1 decreased in 2005, after its steady increase from 1980 to 2000.

Power shortages during the early new century left the central and local governments anxious to bring energy conservation to the policy agenda again. During Hu administration, reducing energy intensity was a top priority in the government's policy agenda. In 2004, the NDRC drafted '*China's Medium and Long Term Energy Conservation Plan*'. It set the target of quadrupling China's GDP at the national level in order to reduce energy intensity in various sectors by 2020, and also identified a number of projects to achieve significant energy savings (Cheng, 2008; Yang, 2008).

The Plan indicated the central government's desire to integrate energy conservation into long-term economic development. The medium and long-term energy conservation projects outlined in the Plan covered the industry, construction, transport, residential, commercial, and other sectors in the economy.

In May 2005, the NDRC initiated 10 major energy conservation projects to implement the 2004 *'China's Medium and Long Term Energy Conservation Plan'*. Energy conservation in the construction industry was bolstered. All buildings constructed after 2006 were required to embrace the new technology to reduce 50% of their energy consumption during the 11th FYP (2006-2010) compared to the 2005 level (Wang, 2005). High fuel efficiency standards were imposed on automakers, which were compelled to produce cars that consume less fuel (Kong, 2005). China's steel industry, as an energy-intensive industry, received much attention for its success in energy saving. In July 2005, the NDRC released the *'Steel Industry Development Policy'*, which specified that the comprehensive energy consumption per ton of steel should be reduced to 0.73 ton of standard coal and below by 2010, and to 0.7 ton and below by 2020 (Cheng, 2008, p. 309). In addition to the administrative measures, the market mechanisms were also adopted. The electricity prices increased twice in 2004 and 2005 respectively. In June 2004, the average price of electricity increased by RMB 0.022 yuan per kilowatt/hour in the south, east, central, and north of China. To contain the careless expansion of energy-intensive industries, differentiating electricity pricing was adopted for some energy-intensive sectors. Extra charges were imposed on enterprises that failed to meet the energy conservation requirements. In May 2005, electricity prices rose again by another RMB 0.022 yuan per kilowatt/hour (Kong, 2005, p. 32).

These policies began to show their effectiveness at the end of the eleventh FYP, when the energy intensity decreased again after a rapid rise of energy consumption in China during the tenth FYP period. During the eleventh FYP, the government identified the rise in domestic energy consumption as a great obstacle to the goal of

development. On the one hand, it began to improve the energy-efficiency of the sectors that would yield the greatest short-term benefits. On the other hand, it began applying the most effective policy instruments. Policy apparatus was created to design and implement energy efficiency policies throughout the country. In August 2006, the State Council issued the '*Decision of the State Council on Strengthening Energy Conservation Work*', which stated that China must put energy conservation at a more prominent strategic position (State Council, 2006b). The government set a specific target to reduce the energy intensity by 20% (compared to late 2005) by the end of 2010. This was the first time China listed energy conservation as a national development goal. The numerical energy industry targets for the efficiency of major industrial products and equipment were specified. For example, in order to discourage exports that relied heavily on energy and resources, China started levying export taxes on energy-intensive products. From July 2007, China eliminated export tax rebates on many low value-added but high energy-consuming exported items. In April 2006, the NDRC focused on key energy-consuming enterprises, and launched the '*Top 1,000 Enterprises Energy Conservation Action Implementation Plan*', to save about 100 million tons of standard coal equivalent in the industrial sectors by 2010. The 1,000 enterprises accounted for the major energy consuming sectors, and their combined energy consumption was about 670 million tons of standard coal in 2004, accounting for 33% of total energy consumption and 47% of industrial energy consumption in the year (Zhang Z. , 2010, p. 548).⁷⁰

The top 1,000 enterprises took the lead in improving energy efficiency. All the participating enterprises signed energy conservation contracts with provincial governments. These enterprises enjoyed several funding opportunities subject to the amount of energy they saved (Price, Wang, & Jiang, 2010). To further cut energy consumption, the State Council issued the '*The Limit of Project Approves*' and authorized the NEPA to implement this policy. Under this policy, the NEPA re-audited the energy-intensive projects/plants. If a plant's energy consumption and emissions

⁷⁰ The data are cited directly from the *Top 1,000 Enterprises Energy Conservation Action Implementation Plan*.

exceeded than the limits, the plant must be shut down. In January 2007, 82 large, energy-inefficient, and high-polluting projects/plants in energy-intensive industries were forced to stop operations (Yang, 2008, p. 565). These policies proved very effective for China to cut down the energy intensity. The ordinal value of AP-1 increased from 9 in 2005 to 10 in 2010.

To summarize, with strong policy support and attractive financial incentives, energy intensity decreased rapidly between 1980 and 2000. However, after the taxation reform in 1994, China saw the weakening of most financial incentives, and the slowdown in the decrease of energy intensity from 1995. As a result of rapid expansion of the energy-intensive heavy industries and rapid rise of energy consumption, energy intensity began to increase since 2000. When energy conservation and energy efficiency were at the core of China's energy policies during the eleventh FYP, energy intensity decreased again, with the lowest level in 2010 among the years in calculation.

4.3.2 Advancement of energy technologies during the reform period

In general, economic reform led to the improvement in energy technology and energy efficiency. The introduction of imported machinery in the mid-1980s opened the door for industrial technology advancement to take off. A variety of financial incentives also fostered the development of energy technologies. Government-sponsored programs created better technologies. Most importantly, macroeconomic reform created a microeconomic environment where the enterprises require the adoption of advanced energy and equipment.

The SOEs reform during the 1990s made fast technology advancement possible. The SOEs, as the major force of technology R&D, stimulated the development of energy technology. This could be seen in the contrast of the technology advancement in the power sector in the 1980s and 1990s. In the 1980s, the less-efficient small thermal

power plants constrained the technology advancement of electricity generation. In the 1990s when SOEs reform was in full swing, thermal electricity generation technology gradually improved. Projects conforming to the larger size requirement and higher technological standards (such as long-distance power transmission technology) were developed by the central government (Zhang & Heller, 2004). During the eleventh FYP period, the government closed down inefficient small generators and replaced them with larger units. The generation units smaller than 300 MW accounted for about 53% of China's thermal power generation in 2005, but less than 31% in 2009. Units larger than 600 MW accounted for 13% of the thermal power generation in 2005, while it increased to 34% in 2009 (Climate Policy Initiative, 2010, p. 2). Technological advancement and the closure of inefficient older facilities helped the larger power plants to improve their generation efficiency significantly. The AP-2 ordinal value increased steadily and consistently during 30 years of economic reform. China's oil refining capacity also improved. The reform in state oil companies in the late 1990s made these companies more business-oriented. Profit incentive of the business-oriented oil companies as well as projected dramatic increase in petroleum demand resulted in a flurry of refinery construction activities (Wang, 1999). Sufficient distillation capacity was available. The ordinal value of AP-3 increased from 3 in 1995 to 6 in 2000 and 10 in 2010.

Since 2000, China's coal mining technologies greatly improved. The '*Coal Industry Policy*' issued by the NDRC in 2007 implemented several major geological surveying and coal mining technologies to improve the output and efficiency of the coalmines (NDRC, 2007c). The '*National Plan for Medium- to Long-Term Scientific and Technological Development (2006-2020)*' ranked efficient coal mining technological development as a key objective (State Council, 2006a). Besides, China made strides in researching for new technologies that can substitute for conventional oil. Coal liquefaction technology drew much attention in the early new century due to China's growing dependence on foreign oil. In August 2004, Shenhua Group, one of China's largest state-owned coal producers, started to build China's first coal liquefaction

project in Inner Mongolia. This project began its operation in late 2008, with the capacity to produce one million metric tons of oil products a year (Wang, 2009). The AP-4 ordinal value increased very fast since 2000, from 3 to 10 in both 2005 and 2010.

4.4 Energy policies of the AC dimension

All energy consumption can affect the environment, thus every decision on energy consumption and economic growth would carry environmental implications. Efficient use of energy can lower energy consumption and improve the environment and vice versa. Policies that affect the environment regarding energy use are discussed in the following section.

4.4.1 Air pollution control during the reform period

In the 1980s, environmental protection was incorporated as an integral part of economic and social planning. A series of legislations and regulations were adopted to protect the environment. However, economic development topped the government agenda at that time. Effects of these legislations and regulations were very limited (Freeman & Holslag, 2009). For example, in 1982, the State Council issued the *'Tentative Provisions on Pollution Charge'*, which stipulated that a pollutant discharge fee of RMB 0.04 Yuan for every 10 m³ of SO₂ emitted in excess of standards would be charged.⁷¹ This policy encouraged enterprises to build pollution control facilities, but with the continuous increase of the prices of raw materials, the operation costs of the enterprises gradually exceeded the pollution charges. Consequently, most enterprises would rather pay for the discharge fees than to reduce emissions (Yun, 1998).

⁷¹ China adopted its Environmental Protection Law in 1979. Article 18 of the Law specifies that "in cases where the discharge of pollutants exceeds national standard (limit), a sewage charge shall be levied in accordance with the quantities and concentration of the pollutants released". This article provided the legal basis for the implementation of subsequent regulations. The Law was revised and the new Environmental Protection Law was promulgated in 1989.

Along with the economic reform in the 1980s was the fast growth of small enterprises, especially the TVEs, which facilitated China's economic development. However, it resulted in environmental pollution because of the TVEs' ignorance of emissions control. In the power sector, for example, various investment sources, easy government approval and low-cost financing led to the proliferation of less-efficient small thermal power plants.⁷² By 1987, 86% of the nation's total generating capacity was made up of plants smaller than 100MW (Blackman & Wu, 1999, p. 698). The small inefficient thermal power plants discharged more energy wastes and caused more serious environmental pollution than the large ones (Ma & He, 2008). Both the AC-1 and AC-2 ordinal values deteriorated in the 1980s. To address this problem, the State Council issued the '*Decision of the State Council on further Strengthening the Work of Environmental Protection*' in 1990, which required the local authorities to strictly implement the '*Environmental Protection Law*'⁷³ and to strengthen the management of polluting and energy-wasting enterprises, especially the small enterprises and TVEs (People's Daily, 1990).

When China was successful in re-invigorating its economy in the early 1990s, it faced a limited supply of high-quality energy resources such as petroleum, natural gas, and electricity. During the mid-1990s, China's domestic oil production could not meet demand. Hydropower development was slow. Nuclear power development was in its infancy.⁷⁴ Sustained rapid economic growth would continue to depend on coal, which in turn would worsen environmental problems. Air pollution from the combustion of coal became more severe. CO₂ emissions, SO₂ emissions and soot emissions increased steadily except for soot emissions which hit the lowest ordinal value in 1995, followed by a rebound in 2000. Correspondingly, the ordinal values of the indicators AC-1, AC-2, and AC-3 decreased steadily and consistently from 1980 to

⁷² Projects of 50 MW capacity or smaller needed the approval of the provincial governments, not the State Development Planning Commission.

⁷³ The 1989 Environmental Protection Law not only authorized the National Environmental Protection Agency to set standards for environmental quality, but also allowed the local authorities to have their local standards for the things not covered by the national standards (MacBean, 2007).

⁷⁴ For more details on this, see the NDRC document '*Abstract of the Ninth Five-Year Plan of PRC National Economic and Social Development and Goals for 2010: 400 Questions to Answer*'. Available at NDRC website: <http://www.sdpc.gov.cn/fzgh/ghwb/gjjh/W020050614801667778911.pdf>

1995. Therefore, environmental protection became a priority on China's political and policy agenda.

After the United Nations Conference on Environment and Development in 1992, '*China's Agenda 21*' was developed. This document emphasized the application of renewable energy, clean coal technology and nuclear power to promote environmental protection. In March 1994, the '*Sustainable Energy Programs under Agenda 21*' was approved by the State Council. In September 1995, the Fifth Plenary Session of the Fourteenth Party Congress adopted the '*CCP Central Committee Suggestions on Formulating the Ninth Five-Year Plan for National Economic and Social Development and the Long-Term Objectives for the Year 2010*'. The objective was to realize sustainable economic and social development, which required the economic growth pattern be transformed from extensive to intensive and that improving the economic efficiency be the guiding principle. The government highlighted that sustainable development must be taken as a major strategy. For sustainable development, economic growth should be coordinated with environmental protection. Since then, the government accelerated the construction of a comprehensive regulatory and institutional framework for environmental protection, and strengthened the position of the national environmental agency. In 1998, the State Environmental Protection Administration (SEPA) was created to support government restructuring. On 1 September 2000, the Air Pollution Prevention Law took effect.

Specific policies dealing with environmental pollution in the energy sector during the 1990s mainly focused on the control of emissions caused by the coal consumption and production in China's energy structure. Penalties and fines were meted out to the violating enterprises. In the 1980s, as discussed earlier, China attempted to impose fines on enterprises that discharged SO₂ and other pollutants exceeding national standards. But the effects were modest because the polluting enterprises found it cheaper to pay pollutant discharge fees than to install pollution control

equipment with clean coal technology. To counter this, the National Environmental Protection Agency (NEPA) increased the fee on a trial basis in 1992: the enterprises discharging SO₂ in excess of national standards had to pay RMB 0.2 RMB yuan per kg SO₂ (Ohshita & Ortolano, 2006, p. 81). A further significant progress was made in 1998 when the State Council approved the NEPA's proposal regarding the 'Two Control Zones' to control SO₂ emissions and acid rain. This authorized the collection of emission fines beyond the 1992 trial regions (State Council, 1998). In 2000, the SEPA issued the *'Notice Concerning Implementation of the Expanded Pilot SO₂ Discharge Fee Collection'* to emphasize the role of the local government to collect the SO₂ emission fines (SEPA, 2000).

Besides imposing fees, the government decommissioned obsolete plants, closed down small thermal power generating units, and monitored thermal power plants' compliance with the regulation to install desulphurization equipment. In 1997, the State Council and the State Economic and Trade Commission (SETC) required the power enterprises to close down small inefficient generating units with generating capacity below 50MW. In September 1999, the Fourth Plenary Session of the Fifteenth Party Congress made arrangements to advance the 'strategic reorganization' of the SOEs. To facilitate the reorganization of SOEs, the government resolutely shut down the 'five types of small-scale industrial enterprises' (wuxiao qiye), including hundreds of small fossil fuel-fired power plants, small coalmines, oil refineries, cement, and glass plants that were polluting the environment and depleting the natural resources. Between 1996 and 2000, around 800 small power plants were shut down. The closure of these plants contributed to reduction of 400,000 tons of SO₂ emissions. In the 1990s, the State Council also required thermal power plants to install desulphurization equipment for their electricity generating units. The equipment must be designed, built, and put into operation together with the operating of the power-generating units. By the end of 2000, electricity-generating units amounting to 5000MW of capacity had installed desulphurization equipment (Chang & Wang, 2010, p. 3360). The TVCM closure campaign in 1998, which was

discussed in 4.2.1, had also a secondary aim of upgrading the environmental conservation role of the small coal mining sector.⁷⁵ All these measures contributed to the slow-down of the increase of SO₂ emissions from 1995 to 2000.

A noteworthy characteristic of the policies formulated in the 1990s was that there was a shift of focus from ‘management by governments’ to ‘elimination and control of pollutants’. For example, in the 1980s, policies were focused on controlling the discharges by enterprises; in the 1990s, the government focused on the control of the production process itself. In the 1980s, the government paid more attention to control of pollutants emitted by a single enterprise; in the 1990s, the government focused on the centralized control of the total discharge volume⁷⁶ rather than an individual enterprise’s polluting activity (Matsuno, 2009).

Despite government effort in the 1990s, these policies were still ‘declarative and unrealistic’, and environmental protection did not appear to be a key issue in the energy sector. The environmental regulations were not coordinated, and different levels of the administration held conflicting interests. The actual implementation did not improve dramatically, because the demand for economic growth exceeded the requirement for environmental protection. This compromised the work of the implementation bureaus at the local level and resulted in widespread

⁷⁵ It is noteworthy that there was no coherent planning in environmental protection. For example, in Shanxi province, hasty closure was carried out by dynamiting the adit (entrance to an underground mine) or shaft, blocking it up with cement, or destroying buildings. The authorities were not concerned about the possible subsidence above the underground mines or the pollution of surface or underground waters (Andrews-Speed, 2004). All of these constitute a threat to the environment. Until now, there has been no policy framework that encompasses the full range of economic, social, and environmental aspects of the TVCMs. The Chinese government still does not take a comprehensive or holistic view of the small coal mining sector. The lack of a comprehensive TVCM policy is accounted by the motivation behind China’s policy-making. For a long time, the economic criteria served as the key incentive for policymaking in China. In the coal sector, for example, an adequate supply of coal to fuel the economy encouraged the growth of the TVCMs. The TVCMs were known for their poor safety records and negative impact on the environment. During the economic slowdown in the late 1990s, when the large state-owned coalmines were undermined by the fast-growing TVCMs, the central government made up its mind to protect the large state-owned coalmines at all costs. It was not because of the poor safety records or environmental pollution that the government decided to close down the TVCMs, but the desire to rescue its own state mines. Clearly, the government had no intention of taking into account the long-term environmental impact when formulating policies.

⁷⁶ The national FYP started to set national emission control targets from the ninth FYP, which selected 12 key pollutants and set the upper limit of total emission quantity for each of them, also known as ‘Total Load Control’ (*Zongliang Kongzhi*), which was first introduced in 1994 and legalized in the revised Air Pollution Prevention and Control Law in 2000 (Chang & Wang, 2010).

non-compliance with the environmental requirements (Economy, 2004; OECD, 2006). A lack of coordination among relevant institutions also accounted for the insufficient implementation of these policies.

Another problem was found in the management of environmental protection at the local level. As the administrative rank of the environmental protection institution was sometimes lower than that of the enterprises under its supervision (Ma & Ortolano, 2000), it had to frequently show 'respect' and defer to the enterprises. This largely resulted from the triangular relations among the local government, the local environmental protection institutions, and the enterprises. The local environmental protection institutions partly depended on the local government for the annual budget and other sources of financing, which were largely collected from the enterprises' taxes. This limited the local institution's authority to impose regulations on the enterprises. Ordinal values of both AC-1 and AC-2 continued to decrease in the 1990s.

The implementation and management of environmental protection continued to prove ineffective in the 21st century and this led to the central government's plan to reinforce its pollution control measures. The tenth FYP planned to reduce the SO₂ emissions in the 'two control areas' by 20%, and to reduce emissions of major pollutants by 10% (compared to 2000 figures) in 2005. To provide technical guidance and support to control the SO₂ pollution (caused by burning coal) and encourage the use of washed coal, the State Environmental Protection Administration, the State Economic and Trade Commission, and the Ministry of Science and Technology jointly announced the '*Technology Policy on Coal-fired Sulfur Dioxide Emissions Control*' in March 2002 (People's Daily, 2002).

However, the SO₂ emissions increased from 19,951,000 tons in 2000 to 25,494,000 tons in 2005, and the soot emissions increased from 11,654,000 tons in 2000 to 11,825,000 tons in 2005. The failure of SO₂ control could be attributed to the several

reasons. First, the policies did not indicate implementation requirements in detail. Although the policies encouraged the use of washed coal, they did not stop the related agencies from receiving equipment designed for low-quality coal from the manufacturers of boilers. Besides, the users of washed coal faced increased costs without any obvious gains of efficiency (IEA, 2009). By 2005, only about 21% of coal produced by China's large scale coal enterprises had been washed (Kong, 2005, p. 47). Second, the Chinese economic development model, which had been planned to be transformed from extensive to intensive production, reversed to be more extensive, which was accompanied by high energy consumption and high emissions of pollutants (Hu & Wang, 2006, p. 11). Third, both economic growth and energy demand exceeded expectations during the tenth FYP period. Since late 2002, the accelerated growth of heavy and chemical industries (such as iron, steel, and building materials) led to a significant increase in the national coal consumption. The SO₂ emissions from the coal-fired power plants worsened the regional acid rain pollution (Hu, Wang, & Yan, 2006, p. 54). Fourth, the pollution treatment projects progressed very slowly. By 2003, half of the key projects were delayed. Fifth, due to the tight electricity supply, the plan to shut down coal-fired electric generating sets below 50,000-kilowatt by the end of 2003 failed. Many generating sets that had already been shut down had to be reopened (People's Daily, 2004).

During the eleventh FYP period, the obligatory targets of environmental protection were listed and the momentum increased rapidly. The eleventh FYP for '*Preventing and Controlling Acid Rain and SO₂ Emissions*' set the target of reducing SO₂ emissions in 2010 by 10% from the 2005 level. In the coal sector, the '*Several Opinions of the State Council on Promoting the Sound Development of Coal Industry*'⁷⁷, a document issued in 2005, stated that the government would continue to shut down the small coalmines that violated safety requirements, wasted resources, and damaged the environment (People's Daily, 2005b). In the power sector, the SEPA signed obligation agreements in 2006 with six domestic large power producers to enforce SO₂ emission

⁷⁷ For the details, see http://www.gov.cn/zwggk/2005-09/08/content_30251.htm

reduction in the eleventh FYP period. Specific reduction targets and emission reduction methods were clearly stated in these agreements. In addition to the requirements on the large power plants, the local governments also had to shut down small-scale thermal power units with high energy-consumption and poor pollution control.

To do so, the State Council issued the '*Notice on Some Joint Opinions of NDRC and the Office of the National Energy Leading Group on Accelerating the Closure of Small Thermal Power Generation Units*' in January 2007.⁷⁸ The Notice specified that the shut-down power plants would receive compensation (equivalent to their profits of three years of power generation). The closure went smoothly and significant progress was made towards this aim (IEA, 2009; Policy Information, 2008). Between 2006 and 2008, inefficient thermal power plants, which accounted for a total capacity of 34.21 GW, were shut down (Chang & Wang, 2010, p. 3356). In 2007, all the inefficient small thermal power plants with the capacity of 14.38 GW were shut down even though the initial closure year plan was 10 GW. The closure helped to reduce raw coal consumption by 18.8 million tons, SO₂ emissions by 290 thousand tons, and CO₂ emissions by 37,600 thousand tons (Policy Information, 2008, p. 4).

Besides the specific obligatory targets set by the government, rising investments helped to improve environmental quality. Between 2006 and 2008, the government allocated more than RMB 90 billion for environmental improvement projects (Chai & Zhang, 2010, p. 4000). In 2010, the government announced at the National People's Congress (NPC) that ambitious environmental protection initiatives were planned. A funding of U.S. dollars 20.7 billion would be spent on engineering solutions for environmental problems (Xin & Stone, 2010, p. 1440). During the eleventh FYP period, China also improved its clean coal technologies including coal gasification, flue gas desulfurization, and coal liquefaction. The total installed capacity of flue gas desulfurization technology increased from 53 GW in 2005 to 270 GW in 2007,

⁷⁸ For the details, see the NDRC website: http://www.ndrc.gov.cn/zcfb/zcfbqt/2007qita/t20070131_115037.htm

accounting for over 50% of total installed thermal power capacity (Zhou, 2010, p. 3759).⁷⁹ By the end of the eleventh FYP, both SO₂ emissions and soot emissions were reduced. The SO₂ emissions decreased from 25,494,000 tons in 2005 to 21,851,000 tons in 2010, and soot emissions decreased from 11,825,000 tons in 2005 to 8,291,000 tons in 2010.

4.4.2 Policies on renewable energies and nuclear power

Renewable energies

With abundant reserves of renewable energy, the Chinese government implemented policies to encourage the development of renewable energy resources beginning in the 1980s. These policies include financial subsidies, favorable taxation, favorable pricing, and supportive industrial and technical policies, reflecting the government's realization of the need to mitigate the environmental damage caused by using fossil fuels.

During the sixth FYP, biogas, small hydro generation, and other renewable energies were encouraged in the rural energy sector. For the purpose of energy structure optimization, the seventh FYP continued to promote the development and utilization of solar, wind, geothermal, and other renewable energy resources (NDRC, 1986). In the 1990s, the government's interests in diversifying energy resources and protecting the environment stimulated the development of renewable energy resources. Several energy-related regulations and laws have articles about harnessing renewable energy resources. In 1995, *'China's new energy and renewable energy*

⁷⁹ Despite the increasing capacity of clean coal technologies, China hardly used them. The policies encouraging clean coal technologies were only 'directive', not 'mandatory', and they were not always consistent because they frequently came from different government departments. Another problem was that both R&D funding and qualified personnel were inadequate. For example, insufficient R&D of ultra-supercritical (USC) units made its core technologies unattainable for the manufacture of power generation equipment. The R&D of circulating fluidized bed combustion technology was also inadequate (IEA, 2009). Similar problems also existed in the application of another critical clean coal technology---carbon capture and storage (CCS) technology. The insufficient R&D funding, absence of a national strategy for the CCS utilization, and the lack of research and experience impeded the CCS implementation in China (Duan, 2010). Consequently, China did not apply the key clean coal technologies effectively on a large scale.

development outline (1996-2010)' was issued to promote a specific target for renewable energy development.⁸⁰ In 1996, the '*Ninth Five-Year Plan for National Economic and Social Development and the Long-Term Objectives for the Year 2010*' was issued. This document pointed out that China should actively develop new energy to improve the energy structure. In addition to the general policy programs, some specific initiatives, laws, and economic incentives were also proposed to promote renewable energy development. '*The 1996 Electric Power Law of the People's Republic of China*', stated clearly in the general provisions that "[t]he State encourages and supports electricity generation through the use of renewable and clean energy resources" (Article 5). '*The Law of the People's Republic of China on Conserving Energy 1998*' reaffirmed the strategic role of renewable energy resources in GHG reduction and environmental improvement: "[t]he State encourages the development and utilization of new and renewable resources of energy" (Article 4).⁸¹ Wind power⁸² was the key to successful renewable energy development. Imported wind turbines were exempted from customs duty from 1990 to 1995.⁸³ Besides, the former Ministry of Electric Power (MOEP) issued the 1994 '*Regulation on Management of Grid-connected Wind Farms*'. The grid administrative authority was required to allow wind farms to connect to the grid and to share the price difference between wind power price and the average price in the grid. In 1996, the former SDPC initiated the '*Ride the Wind Program*', which aimed at establishing a high quality wind turbine generator sector in China. This initiative successfully introduced the wind turbine generator technology into China (Xia & Song, 2009). Preferential loans of RMB 900 million Yuan were to be invested in wind turbine installation with a total capacity of 81.6 MW. At the same time, subsidies were provided for the diffusion of wind power technology (Liu, Gan, & Zhang, 2002, p. 758). Another

⁸⁰ For the details, see China's new energy and renewable energy development outline: <http://www.ccchina.gov.cn/cn/NewsInfo.asp?NewsId=3820>

⁸¹ The Law of the People's Republic of China on Conserving Energy was revised in 2007. The revised version took effect on 1 April 2008.

⁸² The development of grid-connected wind power began in the late 1980s. In 1986, two pilot wind farms were built, one in Rongcheng County in Shandong Province and the other in Pingtan County in Fujian Province. Wind farms have been constructed throughout China after the two pilot projects and this led to the rapid increase in the installed capacity of wind in the 1990s (Liu, Gan, & Zhang, 2002).

⁸³ To develop domestic wind turbine industry, the tariff ratios were adjusted in 1996 and the actual duty level was increased.

program, the *'Brightness Project Implementation Planning'*, was established in 1998 to provide electricity in remote northwest areas via several wind and solar power systems (NREL, 2004a). In 1999, the State Planning Commission and the Ministry of Science and Technology jointly issued the *'Notice on Issues of Further Support for Renewable Energy Development'*. It stipulated that preferential loans would be provided to finance renewable energy projects to promote electricity generation.

At the beginning of the new century, the document *'Outline of Action for Sustainable Development at the Beginning of the 21st Century'* expressed the government resolution to develop renewable and clean energy. The government aimed to reduce the proportion of coal in the primary energy consumption and develop energy-saving stoves and exploit biogas, solar, and wind energy in suitable rural areas to improve the rural energy structure (People's Daily, 2003b). In 2001, the State Development and Planning Commission launched the *'Sending Electricity to Townships'* (*'Song Dian Dao Xiang'*) program to develop renewable energy supply for more than 1,000 townships. The program, completed in June 2003, installed 200 MW from small hydropower and 840 kW from wind power (NREL, 2004b). Using *'Song Dian Dao Xiang'* as opportunity, China rapidly developed solar photovoltaic and small wind power and hydropower, and promoted decentralized renewable energy technological development in the rural areas. Under the background of improving county environment, China vigorously developed rural biogas, which was enlisted as a national debt project since 2003. The central government invested more than RMB 2.5 billion Yuan per year to develop rural biogas (China Renewable Energy Society, 2009, p. 13). The government subsidies on technological dissemination helped China succeed in developing the rural household biogas. The biogas industry and market were formed. By 2006, 70 million rural residents benefited from the biogas development (Gan & Yu, 2008, p. 533).

But these policies could not stop renewable energy in total electricity generation from declining from 23.4% in 1985 to 16.8% in 2005. Several factors hindered China's renewable energy development. First, the regulatory framework for the renewable

energy sector failed to provide clear guidelines on the scope of duties for the renewable energy policymaking. The duties were spread over a variety of institutions including the NDRC, SETC, Ministry of Water Conservation, Ministry of Science and Technology, Ministry of Finance, Ministry of Agriculture, former Ministry of Power, and former Ministry of Forestry, and so on (Cherni & Kentish, 2007; Zhang, Yang, Shi, Zheng, Wang, & Li, 2009). All of them had sections dealing with renewable energy. Each institution made its policies independently without consulting or coordinating with its counterparts. The lack of consistency and coordination made it difficult to develop renewable energy effectively in the long run.

Second, subsidies for renewable energy were insufficient and blocked from reaching the lower levels. China's technical R&D investments in renewable energy were inadequate too. The technique-intensive renewable energy development required a large amount of R&D funding but in China, only a very small proportion of total investment in renewable energy was directed to technical R&D. For a long time, the reform of large and medium SOEs was delayed. Domestic enterprises, which should have been the main investment body, had invested too little in renewable energy development. The investment mainly depended upon government funding, foreign loan and donation, and foreign direct investment. China's investment in the renewable energy R&D amounted to only 0.045% of its total GDP in 2005, which was much lower than that of industrialized countries (Zhang, Yang, Shi, Zheng, Wang, & Li, 2009, p. 446).

Third, the government intentionally kept electricity prices low to support economic growth. The delay in the liberalization of electricity pricing also hindered renewable energy development. The prices of electricity generated by renewable energy were much higher than those of coal-fired electricity. For example, the wind power price was considerably higher than the conventional power price, making it less competitive than conventional power. As the pricing regulation ensured high wind power tariff for developers to generate wind power, they sought the approval of high

prices and did not pay attention to cost reduction. Besides, the pricing regulation did not help the local utilities to share the price difference nor purchase power from this clean but costly source. In short, the pricing regulation provided little economic incentives for either wind power developers or grid companies, thus impeding the development of wind energy.

Fourth, the nature of these policies was administrative rather than market-based. The administrative measures sometimes hindered renewable energy development in China. For example, the customs duty exemption on wind turbine did not create a fair competition environment for domestic wind turbine manufacturing. When the preferential loan program ended, the investment in wind farm construction rapidly shrank and stalled the increase of wind power capacity (Liu, Gan, & Zhang, 2002).

Fifth, the power sector reforms did not make the policy framework conducive for the rapid development of renewable energy. China's power sector has been disaggregated both vertically and horizontally, evolving into a 'dual electricity system' with dominant state planning at the core, and decentralized generation and transmission companies at the periphery (Cherni & Kentish, 2007). The government's cautious approach to the liberalization of the renewable energy industry was met with uncertainty on the part of investors.

The year 2005 was a turning point in renewable energy development. The NDRC decided to implement projects on renewable energy and new energy high-tech industrialization between 2005 and 2007 to accelerate the process of the industrialization of renewable energy (People's Daily, 2005a). The then-Vice Chairman of NDRC, Chen Deming, announced the government plan to accelerate renewable energy exploitation. China was thus positioned to develop renewable energy resources on an unprecedented scale (Martinot & Li, 2007). The government began to take substantial effort to create a legal environment for renewable energy development. The 2005 Law of Renewable Energy highlighted the strategic position

of renewable energy in the exploitation and use of energy resources.⁸⁴ It provided a coherent framework and legal basis for increasing the renewable energy share in China's electricity system. It was "a very positive development for the renewable energy industry in China" (Cherni & Kentish, 2007, p. 3627). The State Council department in charge of energy was expected to draw up medium- and long-term goals for the national total renewable energy development and utilization. For the first time, a renewable energy target was written into the Law.

Immediately after the Law was passed in 2005, China began to enact several more relevant supporting laws and regulations to develop renewable energy. According to the Law, the NDRC announced the '*Plan on medium- and long-term development of renewable energy resources*' in 2007.⁸⁵ The Plan, as a comprehensive complement to the Renewable Energy Law, quantified the specific development goals of renewable energy resources and stipulated the setting up of a fund to support the renewable energy R&D. It was projected that by 2020, China would have 300 million kilowatts installed capacity of hydropower, 30 million kilowatts installed capacity of biomass power, 30 million kilowatts installed capacity of wind power, and 1.8 million kilowatts installed capacity of solar power (NDRC, 2007b). According to China's Renewable Energy Law and subsequent guidelines introduced in 2005, all major power companies in China were expected to create 3% of their energy from renewable resources other than hydropower by 2010 and 8% by 2020 (Cyranoski, 2009, p. 372). All these goal specifications guided the development of renewable energy resources in China.

Other laws and regulations were issued to manage the pricing and special capital in renewable energy electricity generation. In 2006, the Ministry of Finance released a fund for renewable energy development. It comprised grants and interest subsidies in power generation, oil alternatives, and construction (Yang J., 2006). These policies

⁸⁴ Renewable Energy Law took effect in 2006.

⁸⁵ The NDRC completed the preliminary draft of the Plan in 2005 (People's Daily, 2005d).

helped to increase the share of renewable energy out of total electricity generation from 16.8% in 2005 to 19.3% in 2010.

Nuclear power

Despite the early development of indigenous nuclear technology, China did not build nuclear power plants until the 1980s. In September 1987, Premier Zhao Ziyang, met with the Director-General of the International Atomic Energy Agency, and expressed that China was optimistic about the development of nuclear technology in agriculture and industry (People's Daily, 1987). The first Chinese nuclear power plant, Qinshan Nuclear Power Plant in Zhejiang Province, began commercial production in 1993. China's first large commercial nuclear power plant was in utilization in February 1994, when the Daya Bay Nuclear Power Station Unit 1 started commercial operation (People's Daily, 1994). Since the utilization of the first large commercial nuclear power plant, the nuclear power growth in China had been slow. In 1999, the first phase of Qinshan Nuclear Power Plant was shut down for about one year for maintenance and repair (Chen & Chen, 2007, p. 2047). As a result, the nuclear share fell from 1.29% in 1995 to 1.24% in 2000.

Due to electricity shortages, nuclear energy was developed faster in the early 21st century than before. The second phase of the Qinshan Nuclear Power Plant and the first phase of Ling'ao Nuclear Power Plant were put into operation in 2002; the third phase of Qinshan was running in 2003; and Tianwan Nuclear Power Plant started operating in 2004 (Chen & Chen, 2007, p. 2047). The operation of new nuclear power plants during the tenth FYP raised the AC-5 up to 2.12% in 2005, the highest among the years in calculation. One favorable factor was perhaps the willingness of the Chinese public to embrace the role of nuclear power in the country's economic development (Zhou, 2010).⁸⁶ In 2006, the NDRC's '*Medium- and Long-Term Nuclear Power Development Plan (2005–2020)*' was approved by the State Council. The Plan

⁸⁶ Public opposition had been a major impediment to nuclear development in the West. However, the Chinese people were often informed of the nuclear-related decisions only after they were made, a result of China's centralized government system and government-driven economy (Zhou, 2010).

proposed to increase China's nuclear capacity to about 40 GWe by 2020 to raise the share of nuclear to 4% of the country's total electricity generation (Zhou, 2010, p. 3755). With nuclear expansion, China continued to grapple with the social, technological, and financial challenges to address waste disposal and other safety concerns. The nuclear industry had "never before been incorporated into national economic planning" (Zhou, 2010, p. 3761). Compared to other energy resources, nuclear energy still contributed a relatively small share in the eleventh FYP period. In 2010, the share of nuclear power in total electricity generation fell to 1.77%.

4.5 Energy policies of the AF dimension

Energy pricing had been a long-term problem for the Chinese government as its deregulation process did not run smoothly. Commodity prices were under strict central government control before the 1978 economic reform. During the reform period, state-controlled prices were gradually replaced by market-mediated prices. However, the price reform in energy sectors was sluggish in the 1980s. In the early 1990s, the energy price reform was accelerated. In 1998, the Chinese government took a wide-ranging reform package to limit government intervention in the commercial management of SOEs. This helped to relax the control of pricing across energy sectors. Under China's energy pricing reform, each energy resource received a different treatment and this resulted in substantial differences for every energy resource, hence the separate discussion on reforms in following subsections.

4.5.1 Policies on coal price

In the coal sector, the market mechanism was introduced in the domestic coal market incrementally since 1979, followed by slow progress in the 1980s. In the mid-1980s, the central government made it clear that energy prices were to increase within approved limits, and that a rational energy pricing system would be formed gradually (NDRC, 1985). In 1985, a dual-tier pricing system for energy resources took

effect. Under this system, coal was distributed at relatively low state-controlled prices, but firms and individuals could purchase more at negotiated prices in the free market (Perlack & Russell, 1991). By the end of 1989, the government decided to solve the problems arising from the two-tier pricing system and the *jiage chuanguan*.⁸⁷ It aimed to first change the coal pricing from 'dual track' to 'single-track', and then gradually abolish the two-tier system (CCP Central Committee, 1989). This helped to progressively liberalize coal pricing and gradually establish the market mechanism in the domestic coal market.

After Deng Xiaoping's 1992 Southern Tour, China entered into a new stage of economic reform.⁸⁸ The domestic economy was reinvigorated and soon overheated as energy prices, including coal, electricity, and oil, rocketed to the highest level of increase in history in 1995. The drastic reform package put forward in 1994 accelerated the formation of the market mechanism in China⁸⁹ and also pushed price increase in the energy sector. All the indicators AF-1, AF-2, and AF-3 have their highest values (and lowest ordinal values) in 1995, of the seven years in analysis. In the second half of 1992, the pricing of some unified distribution coalmines in the eastern region were liberalized. The coal trading market was established in Shanghai (People's Daily, 1993). In 1993, the central government announced its intention to decontrol the pricing of coal. It stated explicitly that a market-oriented pricing mechanism should be established and energy and raw materials prices should be adjusted accordingly (Li, 1993a; State Council, 1993). On 1 December 1993, Prime Minister Li Peng stated in the national economic work conference that the pricing of the unified distribution coalmines would be liberalized in 1994 (Li, 1993b). Therefore, the unified distribution coalmines were pushed to compete in the market. Coal retail prices began to be deregulated. However, the guiding role of the central government still existed. In 1994, the State Planning Commission announced that the coal prices

⁸⁷ See chapter 5 for a discussion of the problems caused by the two-tier pricing system and the failure of *jiage chuanguan*.

⁸⁸ For the detailed discussion, see chapter 5.

⁸⁹ For the detailed discussion, see chapter 5.

should not rise too rapidly lest the downstream consumers would be seriously affected. In addition, the coal-consuming enterprises were not allowed to raise their own prices to recover rising costs. The coal sold for household use was also controlled according to the State Council pricing policy (State Planning Commission, 1994). Moreover, the subsidized and controlled prices for coal supplied to large power stations indicate that the government still retained direct control over pricing in the key areas of electricity generation (Tu, 2011).

After China's economy recovered from the Asian Financial Crisis in 2002, energy consumption increased rapidly. The thermal coal demand also grew dramatically. The increased demand, however, did not arouse the thermal coal producers' enthusiasm to increase the coal supply. This was due to its low price supervised by the central government. In order to increase the thermal coal supply, the central government relaxed the pricing controls over thermal coal in 2002. Consequently, the central government no longer directly controlled coal pricing (Peng, 2009), but continued to intervene for a long time. The government issued the 2004 Coal-Electricity Price Linkage Mechanism⁹⁰ to lower the financial pressure caused by high coal prices in the power sector. In 2009, the NDRC gave coal enterprises and power plants the right to directly negotiate thermal coal contracts. After that, the government stopped intervening and the deregulation of coal pricing finally materialized (Tu, 2011). Since 2000, the coal market became more liberalized and mature, resulting in modest AF-1 values in 2005 and 2010, hitting 5 and 6 respectively.

4.5.2 Policies on electricity price

Low financing costs and subsidized coal prices kept electricity prices rather low in the early 1980s. The standard nationwide electricity prices in China did not change

⁹⁰ Since 2002, China's electricity pricing is still almost completely controlled by the government whereas the price of coal, the main raw material for electricity generation, is decided by the market. A sharp increase in the price of coal would create operating difficulties for China's power generation companies. China responded by linking coal and electricity prices. However, the linkage was "not a free market adjustment"; it was "regulated and determined periodically by the NDRC to avoid extreme price fluctuations" (Ma & He, 2008, p. 1704).

before the economic reform. With the reform, the Chinese government increased electricity prices to realistic market levels. In 1985, electricity tariffs were increased for the first time throughout the country. The government recognized that the gap between energy supply and demand was largely caused by severe power shortage. In order to increase the supply of power, curb the increase in demand, and increase investment in the power industry, the central government introduced several policies to reform electricity tariffs. In 1985, the State Council issued one of the most important policies to encourage foreign investment in the power industry. By implementing the policy 'Encouraging Investment in the Power Industry and Executing Multi-tiers of Electricity Tariffs', it established a multi-tiered and diversified pricing system (Yang & Yu, 1996; Lam, 2004).

The new local power plants established after 1985 did not get cheaper fuel supplies as only plants built by the central government received such benefits. A new policy compensated the new plants with tariffs based on actual costs via a special dual-track pricing system (Chen, 2010). As a result, these independent power producers (IPPs) did not seek to control cost nor improve efficiency but passed the cost fluctuation onto the generation price. To get a higher price, some IPPs would even exaggerate their costs (Ma & He, 2008). This caused the overall level of electricity generation prices to rise rapidly. In 1987, the Chinese government issued the '*Two-cent policy*' to increase electricity tariff by two Chinese cents per kWh throughout China. All households and a few electricity-intensive industrial sectors were exempted from this policy.⁹¹ The local governments used the revenue to build large and medium power plants (Lam, 2004; Hang & Tu, 2007).

In the early 1990s, the enforcement of relevant pricing policies resulted in highly diversified electricity tariffs. In 1991, the central government issued the '*High-in and High-out*' policy to prevent the state-owned power enterprises from running into

⁹¹ The '*Two-cent Policy*' lasted from 1987 to 1996.

deficit. This policy allowed electricity tariffs to fluctuate subject to the prices of the primary energy and other production materials (Yang & Yu, 1996). In 1993, a '*New Plant, New Price*' policy was issued to reflect capital costs. The provincial grids adopted new, higher base rate schedules. The new power plants built after 1992 were allowed to sell power to the provincial power companies at prices that repaid loan capital with interests. With the implementation of the '*New Plant, New Price*' policy, the prices of electricity generated by the new power plants were significantly higher than those generated by the old plants. Electricity tariffs increased rapidly (Lam, 2004). The AF-3 ordinal value turned out to be the lowest in 1995. In some remote rural areas, electricity tariffs were illegally imposed.⁹² The surcharges were collected to supplement administration funds. The tariff-setting system in China was described as 'extremely complex and heterogeneous'. The electricity tariffs and the rules and regulations for price-setting were so confusing that no one could fully understand how the tariffs were determined (Andrews-Speed, 2004).

The distorted and confusing electricity tariffs in the mid-1990s stimulated the reform of electricity pricing. The 1996 '*Electric Power Law of the People's Republic of China*' provided the legal basis for China's electricity tariff reform. To simplify the electricity prices and boost investment in the old and new generation plants, a new tariff scheme was implemented in 1997. The scheme was formally issued in '*Notice on Regulating Administration of Electricity Prices*' in 2001. The new scheme allowed wholesale prices to be individually subject to the approved cost of a power plant. Based on an average generation cost and a unified internal rate of return on capital during the remaining operation period, the price was actually an operation-period price (for incumbent power plants) or a unified yardstick price (for new plants) (Ma & He, 2008). The new policy improved the AF-3 indicator, with its ordinal value increasing to 7 in 2000.

⁹² The local governments imposed illegal surcharges on top of the catalogue prices, which made the rural users pay higher tariffs than urban users. In 1999, the illegal electricity surcharges for rural users were abolished to lower tariffs in rural areas.

Since 2002, the electricity reform entered a substantive stage. After the separation of generation interests from grid companies, the reform was formally launched via a tariff formation mechanism to build a competitive market for electricity. In 2003, the State Council issued the *'Tariff Reform Plan'* (People's Daily, 2003a), which provided the preliminary framework for future pricing reform.⁹³ In 2005, the NDRC issued three milestone policies for electricity pricing: *'NDRC Interim Provision on the Regulation of Whole Electricity Price'*, *'NDRC Interim Provision on the Regulation of Retail Electricity Price'*, and *'NDRC Interim Provision on the Regulation of Power Transmission and Distribution Price'*. These policies set the new electricity pricing scheme in China's power industry. The new scheme set a structure of two-part prices for electricity in the wholesale market. The two parts were capacity price and system marginal price. The former was set by the NDRC Department of Price while the latter was determined by market competition. This new scheme linked the wholesale electricity price directly to fuel cost. At the early stages of the implementation of the new scheme, the government controlled the retail price. However, the government would allow it to be determined by the market forces later on when the distribution activities are separated from retailing activities. This new scheme was aimed at injecting competition into the wholesale market first and gradually introducing it into the retail market (Pittman & Zhang, 2010). In 2009, electricity producers and wholesale end-users were allowed to negotiate prices with each other directly (Betz, 2013, p. 20). These policies, which tried to introduce competition into the power market, continued to improve the AF-3 indicator while its ordinal values remained at the highest level both in 2005 and 2010.

4.5.3 Policies on oil price

Crude oil had been sold at a single and state-controlled price before the economic reform. In 1981, the State Council approved the *'Production Lump Sum Policy'*, which allowed the over-quota production to be sold at the international oil price. From

⁹³ For details, see <http://hzj.serc.gov.cn/news?id=1043>.

then on, the domestic oil prices were subject to two-tier pricing system: quota oil sold at fixed prices and oil in excess of the quota sold at freely negotiated prices. (Lin B. , 2010). From January 1993, the in-plan output from certain oilfields was sold at international prices. In 1993, the government adjusted the quota prices closer to the global prices and expanded the scope of production for the market. The proportion of market-priced refined products increased from about 10% in 1983 to 65% in 1993. From 1988 until 1993, the in-quota prices⁹⁴---the prices set for allocations within the plan---for crude oil were raised from 115 to 300 RMB Yuan/ton for low prices and from 500 to 700 RMB Yuan/ton for high prices (Wang, 1995, p. 630). The AF-2 indicator hit its lowest ordinal value in 1995.

Along with Deng Xiaoping's 1992 Southern Tour and the ongoing reforms to construct a socialist market economy, China's national economy had expanded quickly between 1992 and 1993. However, excessive increases in the prices of basic goods and basic production prices caused the inflation pressure to rise again. The central government regarded the stabilization of prices to curb inflation as the most urgent task in the country's economic work (Peng & Chen, 2011b). In the oil sector, the high inflation and overheated economy forced the government to control the prices of oil and refined products again in 1994. In April 1994, the State Council approved the *'Opinions on the reform of the crude oil and refined oil circulation system'*. The *'Opinions'* abolished the two-tier pricing system for crude oil and oil products to make way for price-setting by the central government to tackle the disorder in the oil market (Lin B. , 2010). Between 1994 and 1998, the pricing of crude oil and oil products was under the strict control of the government. Restrictions on oil pricing were imposed to discourage imports and stimulate domestic output. In the second half of the 1990s, the anti-inflation measures took effect. The implementation of the macroeconomic regulations had gradually improved the fiscal and financial situation. The inflation rate fell to 8.3% in 1996

⁹⁴ There were three different prices in the upstream sector: in-quota low prices, in-quota high prices, and market prices.

while the GDP grew at satisfactory rates (Dreyer, 2008, p. 156). This created a more favorable environment for the oil pricing reform.

In 1998, the oil pricing changed again. The Chinese government made a revolutionary decision in June 1998 to peg its domestic oil price to Singapore prices, with a one-month lag built in. Since then, the domestic oil prices had been based on Singapore export prices and were adjusted monthly. This was seen as a significant step to integrate China's oil industry into the world market (Anonymous, 1998; Hang & Tu, 2007). In November 2001, the domestic oil prices were adjusted to peg to the package price (the prices of New York, Rotterdam, and Singapore markets) (Lin B. , 2010). The market mechanism had begun to play a fundamental role in oil pricing. Compared to the 1990s, the oil market became relatively mature since 2000, and hence stabilized the ordinal value of the indicator AF-2 at 8.

The swinging between control and relaxation of oil prices in China shows that frequently the government very passively issued energy policies just to solve the problems whenever and wherever they took place. Similarly, the way the government managed the tensions (whenever there were) was like this: they tried to settle the problem whenever and wherever they met the problem. The government did not have forward-looking energy policies. The reason behind this lies in the argument of the study: there are no energy policies in China that have been proactively issued and originally intended to improve energy security.

4. 6 A chapter summary and further discussion

China's energy policies have directly affected energy security indicators, making different shapes and areas of grids as presented in chapter 3. In the process of promulgation and implementation of these energy policies, the challenges are various. The ineffective coordination at the local levels could be one challenge, which is especially prominent when the environmental protection is concerned. On the one hand, the Chinese producers violate environmental regulations to reduce cost of

production. On the other hand, it is often to the advantage of local governments to allow the pollution illegally in order to promote faster economic growth of their own regions and the central government cannot control them. Local government officials benefit from higher rates of economic growth as they receive credits for economic development and even bribes from the polluting producers. These factors have hindered the implementation of environmental regulations, and worsened or slowed down the improvement of the AC dimension.

Another challenge could be found in the SOEs' increasing independence and their capability to affect the central government's policies. That is where the actors directing the SOEs matter. For example, the economic reform has gradually liberalized and decentralized Chinese industry. While energy has remained a strategic sector, there has still been a great shift of power from government to the NOCs. For instance, CNPC was created from the Ministry of Petroleum Industry and Sinopec was established by merging assets from the Ministry of Petroleum Industry and the Ministry of Chemical Industry. The power and influence these ministries had held over the policymaking process were largely transferred to these NOCs (this is intensively discussed in chapter 5).

Since June 1998, China implemented a new and more market-based oil pricing system that improved the NOCs profitability. In addition to the new pricing system, the then-premier Zhu Rongji deliberately enhanced the financial and administrative autonomy of China's NOCs to prepare them for the listing of their subsidiaries on international stock markets. The price adjustment and the enhanced autonomy of NOCs facilitated the overseas share listing of CNPC and Sinopec in 2000. The NOCs lobbied for further progress in liberalization of oil price setting. In November 2001, the domestic oil prices were adjusted again and the market mechanism has begun to play a fundamental role in oil pricing. All these factors contributed to increase of profitability and financial independence of the NOCs. Greater profitability brought the NOCs greater autonomy from the central government, and greater independence

provided them with additional protection against government intervention (Downs, 2006). For example, the NOCs stated that the Energy Leading Group was not a decision-making bureau and it could only give suggestions on their activities. Furthermore, the power of the NOCs (and other energy companies) has been fully demonstrated by their successful lobbying in recent years to prevent formation of a ministry-level energy agency. This leaves the government with relatively less capability in pursuing strategic energy objectives (Jiang & Sinton, 2011).

However, the growing conflicts among interest groups are only intervening variables that account for energy policy-making. They are not the key force behind the promulgation and implementation of energy policy in China. It is the macroeconomic reform that makes itself a force so strong that it diminishes all intervening variables. Macroeconomic reform is the key driving force that is behind the energy policy and security formation. The following chapter analyzes macroeconomic reform and its impact on energy policies in China.

Chapter 5 The Impact of Economic Reforms on the Energy Sector and Energy Security

The quantitative analysis in chapter 3 shows that China's energy security was at its best during the sixth FYP period (1981–1985) and subsequently deteriorated until 1995. During the ninth and tenth FYP periods (1995–2000 and 2001–2005 respectively), the situation improved but fell short of its best record. In the eleventh FYP period, the situation deteriorated again. In Chapter 4, the author analyses how energy policies have affected China's energy security situation. In this chapter, the author argues that China's energy policies are only reactive to its macroeconomic reform. The macroeconomic reform is a variable so strong that it predominates over all over factors that might function in China's energy policy promulgation and implementation. By analyzing the predominance of macroeconomic reform, the author also gives the reasons why China's energy security situation, despite some improvements in the new millennium, fell short of the level of the early reform period (discussed in chapter 3). Reasons for the inefficacy of China's energy policies in restoring the situation to that of the initial reform period (analysed in chapter 4) are also given here.

Amid economic reform, China's energy sector also experienced a series of reforms. China's energy policies, issued and implemented along with economic reform measures, have deeply affected its energy security situation. In other words, it is the economic reform that determines the central government's energy policy decisions which affects the evolution of the energy security situation. Energy policies only passively respond to the economic reform measures, and cannot play full function in pursuing energy security of the country. What are the reforms implemented in the energy sector in response to the economic reform? What is the impact of China's energy sector reforms on its energy security situation? Answers to these questions are addressed in detail in this chapter by discussing China's economic reform policies and analyzing how the macroeconomic reform compels the reform in energy sector

and affects the formulation of energy policies.

5.1 Introduction

Before the economic reform, China had a Soviet-style centrally-planned economy (often called a 'command economy') which could mobilize resources for rapid economic development. Since the central government during that time desired high growth rates to be on par with and eventually overtake the developed countries quickly, they favored heavy industries such as steel and machine building. A large share of the nation's resources was thus channeled to these industries. Consequently, China's traditional economic system was driven by a heavy industry-oriented development strategy (Shirk, 1993). As heavy industries are mostly capital-intensive and China was then a capital-scarce economy, the central government had to 'artificially suppress' the prices of capital, energy, raw materials, and so forth in order to lower the capital formation threshold in these heavy industries. The distorted prices of these production factors led to a 'shortage economy', characterized by a combination of planned resource allocation system and dependent micro-institutions (Lin, Cai, & Li, 2003). During this period, China's economic efficiency was low. Energy and transportation infrastructure was neglected and not reflected in annual growth rates. The result was that the nation's economy was severely constrained by energy and transport shortage (Shirk, 1993). The people's livelihoods suffered. The mass living standards were very low.

To revamp China's economy, the central government initiated economic reform in 1978. In the past more than 30 years, China experienced a drastic economic transition with a continuous high rate of GDP growth undergoing various economic reforms. These reforms could be categorized into three phases covering Deng Xiaoping, Jiang Zemin, and Hu Jintao administrations respectively.⁹⁵ The first phase

⁹⁵ With regarding to the division of reform stages, scholars' views varied according to their categorizing coarseness and basis (Lin, 2009b; Ma & Cao, 2002; Tan, 2007). This study divides the reform period in accordance

of the reform (1978-1992) was a period of unexpected fast economic growth during Deng Xiaoping's administration. The Tiananmen accident in 1989 brought the momentum to a halt and the three-year adjustment period lasted until 1992. This phase of the reform was very experimental and limited. It started in the rural area with the Household Responsibility System (HRS). With its success, the reform was extended to urban industrial sectors in 1984. Since Deng Xiaoping's Southern Tour in 1992, the reform underwent recovery with full range encompassing many aspects. The second phase of the reform aimed at the establishment of a 'socialist market economy, and largely focused on fiscal, financial, and state-owned enterprises (SOEs) sectors. The third phase of the reform was a response to the success of the second phase, which brought urbanization, social equality, and environmental pollution to the forefront of governmental concerns. The priorities of each reform phases had a direct bearing on the energy policies. At the same time, the characteristics of economic reform through incremental change are reflected in the energy sector, making changes in energy policy incremental as well. Maxims such as 'take one step and look around before taking another', 'take small steps at the early stage', and 'crossing the river by groping the stones', which appeared frequently in the government official documents in the initial reform period, were actually applied throughout economic reform for more than thirty years. Correspondingly, tried and tested measures were also adopted throughout energy policy making. As Lin and Tsai (2004) characterized:

"China has adopted an alternative gradual, evolutionary approach to the transition since the reform started at the end of 1978. This approach is piecemeal, partial, incremental, often experimental, and especially without large-scale privatization. The Chinese approach is neither guided by a well-founded theory nor followed a predetermined blueprint" (p. 336).⁹⁶

China's approach to economic reform lacks a blueprint. Neither does its energy

with governmental administration periods to assess their respective policy emphasis.

⁹⁶ The alternative is in contrast with the big bang approach of reform adopted by Eastern Europe and Former Soviet Union.

policies. The reaction and responsiveness make China unable to have ‘planning’ and coherent energy policies. China’s energy security did not improve over thirty years of economic reform. The following sections explain and analyze economic reforms and their impact on the energy sectors in three phases: section 5.2 focuses on the first phase of the economic reform, 5.3 the second phase and 5.4 the third phase respectively.

5.2 Economic reform and energy sector reform: the first phase (1978-1992)

When the Chinese government began its economic reform, it did not have any blueprint. The measures taken were gradual and piecemeal to deal with the most pressing economic problems. The step-by-step approach had four major objectives: to institute a contract responsibility system in agricultural sectors, to revive private sectors in urban areas, to delegate greater authority to SOEs, and to reform the irrational price system (Dreyer, 2008). These objectives had all been reflected in the major reform measures in the first phase of the reform. China’s economic reform was initiated with the Third Plenary Session of the Eleventh CCP Central Committee, which identified the guideline, principle and direction of the reform. It pointed out that:

“One of the severe deficiencies in our country’s economic management system is the over-concentration of power, and it is necessary to shift it to lower levels under proper leadership so that the local authorities as well as industrial and agricultural enterprises will have greater management authority under the guidance of unified state planning.” (Peng & Chen, 2011a, p. 5)

The Session clearly delivered the thought of decentralization of economic power to the lower levels of the economy, which gave much room for the economic reform at the micro-level. This thought constituted a platform for the policies implemented throughout the initial period of the economic reform. The introduction of HRS, the rise of township and village enterprises (TVEs), and the allowance for ‘market’ and

enterprises to play their dual roles in the national economy—all reflected this thought of decentralization and the government's reform measures at the micro-level. The delegation of autonomy and profit-sharing to micro-management institutions gave production incentives and resulted in surplus (above-planned) new products/resources, which were allowed to be disposed at the discretion of the micro-management institutions. It follows that a new channel to allocate resources was needed and this led to the emergence of the dual-tier pricing system. The reform at the micro-level had created spillover effects at the macro-level. The following subsections discuss these reform measures and analyze their impact on the energy sector.

5.2.1 The initial period (1978-1984): Planned economy dominating, market regulation supplemented

Adjustment of the economy

Beginning with the first Five-Year Plan (1953-1957), China's regional economic development had followed the strategy of balanced development for the interior inland provinces. This strategy greatly undermined economic development. Due to the requirement for the 'Third Front' factories to 'scatter and hide in mountains' (*Fensan, Kaoshan, Yinbi*), the organic connection of production was artificially severed (Peng & Chen, 2011a). This development strategy of pouring investments in the interior regions clearly violated the comparative advantage principle. The growth of the interior regions occurred at the expense of the coastal regions and lowered the overall growth rate of the national economy (Démurger, Sachs, Woo, Bao, Chang, & Mellinger, 2002). Therefore, during the initial period of the economic reform, the guiding ideology of China's economic development was to adjust, reform, rectify, and improve the economic order (*tiaozheng, gaige, zhengdun, tigao*). In a State Council workshop held in March 1980, Deng Xiaoping stressed that "(we need to) play comparative advantages and circumvent disadvantages, and admit to the problem of imbalance" (Peng & Chen, 2011a, p. 124). The development strategy was thus shifted

to an efficiency-based one. The landmark for this strategic shift was the sixth Five-Year Plan, which made a significant readjustment of the regional economic development strategy by means of a shift from focusing on balanced development to focusing on macro-economic returns and 'efficiency first with due consideration to fairness' (*Xiaolv Youxian, Jiangu Gongping*). Therefore, the regional economic development priority began to move to the light textile industry and technological innovation of the existing textile, mechanics, and electronics industries in the eastern coastal cities. At the same time, energy and raw materials bases in the interior areas were also enhanced to fuel the industrial development in the east. The decision to adjust, reform, rectify, and improve the economic order had led to the adjustment of energy industry distribution. As discussed in chapter 4, the adjustment of coal industry most typically reflected this decision. The coal industry was shifted to the coal-rich areas, especially Shanxi and eastern Inner Mongolia, leading to a great increase in coal output. The AV-1 indicator was thus greatly affected by the central government's decision to adjust the national economy.

The introduction of HRS and the coal sector reform

The economic reform stimulated the development of town and village coal mines (TVCMs), the root of which was the HRS initiative, a reform in the agricultural sector. At the beginning of the reform, nobody knew where the reform would lead to. As discussed, the reforms were characterized by experimentation ('crossing the river by groping the stones'). The first 'stone' was the HRS, whereby farmers were allotted usage rights of the land with contracted production quotas. This allowed them to make operating decisions independently as long as they fulfilled the terms set by the contract with collective organizations. More importantly, the over-quota production could be disposed freely by the households (Hou, 2011). This was also the starting point of the delegation of autonomy. This rural household system reform spurred farmers to be more efficient when farming. This led to high agricultural productivity, which meant that fewer workers were needed by the farming work and thus

provided surplus labor for the rural non-agricultural sector.⁹⁷

In the early 1980s, the government issued a new policy towards rural non-agricultural development described as ‘leave the land plot but not the countryside; enter the factory but not the city (*Litu bu Lixiang, Jinchang bu Jincheng*)’. In other words, the peasants still remained in the countryside but were allowed to participate in non-agricultural activities. This policy made the non-agricultural development in rural area “not so much as a way to serve and support agriculture but as a way of generating employment opportunities so that surplus rural labor could be reallocated from cultivation to more productive activities while keeping rural-urban migration to a minimum” (Ho, 1995, p. 361).⁹⁸

The rural household system reform provided outlets for expanding TVEs, which were ‘a new force that just came into being spontaneously’, as Deng Xiaoping described (Vogel, 2011, p. 445), and shot up quickly. The TVCMs, as one of the major forces of TVEs, began to develop.⁹⁹ The policy shift to the rural non-agricultural sector relaxed the TVCMs development throughout the country. First, the reform provided surplus labor for the TVCMs as discussed. Second, the reform stimulated changes in the investment system to provide funding for the TVCMs. The underinvestment in the

⁹⁷ In 1978, ‘commune enterprises’ employed 28.3 million people whereas in 1992, 105.8 million people were employed in TVEs (Vogel, 2011, p. 447).

⁹⁸ The responsibility system reform called for persuasive theoretical supporting documents, which gave birth to the document ‘Several Issues Concerning Current Rural Economic Policies’ in January 1983. This document highly appraised the Household Responsibility System and proposed ‘two transitions’ (Liangge Zhuanhua). One was the transition from subsistence or semi-subsistence economy to larger commodity production, and the other was the transition from traditional agriculture to modern agriculture. This stimulated large-scale commodity production in rural sector. The rural commodity economy became prosperous since then (Peng & Chen, 2011a).

⁹⁹ The term, ‘township and village enterprises’ (TVE), first appeared in China’s official documents in 1984. The emergence of TVEs has a long history. The predecessors of TVEs were enterprises run by communes and brigades in the late 1950s. Before the reform, their development had experienced ups and downs. The ‘Decision on Several Issues on Accelerating Agricultural Development’ passed in 1978 at the Third Plenary Session of the Eleventh CCP Central Committee pointed out the need to increase the proportion of revenue of commune and brigade enterprises in the total commune revenues. Agricultural products that would be better processed in rural areas should be processed by these enterprises. This document greatly encouraged the development of these enterprises. In July 1979, the State Council promulgated the ‘Provisions on Several Issues Regarding the Development of Commune and Brigade Enterprises (Trial)’, which clearly stated that the commune and brigade enterprises could enjoy a low tax or no tax policy. Newly established small iron ores, small coal mines, small power stations, and small cement plants could be exempted from taxes for three years since their start-up. This document brought to these enterprises a historical turning point in their development. During the first half of the 1980s, the commune and brigade enterprises became an important force in national economy. To adapt to the transformation of rural communes into township and village governments, commune and brigade enterprises were renamed as TVEs in 1984 (Peng & Chen, 2011a).

coal industry before the reform indicated that the investment system must be changed. A successful policy encouraged investment in the coal industry in the early reform period: 'walking on two legs',¹⁰⁰ meaning that the central government actively encouraged the use of social and individual funds to develop the capacity of TVCMs (Compilation Commission, 1999). Third, the reform freed up the pricing system to some extent. The introduction of the two-tier system in the coal sector in 1985 increased incentives of production in the coal industry, particularly the TVCMs. Fourth, following the example of HRS, a 'General Contract Programme' was put into practice in the coal sector in 1985, and this further promoted coal production (Andrews-Speed, 2004; Chen & Chen, 2007). Completely flexible in adapting to market demand, the TVCMs supplemented state coalmines supply significantly: the annual TVCMs output increased at a rate of more than 20% in the early 1980s; by 1996 the coal produced by TVCMs had constituted more than 50% of the country's total output, which finally brought China's long history of coal shortages to an end (Rui, 2005, p. 698). The delegation of autonomy at the local levels and the liberalization in the rural sector deeply affected the AV-1 indicator.

Emergence of the word 'market' with very cautious reform measures

In the 1980 government work report, Premier Hua Guofeng stated at the beginning of the reform, that the government would change the economic regulation mechanism from single planning to the planning-cum-market combination. From then on, the word 'market' began to appear frequently in China's official documents and was embedded in China's leading ideology of economic reform. At the end of 1981, Premier Zhao Ziyang stressed in the government work report that the basic direction of China's economic reform should adhere to the premise of the socialist planned economy and at the same time, allow the market to play a supplementary role.¹⁰¹ This was the first systematic economic reform model created in the 1980s.

¹⁰⁰ One leg was the state coalmines and the other the TVCMs.

¹⁰¹ This thought was reiterated by Hu Yaobang as the principle of "planned economy playing the leading role and market regulation playing the supplementary role" in the 'Report of the Twelfth Party Congress' made in September 1982, titled 'Creating A New Situation in All Fields of Socialist Modernization' (Peng & Chen, 2011a).

The twelfth Party Congress in 1982 stressed that the fundamental issue of economic reform was the dominance of planned economy supplemented by market regulation (Guo & Li, 2009). It could be seen through these statements that at the beginning of the reform, the concept of 'market' had been in the mind of the reformers. However, it was surely not the right timing for China to adopt a free market. Therefore, the word 'supplementary' always went together with 'market'. The government could afford to let the market simply play a 'supplementary' role. This economic structure determined that most industries and SOEs were still firmly in the hands of the government. The government's major task during that time was to lay a good foundation for further reform rather than drastically reform the nation's economic structure. Reflected in the energy sector, a key sector in the economy, there were no major reforms in the energy enterprises. Although the government emphasized decentralization, it tightened its control over enterprises of key importance to the national economy at the early stage of the reform. The government work report stated that production of essential goods should be carried out in accordance with the mandatory state plans (People's Daily, 1981). As a consequence, reform did not take place in the state enterprises of the energy sector at the beginning of the reform period. Since state enterprises are the key forces for technological advancement, what corresponded with the inert state enterprises during that time was low AP ordinal value. Since energy pricing was largely controlled by the central government, the initial reform period saw low and stable energy prices, which resulted in high AF value during that period.

Summary

From the initial reform period, macroeconomic reform in China began to function as a predominant force affecting energy policies. The major reform then was the introduction of HRS and delegation of autonomy to micro-levels. This provided opportunities for the TVEs to enter into new lines of business to engage in almost any income-generating activities. Among them were the TVCMs, which have affected China's coal sector throughout the reform period. The adjustment of the economy

and the emergence of the concept 'market' prepared the government for subsequent reform measures in both the economy and energy sector. During the early 1980s, relatively abundant energy reserves, sound environments unscathed by the fast economic growth, and low and stable energy prices—three factors made the rhombus (presented in chapter 3) the largest in 1985, depicting the best energy security situation during the reform period. The macroeconomic reform, from its very beginning, began to show its powerful strength in prompting policies and reforms towards the energy sector.

5.2.2 From rural to urban: further and faster reforms until 1989 (1984-1989)

Emergence of 'socialist planned commodity economy' and 'socialism with Chinese characteristics'

Success in the rural reform gave the government confidence to extend the reform to the urban area. China's urban reform was mainly focused on improving the performance of SOEs. In May 1984, the State Council issued 'Regulations for Further Expanding the Autonomy of State-Owned Enterprises', which granted enterprises more autonomy and flexibility to participate in the 'market' after meeting their official targets. The term 'socialism with Chinese characteristics' advocated by Deng Xiaoping granted the SOEs expanded use of market prices under the two-tier pricing system (Vogel, 2011). More decision-making power was devolved to them under the assumption that they would be in a better position to judge what to do. This greatly increased the production incentives for these enterprises. Productivity soared and products variety increased (Dreyer, 2008). In addition to the increase of vigor of SOEs, the urban reform also created new markets and found new sources for raw materials, contributing to the expansion of TVEs and urban collective enterprises (Brandt & Rawski, 2008). The economic contribution of the private sector in urban areas burgeoned.¹⁰² All these prepared China's economy to move towards a market

¹⁰² Since the early 1980s, private enterprises have been allowed to operate and develop. In 1982, the 5th National People's Congress stated that the State sector was the centre of economy and the non-State sector was the supplement. This statement gave the non-State sector the legitimacy and was formally incorporated in the

economy. The macroeconomic reform that originated in the rural area spread into the urban. It was such a natural and unstoppable process that it had penetrated into most sectors of the economy before people realized that.

Yet the government grasped the moment to issue official document to give legitimacy to the reform spreading across the country. In October 1984, the Third Plenum of the 12th Party Congress approved the 'Decision on the Reform of the Economic Structure', which officially coined the phrase 'to build socialism with Chinese characteristics', paving the way for further market expansion (Peng & Chen, 2011a; Vogel, 2011). To further revamp China's rigid economic structure, the 1984 Decision made it clear that China's economic structure must undergo reform. Affirming the progress of the past six years, it officially sanctioned commodity production and exchange, expanded the reform from the agricultural production sector to the urban industrial sector and proposed the theory of 'socialist planned commodity economy' (Fei & Hou, 1994, Larus, 2005; Peng & Chen, 2011a). It officially gave legitimacy to comprehensive market reform in China and reduced the scope of central planning and at the same time, expanded enterprises' operational autonomy.

Under this background, some of the central government's responsibilities were delegated to sub-national governments. Large and medium-sized state enterprises were given more autonomy (Fewsmith, 1994; Research Committee of China's Economic Structural Reform, 1987). The delegation of autonomy was reiterated in the Thirteenth Party Congress report in 1987, which pointed out that the 'socialist planned commodity economy' should be an internally unified system of the plan and market: the State regulates the market, while the market leads the enterprises. The reform decision to delegate more autonomy to local governments and enterprises provided a favorable pro-local context for the power sector to launch its first round of reform, diversification of investment at local levels (Chen, 2010).

Constitution Amendment in 1988 (Hou, 2011).

Power sector reform

In the mid-1980s, rapid economic growth led to surging demand for electricity. The gap between electricity demand and supply had widened. Premier Zhao Ziyang had mentioned several times in his government work reports that the electricity supply was running low. When the economic reform began in 1979, electricity shortage was about 10 GW of capacity and 40 TWh of generation. By 1986, the capacity shortage had grown to about 15 GW and the generation shortage was 700 TWh (Zhang & Heller, 2004, p. 25). Thanks to the macroeconomic reform that delegated more autonomy to the lower levels, the central government stimulated investments in electricity generation by decentralizing investment authority. The local governments, SOEs, and foreign companies were encouraged to finance and have their own power generation facilities. Incentives to diversify financing sources were issued by the State Council in 1985.¹⁰³ The document, 'Provisional Regulation on Encouraging Fund-raising for Power Construction and Allowing Multiple Electricity Prices', reflected the theme of the policy: "who invests, who uses the electricity, and who benefits". The initiative increased the sources of investments in energy industry. It was estimated that from 1981 to 2001, about RMB 1,107 billion Yuan was invested in new generation and delivery capacity, leading to impressive development of the Chinese electricity industry (Zhang & Heller, 2004, p. 6). As various new sources of capital were attracted, the financial burden on the central government was reduced. The share of the central government investment decreased from 78% in 1985 to 52% in 1988. During this period, around 40% of the newly increased generation capacity was financed by the new investment sources (Lu, 1993, p. 53). This policy was quite effective in terms of removing the financial constraint in China's power industry. Installed capacity was greatly increased and AV-4 indicator was largely affected during that time. It is noteworthy that despite the introduction of new actors and new dynamics in the electricity sector, and the Chinese electricity industry evolved from a system exclusively owned and controlled by the central government to a

¹⁰³ Before that, the only source of energy investment financing had been the central government.

system with dominant central planning and decentralized generation owned by various investors, the power sector during the first phase of the economic reform did not significantly “shift the underlying operations, market rules, corporate governance or regulatory/environmental performance” of the electricity enterprises (Zhang & Heller, 2004, p. 32).

Two-tier pricing system

Early economic reform during the late 1970s saw the emergence of a two-tier pricing system. This system consisted of two types of pricing: a government-set price covered by the state plan and a negotiated price for the products above the state quota. In 1985, this system was formally constructed by decontrolling the price of the market portion of industrial goods sold outside the plan (Byrd, 1987). It was a logical outcome of the process of economic reform. It came into being spontaneously along with delegation of autonomy and surplus of products. This system emerged in the energy sector in early 1980s.

In 1981, to develop the oil industry, the State Council permitted the Ministry of Petroleum Industry to adopt the contract responsibility policy. The selling prices of crude oil produced above the quota were based on international prices. In 1983, in order to increase supply of oil products and funds for oil exploration and development, the State Council permitted local oil products (produced and sold domestically) to be sold at international prices, thus creating two-tier pricing for oil products by phasing out subsidized prices for them.

In the same year, to stimulate coal production, a 25% to 50% price markup for above-quota production was implemented, thus giving rise to two-tier pricing for coal (Peng & Chen, 2011a; Wright, 1996). Consequently, some were distributed at market prices, while others were sold at state prices under the control of the planning system. Since 1984, local state mines were allowed to sell coal produced over their quotas at a premium, and all non-state mines were allowed to sell their

products at market prices. In 1986, the central state mines were also given similar concessions for their over-quota output (Wright, 1996). The two-tier pricing system was successful providing sufficient incentive for coal producers to increase production and for coal consumers to hold back consumption. It also fostered the growth of the TVCMs (Zhang, 1992). The two-tier pricing system was established for natural gas sector as well in the late 1980s.¹⁰⁴ The indicators AF-1, AF-2, AF-3, and AF-4 began to deteriorate in their ordinal values. The penetration of two-tier pricing system into the energy sector shows how the macroeconomic reform affects energy policies and how the energy sector reacts to the macroeconomic measures.

As an interim measure, the two-tier pricing system was effective, but it also had the unintended result of hoarding and speculation. Speculators bought as much as they could at the state-set price and sold them at a higher negotiated price. These practices caused serious economic inefficiencies. From the point of view of the national economy as a whole, the two-tier system had led to economic chaos and corruption. The enterprises tried to hide their production capacity so that they got lower production quotas from the state.¹⁰⁵ Smuggling also happened. Under this system, the smugglers resold allocated materials and made profits (Wu & Zhao, 1987). The two-tier pricing system was seen by the World Bank as the economic basis of corruption (Zhang, 1992). Officials made profits through the system (*guandao* in Chinese), which contributed to widespread corruption in China at that time. The defects were especially obvious in the energy sector. As a sector of basic raw materials, its prices were set far below their actual production costs, while the products made from them could be sold at much higher negotiated prices. This made the hoarding and speculation activities in the energy sector, particularly the coal sector, very serious. All these led to shortages of energy and other raw materials.

¹⁰⁴ Historically, gas prices were set low for the reason of subsidizing fertilizer and other industrial production. The low gas prices offered little incentive for the development of natural gas industry, which partly explains why natural gas still accounts for a small portion of China's energy structure.

¹⁰⁵ The state enterprises would surely try to sell the maximum proportion of its output at the market prices and to minimize the quota within the plan set by the state. For example, the state coalmines spent much time in negotiating their obligations under the plan so that they could minimize the portion that circulated within the plan and maximize their returns.

The drawbacks of the two-tier pricing system were more prominent in the late 1980s along with the increase in exports. Trading companies rushed to export severely underpriced energy and other raw materials, and sold them at much higher international prices. The result was a severe shortage of these materials domestically (Dreyer, 2008). In addition to the speculation in the energy sector, low state prices of coal discouraged efficient coal utilization resulting in low boiler efficiency and poor building insulation. As state coal was cheap, industrial boilers used much more coal than was necessary; building insulation became low priority (Albouy, 1991). The pricing system had to be changed and this led to the government decision to 'cross the price hurdle'.

Price reform and 'cross the price hurdle' (jiage chuanguan)

Back in September 1982, when Hu Yaobang made the 'Report of the Twelfth Party Congress' titled 'Creating A New Situation in All Fields of Socialist Modernization', it was mentioned that there was a need to reform the pricing system and price management measures 'in a steady manner' (Peng & Chen, 2011a). However, problems caused by the two-tier pricing system left the central government determined to accelerate the price reform. The government believed that too much emphasis on price stability would only cause difficulty in price reform. Since the mid-1980s, the central government frequently expressed its determination to reform the pricing system.¹⁰⁶ The major aim was to readjust prices at the macro level to reflect demand and supply more closely. With greater pricing flexibility, economic resources could be reallocated to aid enterprises to adapt rapidly to the changing economic conditions (Wright, 1996).

The price reform took place in the mid-1980s. The 'Decision on the Reform of the Economic Structure' adopted by the twelfth CCP Central Committee in October 1984 directly propelled the pricing reform to readjust irrational prices and make them subject to the principles of supply-demand forces. The pricing reform was laid out in

¹⁰⁶ See People's Daily, 1985a; 1985b; 1985c; 1985d.

two steps, as proposed in 'Suggestions on Formulating the Seventh Five-Year Plan for National Economic and Social Development' in 1985. First, from 1986 to 1987, stabilizing the economy was top priority. Hence, improving indirect regulation on macro-level was emphasized without any drastic pricing reform. This was actually the preparation stage of the pricing reform.

Second, from 1988 until 1990, the indirect macro-regulation and reform of production pricing were to improve. Adhering to 'Suggestions,' the government began to mobilize the pricing reform in 1985. It was stated in the People's Daily that the pricing system was not reasonable because pricing did not reflect the value of goods, nor did it reflect the relationship between supply and demand. The pricing system must be reformed. The reform which covered all national economy impelled the price reform in the energy sector. In the early 1980s, the energy prices were so low that some prices were only equivalent to a fraction of the international market price. Nevertheless, the costs of the processing enterprises were much higher than those of the products in the international market. This was because the cheap energy put no pressure on the processing enterprises to reduce energy consumption and improve technology and economic efficiency. Therefore, China must reform its pricing system to mobilize the energy enterprises to increase production and reduce costs (People's Daily, 1985a). At the same time, the government emphasized that the price increase should remain affordable for processing enterprises (People's Daily, 1985b).

The idea of the reform schedule and measures was good. It was believed that without the reform, it was impossible to create a complete socialist market system that was indispensable for the development of the socialist commodity economy (People's Daily, 1987). Towards the end of the 1980s, the government decided to accelerate the price reform. In the government work report on 15 March, 1988, the Acting Premier Li Peng indicated that the State Council decided to take comprehensive supporting measures to reform the pricing system. At the same time,

accelerated economic growth in the first half of 1988 led to inflated demand for consumption and investment. The government report and the economic situation then increased the expectation of inflation.

In early August 1988, when the 'Preliminary Plan on Price and Wage Reform' approved by Political Bureau of CCP Central Committee was publicized in the media, people misunderstood that the prices would be fully deregulated. This brought about a surge of panic buying across the country that severely hindered the progress of pricing reform (Peng & Chen, 2011a). Making matters worse, on 24 August, 1988, the People's Daily published an editorial stating that the old price formation mechanism had been a large obstacle of reform and economic development. The price reform 'hurdle' must be crossed. The price reform could not be delayed any more. Otherwise, the price reform would only be more and more difficult (People's Daily, 1988). The editorial exacerbated the people's panic. This situation was the so-called '*jiage chuanguan*' in 1988. Through the price reform, the government had expected to gradually form a reasonable price system that would reflect the true value of the product and the relationship between supply and demand. However, the price reform in 1988 was interrupted and '*jiage chuanguan*' failed at last. The overheated Chinese economy exacerbated by the panic buying turned to be out of control in late 1980s. In 1988, the inflation soared from 7% to almost 19%. The crazy high inflation rate and the provoked bank run forced the central government to tighten the economic policy by stringently controlling investments and credits until the end of 1991 (Hussain & Stern, 1991, p. 146).

On 30 August 1988, the twentieth executive meeting of the State Council restated 'stabilizing the economy' and highlighted that market-regulating prices of most commodities specified in the price reform plan was a long-term objective. The following year's growth rate of retail prices would be significantly lower. On the same day, the State Council issued the 'Urgent Notice on Current Price Work and Stabilizing the Market'. The meeting and the notice curbed the 1988 pricing reform (Peng &

Chen, 2011a). A series of stringent measures were adopted to restrict spending and control inflation. In late 1988, China began to cut back capital construction to impose control over the pace of economic development. But as the inflation continued to increase, the central government adopted much more stringent measures in 1989 to exert greater control over the economy.

As a result of these tightening measures, together with the economic sanctions imposed by some foreign countries after the Tiananmen Square protests of 1989, China saw a steep economic downturn in the subsequent years (Dreyer, 2008). Inflation was effectively controlled. In 1990, the growth rate was 3.8%, which was a significant decline from 11.3% in 1988. Consumer price index fell from 18.8% in 1988 to 3.1% in 1990 (Vogel, 2011, p. 473). Until 1990, there was not much decrease in ordinal values of the indicators AF-1, AF-2, AF-3, and AF-4, which hit 8, 9, 9, and 9 respectively. China's economy had entered into a period of adjustment and recovering.

5.2.3 Adjustment and recovering of the economy (1989-1992): Combination of planned economy and market regulation

The relatively depressed economy in the early 1990s offered an ideal opportunity for the central government to rescind certain stringent measures. Though the national economic situation improved, the government was still uncertain how to proceed. Evidence could be found in Jiang Zemin's National Day address in 1989. He stated that an economic system should be created such that the degree, manner and scope of the combination of planning and market regulation could be adjusted and improved according to the actual situation in China (Guo & Li, 2009). But Jiang did not mention specifics so the government did not know how to adjust the combination. This uncertainty was also reflected by the government's contradictory pronouncements of the need for structural reforms on the one hand, and for economic retrenchment on the other hand. This period was described by analysts as

a suspended economy in a state of disequilibrium (Dreyer, 2008). Nonetheless, reform tendencies had already been strongly entrenched in the economy and its continued transformation to a market economy cannot be reversed.

During the two years of adjustment/rectification, the central government managed to maintain the stability and continuity of the policy of reform and opening up, and introduced macroeconomic measures to expand the range and the extent of market regulation. The 'Report on the Ten-Year Plan for National Economic and Social Development and the Draft of Eighth Five-Year Plan' made in March 1991 indicated that the government would continue its exploration on the specific ways and forms to combine planned economy and market regulation. In early 1992, the overall economic situation has improved. GNP increased by 7% in 1991 compared to the figure in 1990; the costs of living of urban and rural residents rose by 3.4%; total fixed asset investment growth rate was 18.6%; retail sales growth rate was 13.2%; export growth rate was 15.8%. As the People's Daily published, "China already has the conditions to speed up reforms" (People's Daily, 1992a).

The economic improvement prepared China to speed up reform and marketization. In early 1992, Deng's southern tour signaled the new period of reforms. In Zhuhai, he reaffirmed that China's development in the past decade proved the efficacy of the principles and policies formulated in the Third Plenary Session of the Eleventh Party Congress, and he concluded that China must stick to them. He also told China's top decision makers decisively: "Development is the absolute principle" (*Fazhan caishi yingdaoli*) (Peng & Chen, 2011b, p. 7). In his talk with Jiangxi Provincial governors, he re-emphasized the necessity of faster development and said "[w]e should be bolder and more open...If there is an opportunity to leap, just leap" (Peng & Chen, 2011b, p. 7).

Deng Xiaoping's speech during his southern tour thus initiated another tide of reform and opening up. The essence of his speech was fully reflected in the report to the

Fourteenth National People's Congress of CCP, delivered by President Jiang Zemin on 12 October 1992. Jiang Zemin stated that the government would accelerate the pace of economic reform and establish the socialist market economic system. To do so, the government should adopt the following measures: transform the operating mechanism of large and medium-sized SOEs and push them into the market; develop the production market, financial market, and technology, labor, information and real estate market; reform the revenue-sharing system; and transform the government's role, and separate enterprises from government management (People's Daily, 1992b). The report initiated a radical package of reforms in the 1990s, including the SOEs reform, fiscal and financial reform, and government restructuring. All these reforms directly affected the energy sector throughout the 1990s, which is discussed in section 5.3 below.

Energy sector during the adjustment period

To rectify the economic order and gradually reduce inflation, the Fifth Plenary Session of the Thirteenth CCP Central Committee passed the 'Decision on Further Managing the Economic Environment, Rectifying Economic Order and Deepening Reform' in November 1989. One main objective of the Decision was to increase the supply of energy and raw materials. To realize this objective, the central government increased input in basic industries. In early 1990, the State Planning Commission and the State Council Production Commission proposed the "Report on Piloting the Method of 'Two-guarantees' in 234 Key Enterprises".

The Report identified 234 key enterprises as 'two-guarantee' (*Shuangbao*) enterprises. The first guarantee refers to enterprises' operating under unified central planning to pledge to turn over to the country the following products: 323 million tons of raw coal, 136 million tons of crude oil, and 367.1 billion kilowatts hours of generating capacity, and so on. The second guarantee refers to the central and local governments' pledge to equip the enterprises with production necessities such as energy, raw materials, and funding. As a result, the total output of raw coal and

electricity generated increased by 2.5% and 6.2% respectively in 1990 (Peng & Chen, 2011a, p. 425). The year 1991 was designated by the State Council as the 'year of product quality, brands, and economic performance' (*Zhiliang, Pinzhong, Xiaoyi Nian*). An important measure taken for this year was 'chain debt clearance'¹⁰⁷, which managed to partially solve the enterprises' fund shortage. This helped to accelerate their capital turnover. A large group of key projects in energy, raw materials, and so on could be completed and put into operation (Peng & Chen, 2011a).

The relaxed economic environment in the beginning of the 1990s witnessed an acceleration of price reform. The central government began to gradually reduce the price differences caused by the two-tier pricing system. From 7 March 1990, a ceiling price was imposed on coal output that exceeded state-quota; from 10 March 1990, ex-factory prices of domestically produced crude oil and some oil products were increased. Price limit measures were also imposed in several other sectors and industries. All these measures made a big step towards the final elimination of the two-tier pricing system (Peng & Chen, 2011a; Wright, 1996).

In August 1992, the State Bureau of Commodity Prices introduced two major initiatives in the price reform: relaxation of government control over a number of production prices and reducing the scope of prices administered by the government. The State Council approved the removal of the state unified maximum ex-factory prices or fixed prices of production of crude oil, oil products and steel above the state plan. In the same year, the newly re-established Ministry of Coal increased the price of state-allocated coal by 20% and this prepared the coal industry for further general price deregulation (Wright, 1996, p. 16). During 1993-1994, the two-tier pricing system of coal and crude oil were eliminated. The macroeconomic measures --- the adjustment of economy after the failure of 'cross the price hurdle' --- created an environment for the final abolishment of the two-tier pricing system, which

¹⁰⁷ 'Chain debts' were actually 'circular debts' involving several enterprises: enterprise A owes enterprise B, which owes enterprise C, while C, in turn, owes enterprise A.

contributed to the lowest ordinal values of indicators AF-1, AF-2, and AF-3 in 1995 among the years in calculation. The emergence and elimination of the two-tier pricing system in the energy sector was inseparable from the emergence and elimination of the system throughout the economy. Once again, energy policy was subject to the macroeconomic measures in China.

5.3 Economic reform and energy sector reform: the second phase (1993-2002)

The second phase of China's economic reform was a time of rapid economic growth. Following a period of economic retrenchment and slowdown between 1989 and 1991, Deng Xiaoping's 1992 Southern Tour reinvigorated China's economy and reinstated the reform movement. The Fourteenth Party Congress held in October 1992 conducted a comprehensive review of the past economic reform. The Congress affirmed that reform was the only way out for China's economic development, officially endorsed Deng's theory of 'building socialism with Chinese characteristics' (Larus, 2005), and proclaimed that the reform aimed to establish a socialist market economic system. In the next year, Jiang Zemin visited Shanghai, Xi'an, Dalian, and Guangzhou to preside over seminars on regional economic work. During the seminars, he emphasized that the reform of the traditional economic system must be continued to establish the socialist market economy and that reform of the investment system, the fiscal and taxation system, and the financial system should be put forward. The core idea was that establishment of socialist market economy should be accelerated as it was vital to solve current and future problems in economic development (Peng & Chen, 2011b). With this background in mind, the Third Plenary Session of the Fourteenth Party Congress in November 1993 made it clear that "the construction of this socialistic market economic system is to designate the State with the role of making fundamental resource distribution decisions on the macro level" (Hou, 2011, p. 422). The Session adopted the 'Decision of the CCP Central Committee on Certain Issues in Establishing the Socialist Market Economic System'. The Decision provided an explanation of the workings of the socialist market

economic system and emphasized that effective measures must be taken to actively and comprehensively promote reform step-by-step in order to establish the system. It served as a guide for China's economic restructuring in the subsequent years.

Since then, China's historical transformation from 'socialist commodity economy' to 'socialist market economy' has begun. A drastic package of reforms to develop 'socialist market economy' was introduced to legitimize market competition in China. The package included three categories of reforms: government structure, national fiscal and financial systems, and SOEs. All these reforms had profoundly affected the country's energy sector. The following subsections review the major reform measures during the second phase of China's economic reform and discuss their impact on the energy industry.

5.3.1 Government structure reform and its impacts on energy sector

Government restructuring

The transition to market economy required the creation of new organizational structures within the government. Prior to 1982, there were nearly 100 ministries under the State Council. The central government performed institutional restructuring every five years respectively in 1982, 1988, 1993, and 1998. Among them, the 1993 and 1998 reforms had more far-reaching implications on the energy sector. In 1993, several ministries were dissolved including the Ministry of Energy. Since then, China did not have a unified national energy agency (Yu, 2010). The State Economic and Trade Commission (SETC) was re-established to supervise the national economy. The SETC and State Development and Planning Commission (SDPC) were assigned to oversee the energy sector and long-term economic planning. Both eventually became "the most influential bureaucratic bodies in the energy sector" (Meidan, Andrews-Speed, & Ma, 2009, p. 601).

After the 1993 reform, there were still 40 ministries and institutions left under the

jurisdiction of the State Council. China's central government was overstaffed and its central finance was overburdened. The year 1998 saw further government restructuring. A plan for the institutional reform of the State Council was adopted in February 1998 during the Second Plenary Session of the Fifteenth CCP Congress. A major aim of the reform is to establish a government administrative system suitable for the 'socialist market economic system'. During this reform, nine ministries of industry had been removed (Peng & Chen, 2011b). In March 1998, the First Session of the Ninth National People's Congress streamlined the State Council. In the year 2000, another nine professional bureaus under the SETC were revoked (People's Daily, 2001).¹⁰⁸ This shows that the central government has made attempts to move away from direct interference tactics to macroeconomic regulation methods in governing specialized departments in SOEs. This introduced the market mechanism into operations of SOEs and reduced government control. Consequently, the government restructuring has made it imperative to reform the SOEs at the same time.¹⁰⁹

Energy sector under the government restructuring

The government restructuring led to the decentralization of leadership in various government departments in the energy sector. This led to the declining ability of the central government to effectively manage the energy industry. For example, in the coal sector, the Ministry of Coal Industry was abolished in 1998 as its administrative functions were transferred to the SETC. Business responsibilities were assigned to the newly-created State Administration for the Coal Industry, which was abolished in

¹⁰⁸ The abolished nine professional state bureaus are: the State Bureau of Internal Trade, the State Administration of Coal Industry, the State Administration of Machinery Industry, the State Administration of Metallurgical Industry, the State Administration of Petroleum and Chemical Industry, the State Administration of Light Industry, the State Administration of Textile Industry, the State Bureau of Building Materials Industry, and the State Administration of Nonferrous Metal Industry (Peng & Chen, 2011b, p. 274; People's Daily, 2001).

¹⁰⁹ The SOEs reform and government restructuring are mutually reinforcing. During the early years of the economic reform, the government had recognized that the planned economy gave the SOEs little incentives for efficient production. In the early 1990s, the government eliminated the transfer of all net revenues from the SOEs to the state to transform them into more commercially-oriented enterprises. In 1994, the tax reform allowed the SOEs to retain residual profits. Despite these reforms, however, many SOEs' commercial decisions in the late 1990s were still largely under government control. Lack of innovation and continuing losses in many SOEs led the second wave of government restructuring in 1998 to further separate government administration from corporate operations.

2001 (Zhu & Cherni, 2009). In March 1998, China's ninth National People's Congress approved the creation of the State Petrochemical Industry Bureau (SPIB) along with the abolition of the Ministry of Chemical Industry. The government functions of China's oil companies had been transferred to the newly established SPIB (Young, 1998). This paved way for the subsequent reorganization of the country's petroleum and petrochemical industry, and gave birth to two large enterprise groups: China National Petroleum Corporation (CNPC) and China Petrochemical Corporation (Sinopec Group) in July 1998 (CNPC, 2012; People's Daily, 2002).¹¹⁰ Since the beginning of the 21st century, respective ministries in charge of coal, petrochemical, and power industries have been abolished. Both the absence of an institution overseeing the whole energy industry and the decentralization of leadership after the government restructuring severely weakened the already fragmented administration in the individual energy sectors and the bureaucratic energy management apparatus in China. The areas of government-controlled decision-making became fewer.¹¹¹ The old planning system lost most of its effectiveness in energy conservation.

In the early reform period, the central government directly invested in energy conservation projects. Energy conservation service centres were established throughout the ministry's systems. As a result of government restructuring, the energy conservation service centres that created channels for increasing the flow of information on energy efficiency technologies, gradually lost their government funding. Some programs were even phased out during the government restructuring. On the other hand, the newly established system expected to promote energy efficiency through market-based instruments had not functioned as intended (Sinton, Levine, & Wang, 1998; Zhao, 2001). Although the ordinal value of AP-1 indicator kept

¹¹⁰ As the sole initiator, Sinopec Group incorporated China Petroleum & Chemical Corporation (Sinopec Corp.) on 25th February 2000, according to the Company Law of the People's Republic of China (Sinopec Corp., 2012).

¹¹¹ Although the NDRC's Energy Bureau was established in 2003, it did not have the authority or resources to effectively coordinate the energy policies and plans among ministries and energy companies. The National Energy Administration (NEA) was established in 2008, but it still did not have sufficient clout to impose its will on the energy policy-making or coordination.

increasing in the 1990s, the government's attention to energy conservation had begun to wane.

There were some mutually-offsetting effects within the government restructuring. In addition to the structural change in the coal, oil, and power sectors, the government restructuring in 1998 reflected the central government's increasing concern for environmental protection. The former National Environmental Protection Agency (NEPA) was upgraded to the State Environmental Protection Administration (SEPA). The former Environmental Protection Committee of the State Council was abolished. The environmental administrative restructuring improved environmental administration and reduced the fragmentation of central government policy-making regarding clean coal technology adoption and environmental protection. On the other hand, however, after the Ministry of Coal Industry was abolished, its environmental responsibility was passed to the SEPA and local environmental protection bureaus, which undertook jobs related to environmental protection for all industrial sectors. The Ministry of Coal Industry, which was once very active in environmental protection in the coal industry and day-to-day administration of environmental matters, stopped carrying out these functions since its abolishment. In other words, though the creation of SEPA did enhance environmental protection in general, less involvement and cooperation from the coal administration led to undesirable environmental protection, particularly in the coal sector (Zhu & Cherni, 2009). The AC-2 indicator deteriorated quickly in the 1990s.

The environmental protection responsibility with regards to the coal sector has been devoluted from the Ministry of Coal Industry to the SEPA and local environmental protection bureaus. With the local governments obtaining the environmental responsibility, successful implementation of environmental regulations will be difficult since there are economic benefits by violating the regulations for environment protection. It is very difficult to manage the conflicting interests of the central and the local levels for some time to come. This problem may only be settled

by strictly enforcing penalties for violation, for example, by severely punishing the governor of the violating region. This requires strong determination on the part of the central government to change the behavior of these governors/officials, but such determination may not be forthcoming.

In addition, the devolution of power and the ineffectiveness of implementation of environmental regulations particularly in the coal sector once again offer evidence in support of the argument of the study: the energy policies are reactive to the country's macroeconomic reforms. The government restructuring resulted in the devolution of power in the environmental sector and this led to less involvement and cooperation from the coal administration when the Ministry of Coal Industry was abolished. Environmental protection in the coal sector was undesirable in the 1990s.

5.3.2 Fiscal and financial reforms and their impact on energy sector

Fiscal reform and energy sector

Before the reform in the end 1970s, China's fiscal system had been dominated by 'unified revenue' and 'unified expenditure'. Under this system that almost no autonomy was in the hands of local governments, it was impossible for them to mobilize local initiatives to increase revenue or control expenditure, and this hindered local economic development. To change the situation, the central government decided to implement a new fiscal system of "dividing revenue and expenditure between central and local governments and of hierarchical responsibility" (*huafen shouzhì, fēnji baogan*) (Peng & Chen, 2011a, p. 87). In February 1980, the State Council promulgated the Notice on Implementing the Fiscal Management System of 'Dividing Revenue and Expenditure between Central and Local Governments and Hierarchical Responsibility'. This document clearly clarified the range of revenue and expenditure of central and local governments. The system improved the fiscal situation of the country (Peng & Chen, 2011a).

However, this system had given excessive stimulus to local industrialization while constraining the central government's revenue-raising capability. Gradually, the steady decentralization of revenue authority reduced fiscal capabilities of the central government. Before the economic reform, financing for social services had been provided by the central government. All revenues had belonged to the central government and all expenditures had been determined at the center. Since the Chinese tax system had rested on the local collection of revenues that were then remitted to the center, as soon as the economic reform started and the mechanism of planned economy began to fall apart, the former revenue system quickly began to erode (Wong, 1992).

The ratio of central government revenue to total government revenue declined from 1985 to 1992. The ratio of fiscal revenues to GDP continued to decline as well (Wong, Heady, & Woo, 1995). The decline in fiscal capacity was accompanied by the underprovided social services and even physical infrastructure investment. In the energy sector, fixed investment in electricity during the 1980s was less than 4% of GDP on average, which was below the rule-of-thumb benchmark of 6% of GDP for successful growth (Naughton, 2008, p. 109). To stem the decline of the revenue/GDP ratio and increase the central government's capability in its macroeconomic management, the State Council issued 'Decisions on Implementing Tax-sharing Fiscal Management System' in December 1993, and implemented it in 1994. The 1994 fiscal reform unified the tax division and established central government's own branch tax bureaus at the local level. By this arrangement, the central government collected shared taxes and then allocated a portion to the local governments. This helped to standardize tax rates and simplify tax categories. The central government also had the authority to carry out tax reduction and exemption (Zhang, Niu, & Bartle, 2006).

However, these fiscal reform measures had some side effects on energy conservation. In the 1980s, the government had offered tax allowances to encourage enterprises to

invest in energy-saving measures. Due to the simplification of the tax system in the 1994 fiscal reform, many of these tax reductions on energy conservation projects and efficient technology development were removed (Andrews-Speed, 2004), resulting in the decline of the share of energy conservation investment in the total energy supply (discussed in chapter 4). Another negative effect was environmental degradation. Local governments implemented the fiscal reform in 1994 by seeking new ways to boost revenue as they were responsible for their own economic growth. Consequently, they often neglected environmental protection in their rush to exceed the energy targets set by the central government. For example, the use of inefficient and highly polluting equipment was often overlooked as long as operations fueled local economic development (Kong, 2011, p. 55). This made it difficult to achieve environmental improving targets and contributed to the deterioration of the AC-1 and AC-2 indicators.

Financial reform and energy sector

China had been trying to reform its old state-planned financial system in the 1980s, by increasing the autonomy and commercial orientation of the banks to a very limited extent (Breslin, 2003). In order to foster market economy with indirect but effective macroeconomic regulations, the central government decided in 1994 to initiate a new phase of financial reform comprising a new and comprehensive set of financial policies. The most relevant policy to this study was converting old specialized banks into regular commercial banks (Li & Ma, 1995). This had a direct adverse impact on the energy sector. With the shift of their operational focus from social benefits to economic benefits, banks were reluctant to extend loans for energy conservation projects because they became highly concerned about the borrowers' repayment ability (Zhao, 2001). Consequently, the preferential interest rates offered for energy conservation projects were cancelled.

In the 1980s, a series of energy-saving incentives were implemented to spur energy savings and energy-efficient technologies (Sinton, Levine, & Wang, 1998). Among

them, two major financing programs for promoting energy-efficient investment were established in the early 1980s. One program was managed by the former SETC which provided interest subsidies to enterprises that would undertake technical renovation for energy conservation. The other program was managed through China Energy Conservation Investment Corporation (CECIC), a government branch in charge of selecting projects for loans and overseeing their progress under the direction of the former SDPC.¹¹² Under this program, the energy conservation loans were on favorable interests, almost one-third below the prevailing rates at that time (Levine, Liu, & Sinton, 1992; Lin, 2007). By 1994, however, the preferential interest rate was revoked along with the financial reform. Since 1996, the share of energy conservation investment to the total energy investment has declined in importance (Lin, 2007).¹¹³

Summary

The transition to a market economy entailed the removal of old regulations that had previously stimulated energy conservation. Tax allowance and reductions for energy efficiency improvement were removed. The energy efficiency loans from the government ceased. The commercial banks operated for economic benefits rather than social benefits. CECIC operated more like a private sector entity rather than a government institution (Levine, 2008). Policies to support energy conservation in China weakened during the turn of the 21st century when China was in transition towards a more market-based economy by reforming its economic systems, which removed old regulations, including measures that had stimulated energy conservation. The financial incentives created in the 1980s were important tools in encouraging energy conservation. Sinton, Levine, and Wang (1998) described the discontinuation of these national incentives as “[o]ne of the great ironies of the economic system reforms of the early 1990s” (p. 827). The fiscal and financial

¹¹² CECIC is a state-owned company that supervised the loans of two billion Yuan for energy-efficiency investment projects, mainly industrial energy-efficiency projects and combined heat and power cogeneration projects (Sinton, Levine, Fridley, Yang, & Lin, 1999). It had been the major channel for the state’s program of energy-efficiency investment.

¹¹³ For more discussion on this issue, see chapter 4, section 4.3.1 Energy conservation and energy intensity.

reforms in the 1990s show how strong the force of macroeconomic reform is that it dominates the energy sector and deeply affects its development trend.

Nevertheless, the central government's fiscal capacity was invigorated through the tax and financial reform. The financial reform improved the central bank's control of state-owned commercial banks, strengthened the central control over domestic stock markets, and increased the country's foreign reserves (Lardy, 1998; Shih, 2009). These reforms reinforced the central government's leverage over SOEs which struggled with losses and debts, paving the way for SOEs reform.

5.3.3 SOEs reform and its impact on energy sector

Reform of SOEs

From the early 1980s, the central government began to render some autonomy to the SOEs via the Contract Responsibility System (CRS). But it eventually proved to be unsatisfactory since it lacked a standard and transparent contract between the state and the enterprises. Politically well-connected enterprises were able to negotiate a better deal with the government (Hassard, Sheehan, & Morris, 1999). CRS was the product of the planned economic system without any clear clarification of property rights, which became the bottleneck of further SOEs reform. At the same time, the Chinese economy became more market-oriented and increasingly integrated into the world economy. To sustain fast economic growth, it was necessary to clarify the property rights to fulfill the SOEs reform objectives for innovations and technological advancement, autonomy of operations and so forth.

As the successors of CRS, the Modern Enterprise System (MES) and the Group Company System (GCS) were to be established during the second phase of the economic reform. The aim was to promote the corporatization of large and medium-sized SOEs and clarify the property rights (Hassard & Sheehan, 1997). This aim was reflected in several government conferences and reports. In March 1991, Li

Peng's government work report to the Fourth Session of the Seventh NPC had stressed the focus of the future of economic reform: to further enhance the vitality of the large and medium-sized SOEs (People's Daily, 1991). In November 1993, the Third Plenary Session of the Fourteenth Party Congress implemented a new round of SOEs reform aimed to remove the SOEs from direct government control and render them more commercially-oriented. In March 1997, the State Commission for Economic Restructuring issued the '*Key Points of the Implementation of the Economic System Reform in 1997*'. This encouraged corporate restructuring by means of leaving most small and medium-sized SOEs to be merged, sold off, or allowed to go bankrupt, as well as establishing and developing large companies and groups (People's Daily, 1997a).

In March 1998, Premier Li Peng stressed in the government work report that the reform of SOEs should achieve new breakthroughs. In some important and key industries, the establishment of large enterprise groups should be encouraged to enhance their competitiveness in the domestic and foreign markets (People's Daily, 1998). The primary aims of the MES and GCS were to adopt modern business management methods and at the same time, reallocate resources and assets and restructure SOEs in order to reduce their reliance on the government, and also create large internationally competitive companies (Hassard, Sheehan, & Morris, 1999; Hassard, Sheehan, Zhou, Terpstra-Tong, & Morris, 2007). The SOEs reform during the second phase of economic reform could be characterized by "a mixture of experimentation and pragmatism". Despite the increased marketization of SOEs via the reform, the state intervention and ownership was still predominant (Hassard, Morris, Sheehan, & Xiao, 2010, p. 507). The SOEs reform and the MES and GCS initiatives were applied to all state enterprises in the national economy, including those in the energy sector. Although the energy sector was one of the pillar industries identified to remain under tight government control, it underwent reform to adopt more commercial approach in business operations.

SOEs reform in the energy sector created the dominant role of the three national oil companies (NOCs) and the State Power Corporation (SPCC). In January 1997, restructuring in power industry was implemented and the SPCC was established. The assets of the Ministry of Electrical Power (MEP) were transferred to the new SPCC. In July 1998, a major reorganization of the petroleum and petrochemical industries led to the formation of the China National Petroleum Corporation (CNPC) and China Petrochemical Corporation (Sinopec), as above mentioned. As 'experimental enterprise groups', CNPC and Sinopec were reorganized along geographical lines. CNPC took over many of Sinopec's refineries and petrochemical plants in northern and western China and retained its own oilfields in these regions. Sinopec took over most of CNPC's oilfields in eastern and southern China and retained its own refineries and petrochemical facilities in these areas. The vertical integration bound together the financial interests of upstream and downstream resources. Since then, an oligopoly was created to ensure profitability of the three NOCs and large enterprise groups in the energy sector were established. These large enterprise groups, either the NOCs or the SPCC, severely limited the competition in the energy industry. This reflects the government's hesitancy in introducing market forces into the country's energy industry and its fear of the risks of rapid market liberalization in the energy sector. In short, the gradualist and incremental ('crossing river by feeling stones') approach reflected the government's cautious optimism towards reform in the energy sector.

SOEs reform in the power sector

Socialist market economy requires its enterprises to be market-oriented. As earlier discussed, the second phase of the reform was characterized by transforming government functions to establish the MES. Enterprises became independent economic entities responsible for their own performance and profits. The multiple sources of investments in the power sector created in the 1980s also required relationship adjustments between government and enterprises, IPPs and power grids, and among IPPs (Ministry of Power Industry, 1995). Under this context, Premier Zhu

Rongji formally proposed in 1996 to corporatize the power industry. In 1997, the SPCC was formally established as a state corporation with independent legal status. The business functions of the previous MEP were transferred to SPCC, while its regulatory and administrative functions were passed on to the SETC (Chen, 2010; Ma & He, 2008). This separation of administrative functions from business operations in the power sector was regarded by the central government as a significant step towards a 'socialist market economy' (People's Daily, 1997b). During the second phase of the reform, SPCC and SETC put forward mainly three policy measures for the power sector: the corporatization of the subsidiaries at the provincial and regional levels; the expansion of nationwide power grids; and the introduction of market competition into power generation.

To corporatize subsidiaries at the provincial and regional levels, the previous provincial power bureaus were converted to power companies and new regional divisions were established. By 2000, all the previous provincial power bureaus and the regional groups came under the management of the SPCC, either as its direct subsidiaries or as its regional divisions. By this way, the SPCC was more vertically integrated. Shortly after the corporatization, the SPCC argued that to create a competition environment, the power market must be large enough to contain a sufficient number of competitors. To create such a large market for effective competition, well-connected interprovincial grids were compulsory (Gao, 1999). The SPCC hence proposed a project to construct and improve cross-provincial transmissions and distribution networks. The nationwide power grids were thus expanded, which once again reinforced the top-down consolidation of the SPCC.

The first two reform measures in the power sector led by the SPCC incurred criticism that the so-called 'market reforms' only strengthened the market power of the SPCC and in fact returned the power sector to the centrally planned economy. To introduce real market competition, the SPCC should separate power generation and distribution from power transmission (Liu, 2004). Therefore, the third reform

measure was advocated by the SPCC to unbundle the generation enterprises from power companies in six provinces (Heilongjiang, Liaoning, Jilin, Shandong, Zhejiang, and Shanghai) to help the generation enterprises compete in an electricity pooling system. But due to their disappointing performance, this reform measure was suspended by the State Council in 2000 (State Council, 2000).¹¹⁴

Generally speaking, the second phase of reform aimed at restructuring the electricity sector to increase efficiency and competition. However, the introduction of market mechanisms in this phase proved to be less effective than the first phase of reform which sought to raise capital for expanding power generation. The success was blocked by cautious approach of the SETC and SPCC against their loss of control of electricity. Instead of injecting the market mechanism further into the electricity sector, the SPCC monopolized the sector: shut down small thermal power plants to protect state enterprises, and controlled most of the transmission and distribution (T&D) assets and half of China's generation assets. These moves severely hindered the creation of a competitive electricity market in China (Ma & He, 2008). The power sector reform affected the AV, AP, and AF indicators in the 1990s (discussed in chapter 4). Due to the Asian Financial Crisis, the electricity supply exceeded the demand, leading to the closure of small plants. This resulted in the lowest AV-4 indicator ordinal value in 2000. The electricity market was actually not competitive, and could not create a mature pricing formation mechanism. The AF-3 indicator hit a moderate value in 2000. The momentum of introducing competition forces in the power sector was stalled in the 1990s due to the SOEs reform, which constitutes a strong force dominating the energy sector. The most positive impact of the power sector reform was this: the state enterprises in the power sector contributed largely as the major force of technological advancement in generation efficiency to the increase of ordinal value of AP-2 until 2000.¹¹⁵

¹¹⁴ Ma and He (2008) argued that the reason of failure of this reform measure was largely because the separation of electricity generation enterprises from power companies was still constrained by the monopolistic SPCC.

¹¹⁵ See chapter 4 for detailed discussion on the evolution of indicator values.

SOEs reform in the oil sector

In the first half of the 1990s, as a result of a series of policy stimulus and reforms after Deng Xiaoping's 1992 Southern Tour, shortages arose for many industrial goods, including crude oil and oil products. Due to the shortage economy as well as the fixed prices and restrictions on imports, refineries had no worries about the sales of their products, so they had little motivation to adjust. However, China's oil sector had to be reformed. The timing was right when China began its new round of SOEs reform with the aim of establishing the MES and GCS in the mid-1990s. In 1998, assets and operations of the Chinese oil industry were reconsolidated into three integrated and territorially protected entities—NOCs, CNPC, Sinopec, and CNOOC—incorporating almost all state-owned oilfields and refineries. Through this organizational structure, the resource-dependent relations between upstream and downstream sectors were managed at the intra-firm level, rather than at the level of government planning. This was described as a crucial shift in industrial management “from administrative to corporate hierarchy in production relations” (Lin, 2008, p. 70). The three NOCs have been empowered to make their own financing and investment decisions. Among the three NOCs, both CNPC and Sinopec accounted for most of the crude oil production, oil-refining capacity, and the natural gas output in China's oil sector. CNOOC, with its operations being primarily offshore, has a marginal role relative to CNPC and Sinopec. With the reorganization, the central government aimed to transform them into integrated oil and petrochemical conglomerates that can compete with major international producers (Young, 1998).

To summarize, China's oil sector has been dominated by an oligopoly situation since 1998. To facilitate the formation of the oligopoly, mergers and acquisitions had taken place during the restructuring in the oil sector. It is noteworthy that many mergers in China during that time were in effect ‘takeovers’: ‘administrative mergers’ with loss-making companies taken over by more powerful firms, under the mediation of the superior authority. The primary aim of the merger was to modernize the loss-making SOEs’ management methods and technologies (Nolan & Wang, 1999).

For instance, in November 1997, Qilu Petrochemical, a subsidiary of Sinopec, took over two SOEs in Zibo, Shandong Province, namely Zibo Petrochemical and Zibo Chemical Fiber. Prior to the merger, the two Zibo plants had been municipal SOEs on the verge of bankruptcy, with losses amounting to RMB 2.13 billion Yuan and liabilities RMB 3.62 billion Yuan (Huang & Yan, 2000, p. 116). After the merger, Qilu Petrochemical has integrated the upstream and downstream sectors of the petrochemical industry in Zibo and has made itself the largest SOE in the petrochemical sector in Shandong Province. This is just one example of many such mergers during the restructuring that strengthened the oligopoly in the oil and chemical industry.

The integration of upstream and downstream enterprises has two prominent categories of benefits: first, the elimination of unnecessary internal competition between oil enterprises in the same area, and attainment of economies of scale; second, advancement of research and development. The second benefit was a result of changes in the size and composition of business portfolios and this greatly improved the AP-3 indicator in 2000. In the case of Qilu Petrochemical, the upstream and downstream industries in Zibo were unified after the merger. The production capacity of acrylonitrile plant was increased from 25,000 tons per year to 40,000 tons per year and the profits of both companies (Zibo Petrochemical and Zibo Chemical Fiber) soared to RMB 650 million Yuan in 1999 while their unit cost was reduced by 35% and 49% respectively (Huang & Yan, 2000, pp. 116-117).

The oil giants not only made themselves conglomerates, but also listed stock companies. When CNPC and Sinopec were created, they began restructuring to transform into full-fledged stock companies. Their subsidiaries were separated into production and non-manufacturing companies, with better quality assets included in the production companies and the social welfare responsibilities given to the non-manufacturing companies. By restructuring, the production companies could be more efficient and attractive to more potential investors (Mollet, 1999). With the

purpose of domestic and overseas share listing, PetroChina was established by CNPC in November 1999 as a holding company for all of CNPC's domestic exploration, production, and marketing activities (Nielsen, 2000). Sinopec Ltd was formed by Sinopec in February 2000 as a joint stock entity under the Sinopec (Wu & Fesharaki, 2001). After this process, CNPC and Sinopec were listed.

NOCs and oil price liberalization

China's overheated economy and high inflation in 1993 resulted in high prices of inputs that affected some downstream SOEs (Goldstein, 1993). The government sought to control inflation by reversing the course of oil price reform. Along with the new tax system and the unified foreign exchange system, the government-mandated price guidelines were put forward.¹¹⁶ In May 1994, prices for both crude oil and refined products were controlled by the government again. Wholesale and retail prices for different regions and cities were also decided by the government. The ex-factory prices of refined oil were set by the government. Products at all gas stations were strictly subject to the government-set prices (People's Daily, 1994). The central government's re-control of prices was seen as a general retreat from reform in the oil sector. This was a sharp reversal from a general trend towards a more open oil market beginning in 1992 (Kahn, 1994). The price control lasted until 1998. At that time, the establishment of the three oil giants sought to upgrade the management system to meet international standards, and for the prices of their products to be consistent with international prices. Coincidentally, China's oil imports expanded substantially since the mid-1990s, particularly after the Asian Financial Crisis.¹¹⁷ In face of the pressure from the NOCs and the increasing dependence on

¹¹⁶ The new tax regulations affected the oil industry to a certain extent. Central taxation of the oil industry had a several-fold increase. Heavy taxation, along with limited price liberalization, left the oil producers with little chance to gain profits (Lin, 2008).

¹¹⁷ It is noteworthy that the price shocks of regional and global magnitude from 1997 till 1998 created a good opportunity in China's history of price liberalization. At the regional level, the devalued refined oil products came into China from the neighboring countries affected by the Asian Financial Crisis in 1997, which resulted in huge losses for Sinopec, China's largest downstream producer. At the global level, the crude oil price collapsed at the end of 1997 and stayed bottom through 1998, which made it fall below the domestic price for the first time in the reform era. Thus, CNPC, China's largest upstream producer, also incurred huge losses when the refineries rushed for cheaper oil imports. Thus, resistance to central government intervention diminished and the central government took major steps to liberalize prices in the oil sector. For more discussion about the forces driving China's industrial organizational and pricing reforms in the 1990s, see Lin (2008).

foreign oil imports, China adjusted its domestic oil prices. In June 1998, China reformed the oil pricing system to peg its domestic oil price to Singapore prices, with a one-month lag built in. Since then, the domestic oil prices had been based on Singapore export prices and were adjusted monthly (Anonymous, 1998; Hang & Tu, 2007). This price adjustment facilitated the overseas share listing of CNPC and Sinopec in 2000. In November 2001, the domestic oil prices were adjusted to peg to package price, namely, the prices of New York, Rotterdam, and Singapore markets (Lin, 2010). The market mechanism has begun to play a fundamental role in oil pricing. The growing maturity of the oil pricing mechanism made the AF-2 indicator improve much in 2000 compared to its lowest ordinal value in 1995.

SOEs reform in the coal sector

The decision to establish MES and GCS led to massive changes in the coal sector through consolidations and closures. The state coalmines were transformed into limited liability companies with the state retaining a controlling interest in the companies. For example, as an enterprise under the direct administration of the State Council, Shenhua Group was formed in 1995 by the Shenfu Dongsheng mines, pit mouth power plants, Huanghua coal transport sea port, and the Shenhua double tracking electrified railway (Peng, 2009, p. 15). This restructuring made Shenhua Group the largest state-owned coal company in China. Its production and sales topped in the country while its fatality rate was significantly lower than the national average. Besides the formation of Shenhua Group, three coking enterprises in Shanxi merged to form the Shanxi Coking Coal Group in 2001. In 2002, Ningxia Coal Group was established by the mines in Ningxia (IEA, 2009). State coalmines still dominated the economy. In 2005, coal mining enterprises that were state-owned or had state-held shares had a design capacity of 1,340.5 Mt per year, which was 59.2% of the national total (Peng, 2009, p. 20).

State coalmines, coal pricing, and the closure of TVCMs

The coal pricing liberalization took a gradual approach, as China's economic reform.

China operated a two-tier coal pricing system before 1994. Under this system, state-owned mines sold coal to SOEs at government-controlled prices that were too low to cover costs. This not only discouraged coal production but also led to serious technology inefficiencies and financial deficits in coal mining companies. More than 90% of state-owned coalmines incurred losses in 1993. Facing this difficulty and on route to establishing a 'socialist market economy', the central government was determined to relax the coal pricing. In 1994, the two-tier pricing system for most of the coal market was abolished and the state-owned mines were allowed to sell part of their coal on the market. The prices charged by the state coalmines were raised to more realistic market levels.¹¹⁸ The AF-1 indicator hit the lowest value in 1995. With market mechanism being introduced into the coal sector to make it profitable in the long term,¹¹⁹ the pricing formation of coal grew more mature. In 2000, the AF-1 indicator improved to a high value.

Despite liberalization, the state coalmines remained very passive towards the reform, and did not work out measures for innovation and cost-cutting. The liberalization of coal prices would not automatically lead to the end of losses of state coalmines. The losses were inherited from historical legacy and could not be eliminated or reduced in the short term (Wright, 1996). In 1996, there were still 72% of the state-owned coalmines losing money (IEA, 1999, p. 51). By 1998, state coalmines incurred a loss of RMB 3.7 billion Yuan, making them the principal loss-maker in China (Rui, 2005, p. 704). The long-term losses of state coalmines, peaked in 1998, prompted the central government to shut down TVCMs nationwide. In the early 1990s, the target of establishing a 'socialist market economy' had stimulated the expansion of TVCMs,

¹¹⁸ The price of power coal was still controlled by the government until 2002. The demand for power coal increased rapidly when China's economy recovered from the 1997 Asian Financial Crisis. However, the artificially low prices of power coal discouraged the power coal producers from increasing supply. To increase power coal supply, the central government further relaxed controls over prices of power coal. Since 1 January 2002, guidance price for power coal has been cancelled. See chapter 4 for more discussions on this issue.

¹¹⁹ The process of liberalization witnessed fierce coal price fluctuation. Since the coal prices began to be decontrolled in 1993, the prices increased quite steeply and the price rise accelerated until the beginning of 1994. Since then, partly as a result of the state effort to control inflation, prices stabilized in 1994. In early 1995, prices rose again quite steeply on a regular basis. It is noteworthy that the coal market had not been totally decontrolled. The government still interfered and adopted control measures when inflation was high, such as in 1994 (Wright, 1996).

and rapid development was evident since 1992. As discussed, during the same period, most state coalmines operated at a loss, but this was not considered a serious problem until the end of the 1990s because the state coalmines did not have to worry about their sales in a market that suffered constant shortages. However, at the end of the 1990s, as surplus emerged, the losses suffered by the state coalmines became prominent (Rui, 2005). In fact, 60% of major state coalmines partially or completely stopped production. Until 1998, the unused production capacity amounted to 90 million tons. In contrast, 51,200 out of a total of 61,000 small coalmines were illegal, with a production capacity of 430 million tons; and 13,000 of the illegal coalmines were located in the fields of the state coalmines (Peng, 2009, p. 19). In addition to the long-term losses, state coalmines also suffered from overstaffing and high welfare expenditure, both legacies of the former state enterprise system. Due to the immature social security system, the government could not allow the large numbers of state coalmines to declare bankruptcy. Hence the TVCMs became the target for closure.

Since the government rectified the coal business order, coal production decreased at the turn of the 21st century. This to a large extent affected the AV-1 indicator. As discussed in chapter 4, it remained the same ordinal value in 2000 as in 1995. Besides closing down the TVCMs to salvage the state coalmines, to help enterprises to cut financial losses and inject greater flexibility, the provincial governments took over the SOEs (Zhu & Cherni, 2009).¹²⁰ The administration of the unified distribution coalmines bureaus was transferred to the local authorities. Thus, the key state coalmines were decentralized to provincial governments while the central government focused mostly on the administration of coal mining safety and environmental protection.¹²¹

¹²⁰ Shenhua Group was an exception as it was still under the central government's control. The main reason that Shenhua Group has not been transferred to any local government is because it is a vertically- integrated enterprise, the operation of which needs approval and coordination from more than four ministries and six provincial governments. Transferring it to the local governments will cause difficulty in coordinating these complex interests (Peng, 2009, p. 19). Another exception was China Coal Energy Company. All the other key state-owned coal enterprises have been supervised by provincial governments (Tu, 2011, p. 5).

¹²¹ The decentralization of state coalmines to local governments does not mean that the coalmines become

5.3.4 Western Development Strategy and its impacts on energy sector

China's regional disparities and the Western Development Strategy

At the very beginning of the reform, Deng Xiaoping recognized that it was necessary to let some people get rich first before the vast majority shared the wealth. The stepwise development started from the coastal east. The past two decades of the reform witnessed economic development gap between the eastern and western China enlarging. In 1999, after two years' high growth rate and low inflation rate, China's economy plunged into deflation. Both domestic investment and consumption fell sharply in 1999. Under these conditions, the government had to implement a series of macroeconomic policies to boost domestic demand and consumption to stop the flagging economic growth and to narrow down regional disparities. Western Development Strategy was one of these policies.¹²² The strategy aimed to balance regional development, boost domestic demand, and develop the domestic market.

The Asian Financial Crisis in 1997 made the policy makers realize that it was unrealistic to drive economic growth by exports in the long term. Therefore, huge investment in infrastructure building made up the core of the Western Development Strategy. In September 1999, the Fourth Plenary Session of the Fifteenth Party Congress formally proposed the Western Development Strategy. Developing Western China's infrastructure became a strategic task for the government in the 21st century. In January 2000, a leading group for the Western development was set up by the State Council. Financial, fiscal and taxation support were offered to the West (Peng & Chen, 2011b).

independent. The behavior of the coalmines is strongly influenced by the local governments, which treat them more favorably as a source of local tax revenues to boost the local economy.

¹²² Hou (2011) pointed out that the driving force for the 'Development of Western China' strategy was the 1997 East Asian Financial Crisis. During the crisis, the RMB did not depreciate, which caused significant losses in Chinese trade. The economic downturn urged the Chinese government to carry out massive fiscal expansion to turn the tide. In other words, the massive stimulus package implemented in the form of 'Development of Western China' was a response to the financial crisis.

Energy sector under the Western Development Strategy

In the energy sector, two large projects were initiated under the Western Development Strategy: West-East natural gas transmission project (*Xiqi Dongshu*) and the West-East electricity transmission project (*Xidian Dongsong*). The West-East natural gas transmission project began in 2000, when the government decided to initiate the Qaidam Basin-Xi'ning-Lanzhou gas pipeline. The project was officially started on 4 July 2002. A 2,500 mile natural gas pipeline was completed in August 2004, supplying Eastern China with gas resources from the West. Its annual capacity is about 12 billion cubic meters (Hou, 2011, p. 426). Foreigners had opportunities to invest in the West-East natural gas transmission project. They could hold shares in the project without limits on the shareholding ratio. The equipment imported for the project could be exempted from tariffs and import value-added tax (VAT) (Peng & Chen, 2011b). The price of natural gas from the West was set by the government, which incorporated market factors. In October 2000, the government began to establish a research group to set the pipeline gas price, which was the key factor affecting the downstream market. On this matter, CNPC and local governments hold different views. The former preferred a higher price of about 1.4 Yuan/m³, while the latter insisted on 1.2 Yuan/m³. At last, the State Council set the price at 1.35 Yuan/m³ (Zeng, 2010, p. 297).

The West-East electricity transmission project started in November 2000. The Project was aimed at transmitting electricity from the resource-rich regions in the West to the regions with high electricity demand in the East (Pittman & Zhang, 2010). It was divided into three areas: the Northern Line, the Central Line, and the Southern Line. Within the Northern Line area, Inner Mongolia and Shaanxi transmitted electricity to the North China power grid; within the Central Line area, Sichuan Province transmitted electricity to the Central China and East China power grid; within the Southern Line area, Guizhou, Yunnan, and Guangxi transmitted electricity to the South China power grid (People's Daily, 2000). The project was supported by fiscal measures. The government borrowed money and invested in the project.

The '*Eleventh Five-Year Plan for Western China Development*' made it clear that the government would "make full use of the western region's advantages such as rich hydropower, coal, oil and gas, in order to adjust the energy structure, and to accelerate the construction of several national energy development bases for hydropower, coal, oil and gas resources and processing bases for major energy and chemical products". By the end of 2008, the transmission capacity of the Northern, Central, and Southern lines of the West-East electricity transmission project amounted to 25.5, 17.5, and 20.2 GW respectively (Chen, Li, & Wu, 2010, p. 7108).

5.3.5 A critical review of the economic reform during the second phase and its impact on the energy sector

Again, the second phase of the reform reflects the force of macroeconomic reform on the energy sector. The Chinese government tried to make the country's economic system more efficient and conducive for a market economy. It restructured the government, reformed its fiscal and financial systems, and the SOEs. The government again was very cautious about its reform measures, strongly evident in the SOEs reform in the energy sector. In spite of that, certain reform measures had mutually-offsetting effects.

The formation of SEPA, generally speaking, was conducive to environmental protection and improvement. However, with regards to clean coal technology adoption and environmental protection, the potential benefits of reducing the fragmentation of central government were diluted by other two major reforms in the 1990s, the fiscal reform and the SOEs reform. First, the 1994 fiscal reform redistributed tax revenues between the local and central government. Since the local governments were allowed to keep a large portion of taxes from the enterprises they supervised, they would very carefully scrutinize enterprise investments and their financial performance. They also had a stake in increasing enterprise profits. Thus,

investments in clean coal technology were not appealing because they took long time to generate returns. Second, since the SOEs reform forced the SOEs to face hard budget constraints and blocked their credit access (Cao, Qian, & Weingast, 1999), the SOEs were reluctant to invest in pollution controls lest they incur loans and lose net revenues. To sum up, the fiscal and SOEs reforms discouraged both the local governments and the SOEs from investing in clean coal technology and other environmental protection activities that took longer time to yield profits. The task division between the NDRC and the SETC was not clear and this made it difficult for energy policies to be coherent. Deepening economic reform during the second phase left the energy sector stranded between the plan and the market. Both administrative measures and economic incentives proved ineffective.

On the one hand, the government tried to make the SOEs resemble 'modern enterprises' in the western advanced economy. On the other hand, in the energy sector, the central government was still reluctant to give the oil and power industries considerable market power. It appears to favor the formation of 'conglomerates' of SOEs, such as CNPC and Sinopec in the oil sector or at least maintain the dominant role of SOEs, such as SPCC in the power sector and Shenhua Group in the coal sector. The aim of the reforms was to allow these SOEs, together with other forms of enterprises in the energy sector, to compete with one another in their respective industry. To some extent, the reforms had improved the efficiency of the new SOEs (such as the above-mentioned case of Qilu Petrochemical) and had promoted market competition.

However, this was not free market competition in the real sense. For example, though competition opportunity was provided between CNPC and Sinopec, no further steps were taken to regulate this competition. As long as these SOEs remain in the hands of the government and dominate the economy, it is hard to create a healthy economic structure where all forms of businesses can coexist and flourish and realize true competition. China will still lack a well-functioning market in the

energy sector in the foreseeable future. The following subsection 5.4.1 further confirms this assertion.

The liberalization in the energy sector was also tempered by the government's desire to maintain control over energy prices. This period saw several major initiatives to reform energy pricing. Until 2002, only the coal prices were largely set by market mechanism. The oil prices, albeit explicitly tied to international prices, were still under the supervision of NDRC. Generally speaking, energy policies in China still lacked coherence and its energy sector was still far from liberalization or marketization. As discussed in chapter 3, the rhombuses are the smallest during the second phase of reform, which indicates the worst energy security situation of the reform period. The Chinese government believed that China should deepen its economic reform and further liberalize its energy sector.

5.4 Economic reform and energy sector reform: the third phase (2003-2010)

Until 2002, the Chinese government had initially achieved its mission of 'establishing socialist market economy', but it was far from becoming a mature market economy. Chinese market economy during the time was dominated by the SOEs, and over-intervened by the government as well. The economy was dominated by the SOEs in the sense that it was still easier for the SOEs to obtain resources compared to other enterprises. The SOEs were still protected to some extent in the market competition to guarantee their profits. Other enterprises were restricted or shut down in the name of resource-wasting or environmental pollution. The economy was under excessive control by the government in the sense that the government was still very powerful in resource allocation and enterprises' market competition. This economic situation resulted in overconsumption of resources by the SOEs, low efficiency in resource allocation, and government corruption (Zhang, 2003b). Therefore, when Hu administration came into power, the government began to accelerate SOEs reform and economic transformation.

In the energy sector, several challenges were faced by the new administration as well. First, China's economy was surging again after its slowdown during the Asian Financial Crisis. GDP was rising at a rate about 10% annually by 2003. Drastic economic growth enlarged the country's appetite for energy. The increasing rate of energy demand rose from 5% in 2002 to 16% in 2003 (Meidan, Andrews-Speed, & Ma, 2009, p. 608). Energy supply could not keep pace with energy demand. The time of energy surpluses had gone. Second, China's energy intensity rose again after its steady and continuous decline since the beginning of economic reform. Third, coal continued to dominate the country's energy structure while the construction of new coal-fueled power plants was accelerating and damaging the environment. In addition to the energy challenges, Hu administration also faced the challenges of enlarging regional and social disparities and worsening official corruption. Since the 1990s, the government finally recognized the challenges facing sustainable development.

The challenges need to be addressed comprehensively so as to correct the errors of 'growth at all costs' during the last two decades of reform. Therefore, the third phase is a natural continuation of the second phase but with the aim to address the errors and, according to the Chinese government, to 'perfect' the socialist market economic system. To improve and 'perfect' the system, Hu administration was committed to the policy innovation to address and resolve the negative effects caused by rapid economic development, including the widening gap between rich and poor, environmental degradation and official corruption. The administration realized that, though economic development is of overriding importance, the growth could not be sustainable if the negative effects were not resolved effectively (Zheng, 2011). As a consequence, 'sustainable development' has directed policy orientation in Hu administration, which is more 'social' in terms of the country's economic development. The 'social' can be seen from the administration's slogans include

‘Harmonious Society’ and ‘Scientific Outlook on Development’.¹²³ Hu administration aims for social equity and balanced growth and hence was careful not to pursue GDP increase at the expense of the social welfare of those left behind (Fewsmith, 2004). The *Decision* of the Third Plenary Session of the Sixteenth Party Congress in 2003 made it clear that social development was not simply the pursuit of GDP growth but the holistic and harmonious progress of society.

From then on, the ‘Scientific Outlook on Development’, which highlights harmonious and sustainable development, became a priority for the Hu administration and greatly affected the energy sector. First, these slogans indicate that environmental protection has attracted more attention of the Hu administration than any of its predecessors. Energy sector, as a major contributor to environmental pollution, was thus directly affected. Second, harmonious and sustainable development needs continuing reforms. At the two conferences (National People’s Congress and Chinese People’s Political Consultative Conference) held in March 2005, the word ‘reform’ was frequently used again. Wen Jiabao, in his Government Work Report, proposed to work even harder to promote economic reform. He set out to reform the following: rural sector, SOEs, non-public economic sector, financial sector, fiscal and tax systems and investment system, and the market system (including the pricing reform) (Peng & Chen, 2011b). All these reforms have their respective projections in the energy sector. Therefore, China’s energy policy has undergone important changes during the third phase of the reform. The following subsections discuss the major reform measures that have affected China’s energy sector and the corresponding reforms in the energy sector in China.

5.4.1 Further SOEs reform

SOEs continued to play a central role in the third phase of the reform process. At the

¹²³ The concept of ‘Scientific Outlook on Development’ was first introduced in 2003 and formally endorsed by the tenth National People’s Congress in March 2004. The concept was incorporated into the constitution by the eleventh National People’s Congress in March 2008.

end of 2004, Chinese Vice Premier Huang Ju made it clear that deepening the SOEs reform was the pivot of economic restructuring and that the SOEs reform should be “accelerated to further do away with obstacles to their healthy development” (Huang, 2004). The urgent task was to cultivate big groups of SOEs to compete in the international market. In 2005, China accelerated the re-distribution of state-owned assets and the regrouping of state-owned firms on the basis of market principles. Until 2010, the SOEs had been more competitive than before, attracting more managerial talents and developing more innovative products and processes. The distinction between the SOEs and private sector companies in China had blurred significantly, and the SOEs began to engage in global partnerships and competition. Generally speaking, during the third phase of the economic reform, the SOEs were careful to separate government functions from business operations and be accountable for their own profits and losses (Hassard, Morris, Sheehan, & Xiao, 2010). Energy sector, with a large share of SOEs, has undergone further reforms during this period.

Energy sector under the further SOEs reform

During the third phase of the reform, the SDPC was authorized to lead the power sector reform and it continued to introduce market competition into the power sector. The reform was formally launched in 2002 when the State Council issued the ‘Electric Power Sector Reform Plan’ to adopt ‘the standard global model of deregulation toward competitive utility markets’ (Zhang & Heller, 2004, p. 36). The reform aimed to break the vertical monopoly of the SPCC and introduce competition by means of diversifying the generating plants. The SPCC was dismantled into five power generation groups,¹²⁴ two power grid companies, and four auxiliary companies. In addition to the vertical separation of the power sector, the SDPC also simultaneously separated the sector horizontally by establishing five regional power grid companies (Chen, 2010; Lam, 2004).¹²⁵ Thus, China’s power sector was

¹²⁴ The five power generation groups are all controlled by state interests. Considering their market shares, the effective power of the central government over the electricity industry does not seem to wane.

¹²⁵ The five power generation groups are: Huaneng, Datang, Huadian, Guodian, and the China Power Investment

disaggregated both vertically and horizontally. Meanwhile, the State Electricity Regulatory Commission (SERC) became an independent regulatory agency for the sector. Soon after its establishment, the SERC's independence and authority raised doubts. However, the State Council still granted it more authority over market reforms. Since 2005, the SERC has proposed a series of reform measures to reinforce competition in the power sector. (Chen, 2010).¹²⁶ Continued introduction of competition into the power market improved the AV-4 indicator in 2005.

Despite the disaggregation in the power sector and the establishment of the SERC, the competition was *de facto* among the major state power generation enterprises. By the end of 2008, state-owned and state-held share electricity production enterprises accounted for 90% of the total in the country (Tu, 2011, p. 23). After the '*Suggestions on Deepening the Reform of the Electricity Sector in the Eleventh Five-Year Plan*' was approved by the State Council in 2006,¹²⁷ the State Grid Corporation of China established 30 electricity exchange centers for further electricity market competition. After the establishment of the electricity exchange centers, the power grid companies would be responsible for only power transmission. This separated power transmission from power market transactions, and market mechanisms were further introduced to the power sector. These exchange centers, however, were criticized for failing to introduce changes to the power sector as they were under the direct control of the State Grid Corporation. Electricity transmission and distribution were still kept in the hands of the State Grid Corporation (The Beijing News, 2006).

Under the central government's direction of deepening the SOEs reform and

Group; the two power grid companies are: the State Grid Corporation of China and China Southern Power Grid; and the five regional power grid companies are: Huabei, Dongbei, Xibei, Huadong, and Huazhong (Chen, 2010). The four auxiliary companies are: Power Generation Consulting (Group) Corporation, Hydropower Engineering Consulting (Group) Corporation, Hydraulic and Hydroelectric Construction (Group) Corporation, and Gezhouba (Group) Corporation (Ma & He, 2008).

¹²⁶ NDRC is still the leading regulatory department, hence limiting the SERC's independence.

¹²⁷ The Suggestions largely reiterated the goals of market reform set in the 2002 'Electric Power Sector Reform Plan'. For more details, see 'State Council approves suggestions on electricity industry reform': http://english.gov.cn/2006-11/02/content_431156.htm.

establishing big state-owned enterprise groups, resource consolidation became the overarching policy in the Chinese coal industry during the third phase of the reform. Formation of big groups of SOEs continued in the coal sector. In 2003, more than 10 coalmines were acquired in Shanxi by the Datong Coalmine Group. In 2004, 10 coal companies were consolidated into the Shanxi Coal Group; the Longmei Mining Group was a merger of four state mines in Heilongjiang. In 2005, the state-owned mines in the province merged into the Sichuan Coal Industry Group. In the same year, three key state-owned mines were consolidated in Anhui. In 2006, the share of national output by the top 10 coal producers in China amounted to 27%, an increase from 14% in 1998 (IEA, 2009, p. 56). The eleventh FYP for the coal industry planned to continue nurturing large-scale coal mining groups and construct 13 large-scale coal production bases. In 2010, output from these 13 coal bases accounted for 87.5% of the national total (Tu, 2011, p. 12). Since 2002, energy intensive sectors such as the power and steel industries boomed and prompted a powerful rebound of the coal industry. Facing the extraordinary demand for coal, the TVCMs boomed again even though the central government repeatedly gave orders not to blindly re-open the already closed small mines (Zhu & Cherni, 2009). The production by large coal industry groups continued to decrease the ordinal value of the AV-1 indicator which fell to 1 in 2010. China's coal production is a typical example that reflects how macroeconomic policies predominate over energy policies. The government decision to make full use of comparative advantages of local resources in the early 1980s rationalized coal industry distribution, which greatly stimulated coal production. Since the 1990s, the fluctuation of coal production was deeply affected by the gradual penetration of liberalization and marketization. All these explain how strong the force of macroeconomic reform is and how it leads the direction of coal production (and thus the AV-1 value). In contrast, the formation of large coal groups provided a sound environment for technological advancement. The AP-4 indicator hit the highest value 10 in 2005, and again in 2010.

5.4.2 Continuing marketization

When the third phase of the economic reform began, the framework of socialist market economic system was still incomplete. Although the planned economic system was not dominant, it still played an important role in many aspects of the national economy. Chinese market economy was still a kind of government-led market economic model in its initial phase of industrialization and marketization (Zhang, 2006). To accelerate the process of marketization in China, the *Decision* of the Third Plenary Session of the Sixteenth Party Congress in 2003 pointed out that the main task was to improve the market economic system. To improve the system, the government revised restrictive policies on the development of non-public economy. Non-public capital was allowed to enter into more industries, as long as the law did not prohibit it. Continued marketization offered opportunities for the energy sector to intensify competition and liberalize prices.

Energy sector under continuing marketization

Since 2005, the government has decided to proceed with the reform of the energy price formation mechanism. It further reduced government intervention in the resource allocation and price formation, and established a market-oriented resource price formation mechanism (People's Daily, 2005c). In the coal sector, testing reforms to fundamentally transform the coal market began in Shanxi in 2007. A major aim was to create an open coal market in 2008, where demand matched supply and all transactions are market-based. Foreign investors were allowed to enter China's coal sector after 2008 (Betz, 2013). Also in 2007, NDRC ceased hosting coal ordering conferences which began in the 1960s for allocating coal resources in China. Government has been much less involved in coal pricing intervention since then (IEA, 2009, p. 58). In December 2009, NDRC issued the '*Guidelines Regarding Improving the Linkage Amongst Coal Production, Transport, and Demand*'. It specified that the thermal coal contracts should be directly and independently negotiated between the power plants and coal companies without government intervention (Tu, 2011, p. 15). Coal pricing and allocation were fundamentally changed from the government-set or

government-indicative system to the market-regulated system. The ordinal value of AF-1 indicator reached a moderate level and remained steady since 2000. It is expected to rise as the market matures. Another prominent impact of further marketization was that the increasingly market-oriented coal sector weakened the central government's control over coal production. For example, the actual national coal production amounted to 3,240 Mt in 2010, exceeding 25% of the output target of 2,600 Mt set by the NDRC in its eleventh FYP for the coal industry.

In the power sector, a series of electricity pricing regulations have been issued since 2002, including *'Electric Power Sector Reform Plan'* in 2002, *'Scheme of the Reform of Electricity Prices'* in 2003, *'Coal-Electricity Price Linkage Mechanism'* in 2004,¹²⁸ and *'Procedures for Implementation of the Reform of Electricity Prices'* in 2005. In the regions where competitive wholesale market was not created, the operation-period prices and yardstick prices formulated in 1997 were still in use. In the regions that practiced the competitive wholesale transaction, the price incorporates two components: capacity price and volume price. The former was determined by the government according to the average cost of all generation units whereas the latter was determined by the competitive market (Ma & He, 2008). Nevertheless, since power industry is a basic industry affecting many downstream industries and millions of households, the government is very cautious with the increase in electricity prices, making the price hike very difficult. Generally speaking, the electricity price is still strictly regulated by the central government. A competitive power market in the real sense has not been established yet. Therefore, China's coal and power sector experiences unbalanced development. The coal sector is already subject to market regulation; the power sector is still largely controlled by the government, despite the introduction of market competition. This caused the AF-3 indicator to remain at the highest ordinal value in 2005, and again in 2010.

¹²⁸ The Coal-Electricity Price Linkage Mechanism was less frequently used in subsequent years due to political pressure to keep the power prices low.

The unbalanced development of reforms in the coal and power sectors resulted in coal price volatility in China. The coexistence of a competitive coal market and a regulated power market created tension between the power and coal sectors. Under the pressure of rising domestic coal prices, the power companies entered international markets to purchase coal and this reinforced their negotiating power in the domestic coal market. As a result, coal prices were more volatile when the power enterprises enter and exit the international market erratically (Peng, 2009). The ordinal value of AF-4 indicator declined fast since 2000, from 6 to 1 in 2010.

Despite the introduction of market competition in the energy sector, Hu administration tried to reassert control over the energy sector with increased administrative means to tighten state control over the energy industry. In March 2003, the government established the Energy Bureau under the NDRC to centralize control over the energy sector and formulate and implement energy policy in a more overarching way (Meidan, Andrews-Speed, & Ma, 2009). From 2003 to 2004, China suffered widespread power shortages, which contributed to a substantial increase in oil demand and imports as diesel generators were run to maintain power. In 2004 blackouts troubled most of China's provinces. Net imports of crude oil grew by almost 50 percent. The power shortages and surge in oil demand and imports stimulated change in China's energy sector management. Dissatisfied by the poor energy governance in China, the central government set up the Energy Leading Group (ELG) in 2005, headed by Premier Wen Jiabao (Downs, 2006). The ELG serves as the steering committee for the central government to reinforce its control over the energy sector. Obviously, the formation of ELG was an extemporaneous decision resulted from the energy crisis of 2003 to 2004 and the leadership's dissatisfaction with China's energy policymaking apparatus. China did not have a forward-looking plan to establish an institute to oversee the whole energy sector, and it still falls short of an authoritative and independent ministerial-level agency to govern the energy sector of the country. This once again shows that the government very passively issued energy policies just to solve the problems whenever and wherever they took

place.

The approach that the Chinese government tried to settle the problem whenever and wherever they met the problem inevitably resulted in contradictory policies and actions towards the energy sector. Driven by the macroeconomic reforms, market competition continued to grow in the energy sector. At the same time, the government continued to intervene in the energy sector as it was regarded as the key sector of strategic importance in the national economy. This is exactly the story: on the one hand, the government cannot stop the force of macroeconomic reform once it is initiated; on the other hand, the government, whenever it deem suitable, try to maintain their control over the 'strategic' sector of energy. The government is frequently put in an afflicting position where it struggles to balance between deepening market reform and steady state control. This also explains why China does not have coherent energy policies.

5.4.3 Increasing attention to environmental protection

China's economic development during the first two decades of economic reform had emphasized the growth of heavy industry, much of which was energy-intensive and environmentally damaging. What made things worse was the government's disregard for its own environmental regulations in its haste to secure economic growth. When Hu administration came into power, the level of pollution in China continued to worsen. GHG emissions abatement became an increasingly important policy concern for the Hu administration. In 2004, after consultation with local and foreign energy experts, the Development Research Center of the State Council announced its *National Energy Strategy and Policy Report*. This report specified the sustainable use of energy as the key national priority. Examples of measures specified in the report include constraining demand for fossil fuels; establishing economic incentives to save energy; encouraging the use of clean coal technology; and implementing stricter energy efficiency and environmental standards (Sinton, Stern, Aden, & Levine, 2005;

Miller, 2006). This report reflected the Chinese government's new conscientiousness on energy security.

As the central government understood that China needed to curb its spiking carbon emissions, it developed an increasingly comprehensive and proactive policy to control CO₂ emissions. Since the tenth FYP (2001-2005), China had gravely fallen far behind its pollution and energy reduction targets: China's global CO₂ emissions soared to nearly 20% in 2005. Environmental concerns were highlighted in energy security policies of China's eleventh FYP (2006-2010), hence setting the goal of cutting national energy intensity by 20% from 2005 to 2010. The 20% energy-intensity target can be translated into an annual reduction of more than 1.5 billion tons of CO₂ by 2010 (Lin, Zhou, Levine, & Fridley, 2008, p. 954).

The NDRC issued '*China's National Climate Change Programme*' in 2007.¹²⁹ The Programme specified energy-related policies and measures to mitigate climate change by reducing CO₂ emissions. These measures include: proper development of hydropower; active promotion of nuclear power development; expediting technology progress in thermal power generation; vigorous development of coal-bed methane (CBM) and coal-mine methane (CMM) industry; promotion of bio-energy development and support for the development and utilization of renewable energy including wind, solar, geothermal and tidal energy (NDRC, 2007c). China was the first developing country that had published a national strategy to combat climate change. In the same year, President Hu Jintao highlighted this report at the seventeenth National Congress of the Communist Party of China:

"The development pattern will be significantly transformed. We will quadruple the per capita GDP of the year 2000 by 2020 through optimizing the economic structure and improving economic returns while reducing consumption of resources and

¹²⁹ For the key elements of the program, see <http://www.un.org/ga/president/61/follow-up/climatechange/China-KeyElements.pdf>

protecting the environment” (Hu, 2007).

As directed by the Program and the government’s determination, ambitious goals were set to attain renewable energy development for long-term energy security purposes. It targeted to increase the share of renewable energy in the country’s energy structure to 10% by 2010 and 15% by 2020. Since 2006, China had invested more than USD 10 billion annually in renewable energy resources (Karl, Han, & Olsson, 2009, p. 128). Until 2010, the AC indicator improved to a level that was almost equivalent to that of 1980. As discussed in chapter 3, Hu administration demonstrates larger rhombuses, compared with Jiang administration.

5.5 China’s economic reform and energy security: a chapter conclusion

China, always cautious about its economic reform, had been guided by the philosophy of ‘crossing the river by feeling the stones’ throughout its more than three decades of reform. At the beginning of the reform, the government did not know which direction to take. It was then imperative to address the irrational distribution of industries left behind by the previous administration. The government adjusted the economy, including the energy industry, by relocating it according to the principle of ‘comparative advantage’. The redistribution fostered the fast development of energy industry in subsequent years.

One major policy introduced in the beginning reform era was HRS, which promoted the fast growth of TVEs, including the TVCMs. Their development has both positive and negative effects on the energy sector. The key advantage was the fast increase of coal production, while the disadvantages were mainly wasted resources and environmental pollution. In addition to the introduction of HRS and the growth of TVCMs in the coal sector, the power sector during Deng administration had also undergone some degree of reform after its opening to foreign and private investors. The two-tier pricing system resulted in government-set and market-regulated prices

in the coal sector. The failure of price reform in 1989 led to the readjustment of the national economy, including the energy sector. From the very beginning of the reform, it is obvious that all the energy sector reforms and policies were merely passive responses (reactions) to the overall macroeconomic reforms. This characteristic is evident during the Jiang and Hu administrations.

During Jiang administration, there were four major reforms that directly affected the energy sector: government restructuring, fiscal reform, financial reform, and SOEs reform. As a result, the energy sector reformed its institutions, its SOEs, and changed its energy conservation performance. During Hu administration, reform priorities were adjusted to address deepening market reform and environmental protection issues. Along with this trend, China's energy SOEs experienced further reforms and extended pollution control. Throughout the reform period, energy policies showed no coherence, such as the policies swinging between control and relaxation of oil prices, stimulation and discouragement of TVCMs development, and the establishment and elimination of government mechanism to conserve energy. The non-coherence is exactly the 'by-product' of the macroeconomic reform. Everytime there is energy policy change or reverse, there must be some major macroeconomic reform measure taking place in advance.

To summarize, China's energy policies did not originate from energy security concerns and were not intended to improve the energy security situation. They have always been passively reactive and responsive to the country's macroeconomic reform. Therefore, it is impossible for China to have a coherent energy policy or energy strategy targeted to enhance the country's energy security. In other words, China's energy policies are constrained by its reform. The macroeconomic reform is such a strong force that it diminishes other factors that might also affect the energy sector and dominates the energy sector policies. Just as a bird cannot fly out of its cage, China's energy policy cannot escape from the limitations of macroeconomic reform. The data indicate that China's energy security has improved to some extent

since 1995 but has not attained the high level of 1985. Future prospects may seem brighter than in what we saw in 1985, but the improvement is still subject to the macroeconomic policies and cannot jump out of the confines of economic reform.

Chapter 6 Conclusion

6.1 Introduction

This study establishes the Macro Economy-driven Energy Security Mechanism and answers the following three broadly defined energy security and policy questions: How has China's energy security situation evolved? What is the impact of China's energy policies on the energy security situation? Why has China not improved its energy security?

To answer the first question, a quantitative framework is constructed to evaluate energy security in China. The framework explains that China's energy security situation has not improved during its three decades of economic reform. To answer the second question, the direct impact of China's energy policies on its energy security situation over the past three decades is examined, and the evolution of energy policies and the energy security situation in China is explained. To answer the third question, the impetus behind the evolution of energy policies and the energy security situation in China is explored. The key reason is that China's energy policies are not intentional policies derived from an early blueprint. Rather, the policies are a passive reaction to overall economic reform and transition. Reform acts as a constraint on energy policies. The reform measures *per se*, as Deng Xiaoping described, were 'crossing the river by groping for stones'. That is to say China's reform has been undertaken slowly, one step at a time. Constrained by the incremental approach of macroeconomic reform, the energy policies, like a mirror, precisely reflect every change in China's macroeconomic policies. Under this condition, the evolution of energy policies, being incremental as well, was subject to macroeconomic reform in China. This made it impossible for China to develop coherent and creative energy policies to improve its energy security. That is why energy security in China did not improve during the three decades of economic reform.

To explain the causality between macroeconomic reform and the evolution of China's energy security, this study establishes the Macro Economy-driven Energy Security Mechanism, which integrates both quantitative and qualitative methodologies to address the evolution of energy security in China and explain how macroeconomic reform drives such evolution. This mechanism consists of two parts. The first part reflects the qualitative methodology adopted by this study. It shows that macroeconomic reforms drive/constrain energy policies and that the energy policies directly affect the four dimensions of energy security. The second part reflects the quantitative methodology this study uses to quantify energy security in China. Through quantification, the figures of each of the four energy security dimensions can be calculated such that whether energy security situation, constructed by the four dimensions, has improved or deteriorated can be concluded. Incorporating the two parts, the Macro Economy-driven Energy Security Mechanism exactly indicates how macroeconomic reforms, as the key and major driving force, via their function in energy policies, have impacted on each of the four dimensions and finally have framed the energy security situation.

Applying the Macro Economy-driven Energy Security Mechanism, this study examines all the major macroeconomic reform measures over three decades in China. It finds that all the reforms have their reflection in energy sector and affect the promulgation and implementation of energy policies. For example, in the 1980s, the central government's decision to rectify the economic disorder led to the adjustment of energy industry distribution. Production efficiency of the coal industry was greatly increased. The Household Responsibility System made an outlet for the fast development of town and village enterprises, among them were the town and village coalmines that greatly contributed to coal production in China. The two-tier pricing system made the in-quota and above-quota coal and oil prices that lasted for nearly one decade. In the 1990s, the State-owned enterprises (SOEs) reform led to the shutdown of town and village coalmines. The SOEs reform also created several

large state enterprises in the oil and electricity sectors, which hindered the marketization in these industries. The government restructuring in the 1990s revoked institutions that had been favorable for encouragement of energy efficiency. Since 2000, further marketization in the economy led to a completely free coal market. To put it simply, every economic reform measure has its reflection in the energy sector and finally frames energy security situation.

The identification of the causality between China's macroeconomic reforms and the evolution of China's energy security has its implications especially for future policy-making. Understanding that China's energy policies are constrained by its macroeconomic reform, the Chinese government could endeavor to have some 'proactive' energy policies to improve energy security. For example, experiences in the 1980s show that administrative measures are more efficient for energy conservation. The government can promulgate favorable tax policies for saving energy. In the coal sector, township and village coalmines that had greatly contributed to China's coal supply should continue to be encouraged. Considering the bad performance of environmental protection in the coal sector after the Ministry of Coal Industry was revoked due to government restructuring in the 1990s, the environmental administrations and other supervising institutions should coordinate to guarantee that these township and village coalmines protect the environment during coal mining. In the electricity sector, the measures to encourage various sources of investment in the 1980s are good examples for the current administration to refer to. The government should continue the variety of investment sources, instead of merely relying on several large state enterprises for investment. In the oil sector, the oligopoly situation does not induce competition efficiently. Although it is not possible to fundamentally liberalize the sector at the moment, further marketization and competition could be introduced by allowing more foreign and private investors, and thus breaking the oligopoly. In fact, the new administration under President Xi Jinping has been working on the measures to

attract new investment sources such as private capitals to enter the energy market. This is an example in point that illustrates the importance of this study in terms of its policy implications.

6.2 Contribution of the study: the quantitative methodology

This study establishes a quantitative framework based on a comprehensive concept of energy security to examine China's situation. The framework incorporates 20 indicators that best quantify the evolution of energy security in China. It consists of two tiers. The first tier, the 4-As framework based on energy economics, is common for all countries. The second tier, the 20 indicators quantifying energy security in China, is country-specific and contingent on data availability. In this sense, the framework is both universal and country-specific. It could do more than evaluate China's energy policy and security, and could be generalized to evaluate the energy policy and energy security of any country by using expanded and/or modified indicators. As long as the key indicators for a country are identified under the framework, the energy security situation of that country could be evaluated. Therefore, the framework is very flexible, expandable, and user-friendly. Future research could be done for the application of the quantitative framework on other countries.

The concept of energy security has evolved over time. In the beginning, it focused on adequate and reliable energy supplies—particularly oil supply—in the narrow sense. In the broad sense, the energy security issue covers various energy resources. Reasonable and stable oil/energy prices are also considered a key component of energy security. To sum up, energy security incorporates three elements: reliability, adequacy, and reasonable price. It is the availability of a stable and reliable energy supply at all times, in sufficient quantities, and at reasonable and affordable prices. These three elements cover several different dimensions of energy security such as

economics, technology, and environment. In terms of the economic dimension, energy security means a sufficient supply of energy resources and affordability by energy consumers. In terms of the technological dimension, energy security requires the efficient use of energy not only by sound management of energy use, but also by technological innovation. In terms of the environmental dimension, energy security requires sustainable energy development, which means that an energy secure country is able to guarantee the availability of energy resources in a sustainable manner. To better understand the essence of energy security, scholars have been trying to add new components and/or dimensions. Beyond the qualitative description of energy security, quantitative indicators have been designed and frameworks incorporating these indicators have been established to quantify energy security, thus making the evaluation and interpretation of energy security more effective.

Based on the existing concepts, indicators, and frameworks of energy security, this study constructs a quantitative instrument —the 4-As evaluation framework (availability, applicability, acceptability, and affordability) —to assess China's energy policies and energy security status. In addition to the framework, this study uses an imbalance index to examine how balanced the development of the four dimensions of energy security in China is. It looks into China's energy security trends starting from the initial period of economic reform and opening up of Deng Xiaoping's administration in 1980 and ending with the late period of Hu Jintao's administration in 2010. The stated timeframe is divided into six periods, reflecting the policy priority change of China's Five-Year Plans (FYPs) for National Economic and Social Development throughout different administrations. The six FYPs discussed are the sixth (1981-1985), seventh (1986-1990), eighth (1991-1995), ninth (1996-2000), tenth (2001-2005), and eleventh (2006-2010) during the administrations of Deng Xiaoping, Jiang Zemin, and Hu Jintao. The implementation of key energy policies and their effects on China's energy security over the three decades are examined.

The quantitative results based on the framework indicate that China's energy security was at its best during the sixth FYP period, but then deteriorated until it hit higher levels between 1995 and 2005. However, this was still lower than the level reached during the sixth FYP period. During the eleventh FYP period, the energy security situation deteriorated again. Policy priority appears to affect the country's energy security status during each specific FYP period. In the sixth FYP, the overall low level of technology negatively affected the status of energy security, but it was offset by relatively low volatility in energy prices and a cleaner environment. The imbalance index also showed that the four dimensions of energy security developed in a relatively balanced way. The policy priority of expanding energy supply did not change much during the seventh FYP. The effort to increase energy production led to an obvious decrease in resources available to China for further exploitation.

The goal to establish a 'socialist market economy' during the 1990s stimulated several strong reform measures, including government restructuring, fiscal and financial reforms, and reforms of state-owned enterprises. One prominent reform was the change in energy pricing. In the eighth FYP, coal prices (except coal for electricity generation) were freed up and electricity tariffs were allowed to increase to some extent. This resulted in faster energy price growth and higher price volatility. The environment continued to deteriorate and the energy security situation reached its lowest point in 1995. The imbalance index also showed that the four dimensions of energy security experienced unbalanced development in 1995. The situation improved a little in 2000 mainly due to the stabilization of price growth and improved energy technology. In the 1980s and the 1990s, even though environmental protection had been stated in policy documents, the government did not take many practical measures to improve the environment.

The expansion of the energy supply to sustain China's fast growing economy continued to be a key goal during the 10th and 11th FYP periods. Technology advancement was emphasized and achieved by the government. The 10th FYP emphasized the introduction of market mechanisms into the energy sector and price liberalization of energy products became more mature. Environmental protection, however, had been neglected for too long and resulted in severe consequences: the environmental dimension of energy security hit the lowest level in 2005. In the 11th FYP, the government took several practical and operational measures to stop environmental deterioration. Technology and market mechanisms continued to develop, but very low energy availability weakened the energy security situation during this period. The low availability also made the development of the four dimensions of energy security very unbalanced, as indicated by the imbalance index in 2010.

In sum, the quantitative methodology explains that China's energy security has not improved during its 30 years' of economic reform. The growing appetite for energy resources has made the quantitative value of the availability dimension decline; the environmental (acceptability) dimension has deteriorated along with energy utilization, only improving a little recently. The affordability dimension has improved after hitting its worst status in 1995. Although the country's technology has progressed continuously, improvement in the applicability dimension cannot reverse the overall energy security status to the level of the early reform period. Energy policy priority appears to have directly affected the energy security situation. In China, the direct effects are constrained by the macroeconomic reform measure, which determines every reform and policy measure in the energy sector.

6.3 Contribution of the study: the qualitative methodology

This study creates a new framework for analyzing energy policies and energy security in China. This analytical framework offers a solution to the puzzle of ‘why China’s energy security situation has not improved despite its three decades of fast economic growth’. It identifies the key variable that has affected the evolution of energy security in China: macroeconomic reform. The analytical framework does not deny that intervening variables, such as centralized decision-making, conflict of group interests, etc., may also impact energy security, but it pinpoints the predominant variable that best explains the evolution trend of energy security in China and why the security situation did not improve during three decades of economic reform. Besides solving the puzzle raised in this study, this analytical framework is capable of analyzing other domestic industrial policies in China, such as agricultural policies. These policies, like energy policy, cannot overcome the constraint of macroeconomic reform in China. Future research could be conducted on these policies using the analytical framework.

The Chinese economy was a highly prescriptive planned economy until economic reform and opening-up began in 1979. Accordingly, China’s energy policies can be broadly categorized into two periods: pre-1979 and post-1979. Before the reform, energy policies were reflected through government investments and overall arrangements in the energy industry and the main focus was increasing the energy supply. Extraction, generation, transport, and allocation of energy resources were directly controlled by the central government. Energy resource extraction was heavily subsidized by the government. After 1979, the Chinese government focused on economic reform to revive the national economy which had been severely disrupted by the Great Leap Forward, the Cultural Revolution, and other political movements. The economic reform process that China embarked on in 1979 saw incremental liberalization of agriculture and the state sector, as well as the gradual

restructuring of institutions to facilitate economic reform and marketization. From then on, macroeconomic reform began to play a key role in energy policy promulgation and implementation, and it became the key variable in energy security evolution in China. Two major measures were undertaken in the initial period. First, the government granted partial managerial autonomy to the micro units in the agricultural sector by the Household Responsibility System (HRS). The withdrawn incentives were reinstated and local and private initiatives were encouraged. The HRS spurred rapid growth of township and village enterprises (TVEs). The entry of rural industries increased competition in the industrial sector. The protected industrial sector was thus effectively opened to new entrants, including township and village coalmines. These coalmines greatly contributed to the coal supply and directly affected coal production in China.

At the same time, a dual-tier pricing system was introduced to allow the resources to be increasingly allocated by the micro units. This system had both a traditional plan and a market channel for resource allocation. During Deng's administration, this system offered valuable flexibility by allowing state-owned enterprises (SOEs) to transact and cooperate with other firms (Naughton, 1999). It constructed favorable conditions for pricing reform in the energy sector at the time. Any production of coal (by state mines) and oil above the quota set by the government could be sold at a higher market price. Price deregulation had begun to promote the exploration and exploitation of energy resources and improve profitability in the energy industry. Marketization was, very cautiously and primitively, introduced in China's energy sector.

During Deng's administration, as the reform progress was very cautious and slow, few reforms were carried out in the state sector except for policies stimulating investment in the power industry. State coalmines and oil companies largely kept

their status quo. Since the state sector was the major force of technology advancement, the AP dimension of the framework did not improve much. The AC dimension did not receive much attention either. The macroeconomic situation and related reform measures determined that energy policies mainly focused on encouraging energy supply (the AV dimension) and partially decontrolling energy prices (the AF dimension). To sum up, the energy policy formulation, given the reform background, reflected the characteristics of China's economic reform. The Macro Economy-driven Energy Security Mechanism worked during Deng's administration as follows: reforms were aimed at increasing incentives and autonomy at the micro-level and expanding market forces and increasing efficiency in resource allocation. The emergence of TVEs was especially prominent. These enterprises drew on labor released from farming by the introduction of the HRS and resources available in the market via the dual-tier pricing system. Correspondingly, the energy sector during this period could be characterized by two major measures. One was the emergence of township and village coalmines, which improved the productivity of the energy industry. The other was the introduction of the unique system of dual-tier pricing, which liberalized above-quota coal and oil prices to a limited extent.

Following Deng Xiaoping's Southern Tour in 1992, China's economy experienced unprecedented rapid development. Jiang's administration saw drastic reform measures in the Chinese economy. Having recognized the numerous basic deficiencies in the economy, the central government launched comprehensive reforms in 1994 in every major sector in the national economy. From 1994 to 1998, broad reforms in the Chinese economy continued and a series of milestone reforms transformed every aspect of the Chinese economy, including government restructuring, fiscal reform, banking reform, SOEs reform, and so on. In rapid succession, most of the remnants of central planning were abolished and price controls were relaxed. In the second half of the 1990s, the Chinese economy was

characterized by a mixture of the old system, which had lost most of its effectiveness, and an emerging market economy that did not function as intended. The reform measures and the relevant macroeconomic situation had a deep impact on the energy sector. Again, China's macroeconomic reform worked as the predominant force directing its energy security evolution. The predominance was reflected mainly in three points.

First, the economic reform weakened the top-down vertical authority of the state government. Jiang's administration witnessed considerable down-sizing of central government personnel, institutional structure, and dedicated funding. The wave of institutional reorganization in 1998 abolished most of the economic ministries and consolidated the planning agencies. China began to move towards a regulatory state suited to a functioning market economy (Yang, 2004). The institutional reorganization also reshuffled the energy sector. The irreversible shift from a planned economy to a market economy necessitated a shift in the authority over the energy sector from ministries to SOEs. The removal of the government from enterprise work made the business of controlling energy production the responsibility of the emerging independent corporate actors. The government's responsibility was mainly to identify emerging trends and forecast future trends in China's energy situation (Cunningham, 2007).

Second, the fiscal reform had mixed effects on energy policies and the energy security situation. On the one hand, national revenues recovered under the new fiscal system. The central government was able to direct incremental resources to lagging regions to balance regional disparities, such as the initiation of the Western Development Strategy. On the other hand, direct government financing for energy conservation projects was abolished even though continued and active government involvement is crucial for energy conservation. This discouraged the development of

energy conservation activities by the enterprises. Since the late 1990s, the decreasing rate of energy intensity has slowed down. In 2005, the energy intensity even increased.

Third, the reform measure during Jiang's administration that had the most far-reaching impact on the energy sector was the reform of SOEs. Although the Deng administration witnessed booming business and fast economic growth, China's economy had deep-seated internal problems. Jiang's administration began to subject SOEs to substantial market disciplines. The government's reform of SOEs created newly empowered corporate actors. The operation of SOEs became more like a business than an administrative institution and they developed an increasingly commercial orientation. In the energy industry, the central government developed restructuring plans for SOEs in the oil, electricity, and coal sectors by creating several rival state-run corporations, which were injected with modern competition. The reform gave these SOEs greater autonomy and improved efficiency. Their market-oriented business behavior increased sharply. Standard international practices were stimulated in the energy sector along with the expansion of SOEs reform.

In addition, the 1994 reforms in finance, taxation, and so on spurred the reform of the energy pricing system. It was generally approved that energy prices should be set by the market. At the same time, the newly established energy corporations required the energy pricing mechanism to be reformed to comply with international standards and practices. The deregulation of coal and oil prices was accelerated in the early 1990s and, when the market track was well on the way, pricing underwent further liberalization. Energy pricing reform has gained momentum since 1996. To put it simply, energy policies under the Jiang administration underwent substantial changes across the government institutions, state industries, and national economy

amid the creation and restructuring of companies, abolishment of ministries, and reformation of pricing systems for energy resources. The strength of macroeconomic reform was reflected in every change in China's energy sector.

In contrast, Hu's administration aimed at overcoming widespread criticisms and social tensions left behind by the economic transition during the Jiang administration. Its macro-policy package was largely a continuation of that of the Jiang administration, but with enhanced policies to deal with the economic and social challenges left by Jiang. The enhancement was reflected in three aspects: deeper reforms of SOEs, continued marketization, and increased attention to environmental protection. Correspondingly, China's energy policies during the Hu administration emphasized continuing marketization and environmental improvement.

First, the Hu administration tried to induce the market mechanism into the energy sector. To some extent, its efforts succeeded. On the one hand, it is true that the market force had been injected into the energy sector with an open coal market, an increasingly competitive power market, and an oil market subject to international oil prices. On the other hand, the competition was largely among state enterprises. The state-owned large-scale coal groups contributed an increasing share of the national coal output, along with government efforts to shut down the town and village coalmines. Despite the disaggregation, the reform in the power sector was actually resource reallocation and the competition was *de facto* among the major state enterprises. The oil sector was indeed dominated by the three state oil companies. Although the coal price was regulated by the market and the oil price was pegged to international price indices, they remained under the supervision of the National Development and Reform Commission. The electricity price was still strictly regulated by the central government. A competitive power market in the real sense

had not yet been established. Changes in energy prices were modest with only regular small adjustments during Hu's administration.

Second, during the Hu administration the environmental issue became a priority on the government's agenda. The environmental regulation framework was a kind of 'command and control' system. The Ministry of Environmental Protection of the People's Republic of China issued regulations. Inspectors were sent to check on the implementation processes and fines were imposed on violators. The problem was that the regulations were not consistent across firms. Large state enterprises received much attention whereas the regulation of small-scale firms, particularly TVEs, was often neglected. This was partly due to officials overlooking pollution caused by firms that local economies were dependent on for jobs and tax revenue (Roumasset, Burnett, & Wang, 2008). Therefore, although the environment largely improved during the Hu administration, the improvement was not consistent over the years.

To sum up, the Macro Economy-driven Energy Security Mechanism was in effect throughout the three administrations. Macroeconomic reform in China was such a strong force that no other factor that might impact energy security evolution could prevail against it. China's energy policies and energy security evolution were strictly constrained by its macroeconomic reform measures. Their passive reaction to China's macroeconomic reform meant that specific policies or programs were formulated independently under each macroeconomic reform measure. China's economic reform and energy policies do not have a worked-out plan. They cannot be put into a unified framework and strategy, and this determines that China does not and cannot have coherent energy policies. China's energy security changed very passively as it was subject to the reform imposed by the central government. Energy policies have directly affected the country's energy security evolution, but energy

policies *per se* are not the key drivers of energy development nor are they the fundamental forces framing the energy security status. Rather, it is the Chinese economic reform that frames the energy security situation. The energy policies that had been favorable to energy security improvement, such as policies that encouraged the development of town and village coalmines, policies that introduced competition and market forces into the electricity sector, and so on, could not be sustained under the macroeconomic reform measures.

The tide of Chinese macroeconomic reform is irreversible. Once initiated, it works like water rushing out of a floodgate with great energy. It started with the micro-management institution reform giving autonomy to micro-management units, as reflected by the introduction of HRS and the emergence of TVEs. In the energy sector, town and village coalmines began to contribute an increasing share of China's coal production. The micro-level reform promoted production incentives and created additional resources. These profits were allocated to sectors that had been suppressed under the pre-reform system. In this way, economic growth was accelerated and the whole society benefited from the profit sharing. This was reflected by the reform of SOEs and pricing reform. Along with the deepening of the reform, the conflicts between the reformed micro-management units and the macro-policy environment became obvious. In the early 1990s, China's fiscal system, financial system, and government structure were no longer compatible with the situation of the reformed micro-level. Since benefits already given to the micro-level could not be taken back, the conflicts required the reform to be extended to the macro-level. That is to say, the incremental process called for a compatible macro-policy environment. The gradualist reform, beginning with the micro-level and non-public sector of the economy, spilled over to the macro-policy environment, which was reflected by the reform package in 1994. The Jiang administration witnessed drastic reform at the macro-level, which once again deeply affected the energy sector in China. At the same time, reform at the micro-level, which was

focused on SOEs, continued. China's energy sector was greatly affected by SOE reforms taking place in the coal, oil, and power industries. During the Hu administration, marketization continued to deepen. Correspondingly, the energy sector continued its reform and adjustment, including its SOEs and prices. As Naughton (2008) put it, these state enterprises "were well positioned to take advantage of the acceleration of the Chinese economy" (p. 123). China's economic reform has definitely affected China's energy policies. Energy policies are just passive reactions to economic reform. The logic of how reform affects energy policies and frames the energy security situation explains why China's energy policies are not and cannot be proactively designed to improve energy security. Macroeconomic reform is an overwhelmingly strong force and has made itself the key variable directing energy policy and energy security evolution in China.

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