ELECTRIC POWER AND ENERGY IN CHINA

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About the Author

Zhenya Liu is the Chairman of the State Grid Corporation of China. As a senior engineer, he is entitled to the special governmental allowances offered by the State Council of the Chinese Government and is one of the most renowned experts in the global economy and energy sector.

The project 'UHV AC Transmission Key Technology, Equipment and Engineering Application' led by Mr Liu was granted the 2012 National Award for Science and Technology Progress (Special Prize). Mr Liu also proposed an innovative theoretical and technical roadmap for UHV transmission tailored to China's needs. Under his leadership, a series of major challenges have been well-addressed, such as the UHV AC voltage control, test technology, system integration and UHV DC large-capacity converter valve, DC engineering standardisation, etc.

Mr Liu has also led the world's first UHV AC transmission project and state-of-the-art UHV DC transmission project to success, through which China has fully mastered the UHV core technology with independent intellectual property rights as well as the manufacturing capacity of full-spectrum equipments. In addition, Mr Liu's publications, including *Electric Power and Energy in China*, and *Ultra High Voltage Power Grid*, have been well-received in China and are bestsellers in their field.

Preface

Energy is an important material foundation for economic growth and social development. The use of energy has brought about revolutionary changes to human society, making production and human life more convenient and comfortable. A historical survey of human social development reveals that every major leap in the progress of civilisation was accompanied by the advancement and transformation of energy sources. At the same time, the development and use of energy have also transformed the natural environment on which humanity depends upon for its survival. Environmental destruction, climate changes and depletion of resources have posed huge challenges for human development. It is humanity's shared desire to build up an energy supply framework that is safe, efficient, clean and economical.

The sustainable development of the energy industry is a key strategic issue that affects China's overall economic and social development. Since China began its reforms and opened up its economy, its energy industry has seen rapid growth, providing robust support for the country's development. However, what has gradually emerged from this process is the tension between economic growth and energy development on one side and resources and the environment on the other. China is rich in energy resources, but its per capita consumption of these resources is lower than the global average. In China's energy structure, coal has long been dominant. High quality and clean energy sources like oil and natural gas, in contrast, are used in smaller proportions, and the level of electrification is low. In recent years, China's demand for energy has continued to grow rapidly. The pollutants and greenhouse gases produced by the massive consumption of fossil fuels have had severe effects on the environment. Given China's limited resources endowments and increasing dependence on foreign oil, there is an inherent risk in the country's energy security. Unscientific development has led to repeated shortages and inadequacies in coal, electricity, oil, gases and transportation. China is expected to continue its economic and social development, and its demand for energy will keep growing. This, together with the increasing complexities of the international energy situation and the climate change issue, will result in greater limitations and conflicts in China's energy development. The pressure to safeguard the country's energy security will also intensify.

To resolve China's energy problems, we must survey the world with our feet planted in China, so as to acquire an overall understanding of the situation. This book begins by analysing the state of energy in the world and in China, and studying the problems faced by the country's energy development and their underlying causes. Recognising the complexity of the energy issue and adopting a grand energy vision, this book proposes a fundamental

approach to resolving China's energy problems. The basic idea involves planning for changes in the mode of economic development, the mode of energy development and the dynamics of global competition; pursuing new industrialisation and modernisation of the energy sector with Chinese characteristics; and creating a relatively comfortable and favourable international milieu. The process of changing the mode of energy development is the process of transforming China's energy strategy. The transformation of energy strategy comprises various dimensions: the transformation of the energy structure from high-carbon to low-carbon mode, the transformation of the energy use pattern from one being extensive to one of intensiveness and efficiency, the transformation of energy allocation from ensuring local balance to an optimised distribution network covering large areas, the transformation of energy supply from ensuring domestic supplies to coordinated utilisation of both overseas and domestic resources, and the transformation of energy services from a one-way supply to smart interactive supply.

The year 2003 was the milestone year marking the strategic transformation of China's energy development. The proposal of the Scientific Outlook on Development brought the Theoretical System of Socialism with Chinese Characteristics closer to perfection. With the Scientific Outlook on Development as a guide, China's energy policies underwent new adjustments and changes, which facilitated the changing of the mode of energy development and the transformation of China's energy strategy. In that year, China's GDP per capita exceeded US$1 000, economic and social development entered a new phase, and the pace of industrialisation and urbanisation accelerated. Thus, the divergence between the supply and demand of energy became more acute, placing critical pressure on changing the mode of development. With the combined efforts of various sectors, there have been some changes in the mode of energy development in China, but there is still a long way to go.

This book analyses the basic premise in resolving China's energy problem and the transformation of the mode of its energy development. It argues that the core of the energy strategy should be electrical power, and that the core mission should be the implementation of the 'One Ultra Four Large' (1U4L) strategy. On this basis, the following issues are systematically discussed: the development and use of energy, the transmission and distribution of energy, the end consumption of energy, the energy market, energy warnings and contingency actions, innovation in energy technology, and ensuring the sustainable development of the energy sector.

The book is divided into nine chapters:

Chapter 1 analyses the world energy situation and gives a summary of its characteristics. It also gives an overview of China's energy situation and the major problems the country faces, and analyses the causes that affect China's energy development.

Chapter 2 proposes the basic idea to resolve China's energy problems and the basic path in implementing China's energy strategy. It analyses the central link in the energy strategy and argues that its core should be electrical power and the implementation of the 1U4L strategy.

Chapter 3 gives a general idea of the development and use of energy in China. It explores the major issues involved in the development and use of coal, oil, natural gas, hydropower, nuclear power, as well as new and renewable energy sources like wind and solar power. The chapter also proposes international energy cooperation and the active exploitation of overseas resources.

Chapter 4 analyses the implication and principles of constructing a modern and comprehensive power transmission framework. It explores strategic issues such as improving the mode of energy distribution by simultaneously developing coal and electricity transmission but speeding up the latter, building up a powerful and smart ultra high voltage (UHV) grid, and refining the oil and gas distribution networks.

Chapter 5 analyses the challenges of China's energy consumption and the structural problems of the green energy consumption model. It focuses on the three strategic measures of implementing energy conservation as a strategic priority, increasing electrification and developing electric vehicles.

Chapter 6 explores the issue of developing energy markets, analysing key points in the building up of the coal market, electricity market and pricing framework for oil and gas. It also discusses the issue of regulating the new energy market.

Chapter 7 is a study of energy warnings and contingency actions. It analyses the implications of boosting the energy warning system and contingency plans. It also describes the thoughts and emphasises on improving the energy warning and contingency systems and the build-up of energy reserves.

Chapter 8 analyses the challenges in the innovation of China's energy technology. It explains its basic principles, the important areas and the goals, and explores effective measures in refining the system for energy technology innovation.

Chapter 9 describes the measures to facilitate the transformation of the mode of energy development from the perspectives of laws, regulations and policies, system standardisation and corporate development. It analyses important issues like being policy-oriented, being more prominent in the international discourse on standardisation and supporting the development of large-scale power corporations.

Looking ahead, the future for China's energy development is grim, with many challenges and difficult tasks. To transcend these difficulties and provide the energy security for economic and social development, a spirit of reform and innovation, led by Scientific Outlook on Development must be harnessed to bring about changes in the mode of energy development, adjustments in the development and use of energy and the optimisation of energy transport and allocation. At the same time, a green energy consumption model must be constructed, the energy market framework fine-tuned and the energy warning system and contingency actions improved. The supportive and leading role of energy technology, the standardization and guidance of laws, policies and standards, and the driving force of the main energy market participants should also be fully harnessed. All these tasks should be tirelessly pursued with a down-to-earth approach.

The ideas and perspectives expressed in this book on the changing mode of energy development are the results of my 40-year career in the energy industry and my thoughts on China's energy strategy. I have also referred to the writings of experts and scholars. As the opinions put forth in this book are my own, there will naturally be inadequacies. By publishing this book, I hope to contribute to the study of China's energy strategy.

Zhenya Liu
May 2013

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Energy: An Overview

The constant changes in global economy and politics, and the development of a new revolution in energy technology, are bringing about a profound transformation in the world's energy structure. Globalisation of the world economy means that this transformation will have a significant impact on China's energy development. Even as the energy industry in China is achieving great successes, it is facing a slew of challenges. A thorough understanding of the energy situation within and outside China, and in-depth analyses of the major problems in China's power industry and their causes are prerequisites to formulating a scientific energy strategy for the country.

1.1 An Overview of the World's Energy Situation

In recent years, economic and social factors, resources and the environment, science and technology, as well as the inherent laws governing energy development, have helped shape new trends and characteristics in the global energy situation.

1.1.1 The Global Energy Situation

As the world today becomes more and more dependent on energy due to economic and social development, energy development is increasingly constrained by ecosystems and the environment. The issue of security is also a matter of concern among many in the international community. It is against this backdrop that a new revolution in energy technology is gestating and developing in the whole world.

1.1.1.1 Unprecedented Level of Dependence on Energy due to Economic and Social Development

Energy development and exploitation is a hallmark of human progress. From a historical perspective, advancements in human civilisations were always accompanied by revolutions in energy technologies. In an agricultural economy, energy is required to satisfy only general human needs, and its main sources were biomass fuels like firewood. In the

Electric Power and Energy in China, First Edition. Zhenya Liu.

second half of the 18th century, the proliferation of the steam engine heralded the first industrial revolution in the history of mankind. Mechanised production began to replace manual labour and the demand for energy increased radically. Coal gradually replaced firewood and so on to become the world's main source of fuel. Energy began to play an important role in the economic and social development of mankind; it became the key element of modernised production and the foundation on which modern material civilisation was built. Between the 19th and the early 20th centuries, the births of two revolutionary technologies—the internal combustion engine and electricity—further consolidated the status of energy as the bedrock of the modern economy and society. The demand for fossil fuels began its meteoric rise. Following the end of the Second World War, with the growth of the automobile industry and the emergence of multinational oil companies, oil consumption rocketed, gradually overtaking coal in the share of the energy consumption structure. The discovery of large numbers of natural gas fields propelled the exploration and exploitation of gas. By the early 21st century, the three fossil fuels of oil, coal and natural gas became the main sources of the world's energy supply, accounting for over 80% of the world's total energy consumption. They provide almost 100% of the energy used for transportation and over 65% of the primary energy for power generation. The exploration and use of energy resources facilitated humanity's progress and the development of the world economy. Modern agriculture, industry and services need the support of energy to stay in operation. It can be said that without energy, modern civilisation will vanish completely.

With human society's increasing dependence on energy, energy has become the key element of sustainable economic and social development. The adequacy and cost of energy supply is having a greater affect on development. The two oil crises in the 1970s had a devastating effect on a world economy that was heavily dependent on oil. In the early years of 21st century, energy prices as represented by oil have seen a large increase, which added greatly to the cost of social and economic development. The era of cheap energy is over. For developing nations still at the industrialisation stage, the ability of energy to put a brake on development is much more pronounced. Developed countries had earlier on completed their industrialisation process by using large quantities of cheap energy resources to fuel the rapid growth of their economies. As developing countries enter their stages of rapid growth, they can no longer obtain large quantities of high quality but cheap energy resources from the global market so easily. They cannot simply replicate the developmental models of developed countries; they must rely on innovation to transform their modes of development and achieve sustained growth.

1.1.1.2 Energy Production and Consumption Patterns are Undergoing Profound Transformation

Since the first Industrial Revolution, fossil fuels have occupied a leading position in human energy production and consumption. Prior to any breakthrough in energy use and before the discovery of new energy sources that are plentiful enough to replace fossil fuels, fossil fuels remain the basic energy sources for the development of the world economy. Human consumption patterns based on fossil fuels will not see a fundamental change for quite some time. In 2009, the world's primary energy consumption was approximately 17.33 billion tonnes of standard coal, with the fossil fuels of coal, oil and natural gas accounting for 80.9%.

Table 1.1 The level and composition of the world's primary energy consumption.

Type of energy	1971	1980	1990	2000	2005	2009
Coal	26.1%	24.8%	25.3%	22.9%	25.3%	27.2%
Oil	44.0%	43.0%	36.7%	36.5%	35.1%	32.9%
Natural gas	16.2%	17.1%	19.1%	20.8%	20.7%	20.9%
Nuclear power	0.5%	2.6%	6.0%	6.7%	6.3%	5.8%
Hydropower	1.9%	2.0%	2.1%	2.2%	2.2%	2.3%
Others	11.3%	10.5%	10.8%	10.9%	10.4%	10.9%
Total (billion tonnes of standard coal)	7.904	10.327	12.516	14.312	16.322	17.331

Source: International Energy Agency (IEA).

Even as fossil fuels have long taken the lead as the main suppliers of energy, the world's energy production and consumption patterns are quietly undergoing profound transformation. Informed by their concern over energy supply security and global climate changes, many countries are beginning to look for alternatives to traditional fossil fuels, and decreasing the share of fossil fuels, especially oil, in energy consumption. The share of oil in the world's primary energy consumption reached a peak in 1973, after which it began to fall steadily. The percentage had dropped to 32.9% by 2009, a drop of 13 percentage points from 1973. In terms of energy end-use, the share of oil also dropped from a peak of 48.1% (in 1972) to 41.6% in 2009. In the same period, the total share of natural gas and nonfossil fuels in global primary energy consumption has shown an increase. Between 1971 and 2009, the share of natural gas went up by 4.7 percentage points, while the share of nonfossil fuels grew by 5.8 percentage points. Table 1.1 shows that quantity and composition of the world's primary energy consumption.

The fall in the share of oil and the rise in nonfossil fuels are especially evident in developed countries. In 1973 the share of oil in primary energy consumption by Organisation for Economic Cooperation and Development (OECD) member countries was 52.5%. Nonfossil fuels accounted for only 5.9%. By 2009, the share of oil had dropped to 37.4%, but nonfossil fuels had risen to 19.0%.

In terms of energy end-use, the share of fossil fuels continued to decrease, while the share of electricity saw a significant increase. Increasing quantities of fossil fuels like coal and natural gas were converted into electricity. Between 1971 and 2009, the share of fossil fuels like coal, oil and natural gas in the world's energy end-use fell by 9 percentage points, while the share of electricity almost doubled, hitting 17.3% in 2009. The level and composition of the world's energy end-use is shown in Table 1.2.

Industry and transportation are the upmost major energy end-users. In the decade after 1998, the transport sector's energy end-use surpassed that of industry. However, with the rise of global oil prices and the industrialisation of developing countries, industry's energy end-use once again exceeded transport in 2008, becoming the biggest end-user sector. In 2009 the total energy end-use of both industry and transport was almost equal, accounting for 27.4% of the world's energy end-use.

The geographical spread of the world's energy use was also undergoing profound changes. The rapid economic growth of developing countries increased the demand for energy. In 2004 energy consumption by developing non-OECD countries surpassed

Table 1.2 The level and composition of the world's energy end-use.

Type of energy	1971	1980	1990	2000	2005	2009
Coal	14.6%	13.0%	12.1%	7.6%	8.4%	9.8%
Oil	46.8%	45.3%	41.4%	44.2%	43.5%	41.6%
Natural gas	14.2%	15.4%	15.2%	16.1%	15.6%	15.2%
Electricity	8.8%	10.9%	13.3%	15.4%	16.4%	17.3%
Thermal power	1.6%	2.2%	5.3%	3.5%	3.4%	3.0%
Others	14.0%	13.2%	12.7%	13.2%	12.7%	13.1%
Total (billion tonnes of standard coal)	6.080	7.688	8.990	10.053	11.255	11.899

Source: International Energy Agency (IEA).

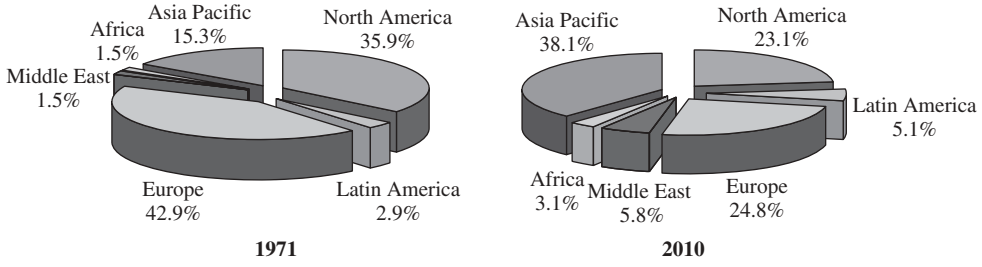

Figure 1.1 Distribution of the world's primary energy consumption.
Source: British Petroleum (BP), *Statistical Review of World Energy*, 2011.

developed OECD countries for the first time. The weight of global energy use began to shift towards developing countries. Among them, the percentage of world energy consumption by China, India, Russia, Brazil and South Africa rose from 26.7% in 1990 to 32.8% in 2009. The annual growth in their energy consumption is 2.1 times the world average.

In terms of energy use, the Asia Pacific is the fastest growing region in the last 40 years. Between 1971 and 2010, it accounted for 55.2% of newly added primary energy use in the world. The region's share in world energy consumption increased from 15.3% to 38.1% (see Figure 1.1). In 2003 the Asia Pacific overtook Europe as the region that consumed the most energy in the world.

In terms of energy consumption per capita, developed countries were still well ahead of developing countries. In 2009 the energy use per capita in OECD countries was 6.11 tonnes of standard coal, but in non-OECD countries it was 1.70 tonnes, a mere 27.8% of the former.

1.1.1.3 Resources and the Environment Exerting More Restrictions on Energy Development

The world's resources of fossil fuels are relatively abundant on the whole. At the end of 2010, the remaining proven reserves of coal stood at 860.9 billion tonnes. The

Table 1.3 Countries with the biggest remaining proven reserves of fossil fuels.

Rank	Coal		Oil		Natural Gas	
	Country	Reserves (billion tonnes)	Country	Reserves (billion barrels)	Country	Reserves (trillion cubic metres)
1	United States	237.3	Saudi Arabia	264.5	Russia	44.8
2	Russia	157.0	Venezuela	211.2	Iran	29.6
3	China	114.5	Iran	137.0	Qatar	25.3
4	Australia	76.4	Iraq	115.0	Turkmenistan	8.0
5	India	60.6	Kuwait	101.5	Saudi Arabia	8.0

Source: British Petroleum (BP), *Statistical Review of World Energy*, 2011 (2010 data).

reserve-production ratio (RPR)[1] is 118 years. For oil, there were 188.8 billion tonnes of remaining proven reserves with an RPR of 46.2 years. For natural gas, the figures are 187.1 trillion cubic metres and 58.6 years respectively. Table 1.3 lists the top five countries with the biggest remaining proven reserves of fossil fuels.

The sustainable supply of resources has become an important factor in restricting the world's energy development. Although the remaining reserves of fossil fuels have yet to impose a substantive limitation on global energy supply, the nonrenewable nature of fossil fuels and the increasing costs in exploration have highlighted the problem of ensuring the sustainable supply of energy. The early 21st century has witnessed the increasing scarcity of overall supply of fossil fuels, especially oil. Given factors like geopolitics, local wars, decreased investments, aged oil fields and increased demand, the demand and supply balance of the world's oil tends to be fragile. The stability of oil supply in the future has become a widespread concern in the international community. For most countries, especially developing countries in the industrialisation phase, the limitations that energy supply sustainability imposes on their socioeconomic development are gradually becoming more obvious, given that new and renewable energy sources have yet to sufficiently replace fossil fuels.

The issue of greenhouse gas emissions produced by burning fossil fuels is also becoming a cause of concern for many people. On a global scale, the carbon dioxide produced by burning fossil fuels accounts for 56.6% of all greenhouse gases emitted by human activity and 73.8% of carbon dioxide emissions (Figure 1.2). In 2009 the amount of carbon dioxide produced by burning fossil fuels reached 29 billion tonnes, 2.1 times the amount in 1971. Emissions per capital also increased from 3.74 tonnes in 1971 to 4.29 tonnes in 2009.

Greenhouse gas emissions produced by the burning of fossil fuels is a major factor that contributes to global climate change. As the issue of climate change becomes better understood, the whole world has recognised the need for the international community to work together to tackle its challenges. Climate change has become a focal issue in international politics, economics and diplomacy. Like the Charter of the United Nations and World Trade Organisation Rules that came before, various accords on climate change are

[1] Reserve-production ratio (RPR) is the ratio of the remaining recoverable reserves to annual production. RPR represents the number of years the existing remaining reserves can support current production rate.

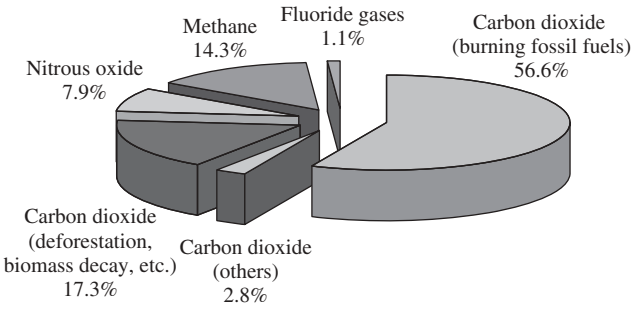

Figure 1.2 Composition of the world's greenhouse gas emissions produced by human activity in 2004.
Source: Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2007: Synthesis Report*.

becoming the most important regulatory mechanisms that will affect world development and world energy development in the future.

In fighting climate change, developing countries are under dual pressures. Developed regions and nations like the European Union (EU), Japan and the United States (USA) have seen improvements in their environmental qualities. For them, the climate change issue has replaced traditional environmental concerns. Most developing countries, however, are still in the industrialisation stage. On the one hand, they face traditional ecological and environmental pressures that come with energy exploration and exploitation; on the other hand, they face the pressure of reducing greenhouse emissions. They have far bigger challenges compared to developed countries. Given the lag in technology, capital and discourse power, developing countries are at an overall disadvantage in the negotiations on carbon emissions with developed countries.

1.1.1.4 Energy Security is a Widespread Concern in the International Community

Energy security refers to the uninterrupted availability of energy supply that can meet the needs of economic and social development at a price that is affordable, while respecting ecological and environmental concerns. With the increasing interconnection and mutual dependence of the world's economies, facilitating the global supply and demand balance of energy and safeguarding global energy security have become urgent tasks that every country in the world must undertake together.[2] Energy security is a widespread concern in the international community and has become a major international issue. The underlying causes for the global community's concern about energy security include the following: (1) The nonrenewable nature of fossil fuels generates a worry about their future shortage. (2) The imbalance of regional supply and consumption of the world's energy. The remaining proven reserves and production of fossil fuels, especially oil, are concentrated in a small number of regions and countries like the Middle East, Russia and so on, but the growth in energy consumption is concentrated in the newly emerging economies

[2] Jinping Xi in a speech delivered at the International Energy Conference in June 2008.

in the Asia Pacific. The imbalanced distribution of resources and user areas causes a worry about the sustainability and stability of energy supply. (3) Many uncertainties exist in energy-producing regions and transport channels. The world's major oil- and gas-producing areas and transport bottlenecks are plagued by many problems such as a complex tangle of interests, political instability, regional tensions, etc. There is a risk of the energy supply being interrupted.

Due to the extreme importance of energy security and the enormous challenges that it poses to the world, it is high on many countries' agendas. Ensuring their own energy security has become a core component in the energy strategies of these countries. Through these measures, the USA can achieve energy independence and be a leader in the green energy industry of the future. To guarantee a stable, reliable and reasonably priced energy supply in the long run, the EU is formulating a shared energy policy. Key measures to ensure the EU's energy security include conserving energy, building up a common energy market, developing renewable energy and smart power grids, and strengthening international cooperation. Energy is at the core of Japan's economic policy. It is proposed that energy security can be attained through promoting vehicles that run on new energy, popularising energy saving technology, making greater use of solar and wind power, developing a new generation of transmission grids. Japan plans to increase the share of self-supplied energy (including traditional domestic energy resources and overseas obtainable energy resources Japan has invested in) from the current 38% to 70% by 2030.

1.1.1.5 A New Revolution in Energy Technology is Brewing

In response to the complexities of the energy security situation, and to resolve the ecological and environmental problems, including climate change, caused by energy use, many countries are attaching a high level of importance in energy technology innovation in the beginning of the 21st century. They are working to develop a new generation of energy technology in the hope that this technological breakthrough will facilitate the use of new and renewable energy, the increase in the efficiency of energy use and the creation of an energy framework with a sustainable supply.

The global financial crisis that began in 2008 has left the world economy badly battered. To free themselves from the effects of the crisis and to revive their economic strength, certain countries are expanding their investments in energy. At the same time as they are ensuring energy supply and stimulating economic growth, they are putting in place their new competitive edge in the postcrisis world. This has encouraged innovation in energy technology on a global scale. The reality demonstrates that 'the global financial crisis has given rise to a new technological revolution, and the world may enter a period that will witness an innovation boom and the rapid growth of new industries, where green development will become the major trend'.[3] A breakthrough in energy technology is an important prerequisite and the key to making green development a reality. A new technological revolution is inevitably a new revolution in energy technology.

[3] Keqiang Li (2010) A deep understanding of the main line of the theme in *Jianyi (The Communist Party of China (CPC) Central Committee's Proposal on Formulating the 12th Five-year Program (2011–2015) on National Economic and Social Development)* to facilitate comprehensive coordination of the sustainable development of the economy and society, *People's Daily*, 5th edition, 15 November 2010.

A survey of global energy and technology reveals that a new revolution in energy technology is brewing; the signs are already evident.

In the area of energy production, countries are actively pushing for the low-carbon and efficient exploration and use of traditional fossil fuels, as well as seeking new energy sources to replace fossil fuels. New innovations in energy production that have garnered considerable interest include the eco-friendly and clean use of coal, large-scale exploration and exploitation of renewable energy sources like wind and solar power, a new generation of nuclear power and unconventional exploration and use of oil and gas.

In the area of energy transport, countries are optimising the allocation of resources and improving the overall coordination and interaction of energy transport systems to ensure the secure transport of energy. At the core of the revolution in energy transport technology are large capacity transmissions using ultra high voltage (UHV), safe and stable operations of large grids, power generation with renewable energy sources and their integration, and smart grids.

In the area of energy consumption, various countries are increasing their energy efficiencies, and gradually bringing about the replacement of oil with electricity in areas like transport. Vehicles with power-saving technology and run on new energy, as represented by the electric car, have a huge market potential.

The new revolution in energy technology will bring about a profound change. The revolution will be led by technological innovation and centred on electric power. With the development of a smart energy system as its direction, the goals of the revolution are to enhance the energy structure, increase energy efficiency, decrease energy consumption, share social resources and achieve sustainable development. On the whole, new energy and the development of smart power grids will become the major engines of the new revolution in energy technology.

1.1.2 Characteristics of the Global Energy Situation

Economic and social development, changes in the international structure and advancements in science and technology have resulted in an unprecedented and profound transformation of the energy industry. Against the backdrop of pursuing the sustainability of energy supply and dealing with the problem of climate change, six major characteristics of the global energy situation have emerged: structural diversity, clean development, long-distance allocation, consumer-level electrification, smart systems and financialisation of resources.

1.1.2.1 Diversity of Energy Structure

With the technological advancements in developing and utilising energy, the growing shortage of fossil fuels and the concern among the world's countries for their own energy security, achieving diversity in energy structure and reducing the dependence on a single type of energy have become a shared strategic alternative among various countries. In the early 1970s oil was the main type of energy consumed in the world, accounting for over 46% of the world's energy consumption at one point in time. Following the two oil