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Energy Economics: Energy Efficiency in China

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Preface

Energy and carbon emissions have become major strategic issues influencing the development pattern of human society and the global political economy.

China is a major player in the production and consumption of energy. With a large population, China is undergoing rapid industrialization and urbanization. Its per capita energy consumption, especially clean energy consumption, is far below that of developed countries; in the future, the total energy demand will continue growing rapidly, and there are uncertainties over the growth rate. China's per capita energy resources, especially quality reserves, are far below the world average; further, with the current level of domestic reserves, it is increasingly difficult to meet the country's economic and social development needs. Energy dependency, especially oil and gas dependency, will continue to climb. Constrained by its development stage and its resource endowments of coal, China's energy development and utilization have caused serious environmental pollution and ecological destruction, negatively influencing human health.

Besides promoting economic development and social progress, China also needs to tackle the new challenges of global climate change and global climate policy. Carbon dioxide emissions are caused by burning fossil fuels; hence, China's energy development faces the difficulty of reducing such emissions, which developed countries have not experienced during their industrialization phase.

The objective of an energy policy is to safeguard supply, protect the environment, and aid in economic growth. Energy conservation and energy efficiency improvement are important and effective ways of responding to these energy challenges.

Energy efficiency is not merely a development issue concerning the natural sciences, engineering, and economic, social, and environmental aspects; it also poses comprehensive, dynamic, and systemic problems in the complex system. This book focuses on research on China's energy efficiency and applies theories and methods in management science and economic science. We hope to be able to enhance the domestic and international energy policy debates and scholarly exchanges about energy economics, as well as provide a reference for China's energy policy and for science and technology professionals in the energy

and climate policy fields. Energy and energy efficiency involve several disciplines. With energy economics as the focal point, this book focuses on ten key issues, which are discussed below.

(1) A comprehensive summary and analysis of the world's and China's energy development

Financial crisis, energy prices, climate change, and low-carbon economy are the keywords in global development in the past two years. The year 2010 is the last year for China to complete the "Eleventh Five-Year Plan." It is also the first year when China clarifies its 2020 carbon intensity target. With this background, this book highlights and analyzes the characteristics of global and China's economic development and the energy supply and demand. In particular, it treats the imbalance in energy consumption worldwide, the evolution of energy structure in major countries, the recent changes in global economic and energy development since 2008, progress in the energy conservation and emission reduction in the "Eleventh Five-Year Plan," and major challenges in energy development in China.

(2) The meaning and measure of energy efficiency

For energy efficiency, there exists some misunderstanding or conceptual deviation. From the perspective of energy as a factor of production, this book, in theory, analyzes the relation between energy efficiency and economic systems and the connotation of energy efficiency. From the perspective of factor substitution and structure heterogeneity, this book gives indicators and measurement of energy efficiency, including energy macro-efficiency, physical efficiency, thermodynamics efficiency, value efficiency, allocative efficiency, utilization efficiency, and economic efficiency. This is done using national economic accounting and microeconomics to analyze basic theory, assumed conditions, correlations, advantages and disadvantages, and the effective range of every indication.

(3) Impacts of structural changes in the economy on energy macro-efficiency

Economic structure is an important topic in all governmental conferences it also occupies an important position in China's short-term policies and long-term planning. National and regional energy macro-efficiency levels are quite different; these differences are caused by factors such as the economic structure, technical equipment, energy structure, resource endowments, climate conditions, geographic location, and so on. However, among these factors, the most important is the economic structure. This book uses layered analysis, from endogenous factors to exogenous factors, to study the impacts of industrial structure, consumer structure, and disposition of income structure on China's energy macro-efficiency. Doing so, it examines the direct and indirect effects of urbanization on energy consumption of households.

(4) Analysis of urban, rural, and regional characteristics of residential energy consumption

Since the beginning of the twenty-first century, China's urban and rural residents' living standards have substantially increased, with an increasing demand for energy

quantity and quality. Nevertheless, the per capita energy consumption is less than 20 % of that of developed countries, and the per capita electricity consumption accounts for 12 % of that of the developed countries. With the continued progress of a well-off society, China's residential energy consumption will continue to grow rapidly. This book analyzes the residential energy consumption characteristics of major countries and differences between urban and rural residential energy consumption and quantitatively analyzes the impact factors of residential energy consumption.

(5) Energy efficiency of key energy-consuming sectors

Energy consumption in the transportation, construction, and power sectors is more than that in other sectors, and the growth rate is fast. This book analyzes the energy consumption characteristics of China's transportation sector, compared with the transportation sectors in the United States, the European Union, and Japan and analyzes domestic and foreign policy relating to energy consumption in the transportation sector. The book also analyzes China's energy consumption in the transportation sector and energy efficiency in the power sector in terms of the transmission and distribution aspects and other issues.

(6) In-depth analysis of the impact of prices on oil demand

With China's recent rapid economic growth, demand for oil is at record highs. From the early twenty-first century to the global financial crisis in 2008, the international price of oil has increased significantly; thus, although not technically accurate, it was believed that a higher oil price would lead to an increasing demand for oil and that rising oil prices did not have any effect on energy conservation. This book quantitatively studies the impact of oil prices on the demand for crude oil.

(7) Comparison of China's regional energy efficiency

China's regional development is uneven, and energy efficiency among its regions varies. Coordinating its regional development is an important aspect of its current and future development policies. At the beginning of the "Eleventh Five-Year Plan", the target was to decrease energy consumption per unit of GDP by 20 % compared with 2005, and then the target is decomposed into regions. At present, China is working to develop the "Twelfth Five-Year Plan", and, the energy conservation and carbon reduction plans on both the national and local district levels by 2020. Comprehensively understanding the differences and changes in the direction and speed of differences of energy efficiency and distinguishing between the subjective and objective reasons for these differences are the preconditions for developing a national and regional energy-saving, emission reduction plan. It is also the precondition for a scientific evaluation of energy-saving performance. In this context, this book empirically analyzes regional energy efficiency.

(8) A comprehensive analysis of energy efficiency policies in developed countries and its implications for China

Since the first oil crisis of the 1970s, developed countries have accumulated more experience and established near-perfect energy efficiency policies. In the 35-year

period (1974–2009), the IEA member countries have experienced overall economic growth of 144 % while energy intensity decreased by 41 %, especially caused by the change in national energy efficiency. This book compares the energy efficiency policies of Japan, the European Union, and the United States, including relevant laws and regulatory, fiscal, taxation, and technology policies, and then it analyzes the implications for China.

(9) Simulation and policy analysis of end-use energy efficiency policies

Investment in improving energy efficiency can reduce the source cost of services. In the absence of additional energy and environmental policy constraints, the efficiency of energy use will be accompanied by a rebound effect that must be at least partially offset by the initial energy savings. This book examines the end-use energy efficiency and the country's economic growth, energy use, and carbon dioxide emissions, focusing on the rebound effect and the various energy and environmental policies in place.

(10) Analyses of the energy efficiency opportunities in China

As the rate of China's energy consumption shows an exponential growth, energy efficiency has never been so urgent and important. China's future energy efficiency direction—whether energy consumption per unit of GDP will maintain its downward trend or whether the emission reduction target, that is, the carbon emission per unit of GDP falling by 40–45 % in 2020 compared with 2005, will be achieved—urgently needs to be explored. This book analyzes the historic opportunities for China's energy, improvement, and judgments on its energy macro-efficiency trend as based on an international comparison.

To be better able to contribute to scientific research, personnel training, and international communication of energy and environmental policy, in 2006, I coordinated with Prof. Yongfa Xu and Keyu Liu to establish the Center for Energy and Environmental Policy Research (CEEP), and I took charge as the first chief. In 2009, the Beijing Institute of Technology President, Haiyan Hu, and the party secretary of Prof. Dacheng Guo invited me and core members of my team to join the Beijing Institute of Technology. The Beijing Institute of Technology's President Office approved the establishment of CEEP in Beijing Institute of Technology, anchored at the School of Management and Economics.

The overall deployment of this project was conducted under the leadership of Prof. Yi-Ming Wei. Further, Hua Liao, Qiao-Mei Liang, Wen-Jing Yi, Zhen-Hua Feng, Jing-Li Fan, Zhong-Yuan Ren, Bin Ouyang, Hai-Bo Wang, Gang Wu, Li Liu, and Jian-Lei Mo participated and completed the relevant sections of this book. Le-Le Zou, Xiao-Wei Ma, Yue-Jun Zhang, Zhi-Yong Han, Jiu-Tian Zhang, Xu-Mei Chen, Jiao-Ling Jiao, Bin Fang, Jie Guo, Kang Li, Zhi-Fu Mi, Kai Wang, Liang-Qiong Xiong, Rui-Guang Yang, Yun-Fei Yao, Ying Yuan, Rong-Gang Cong, Mei-Ning Duan, Lu-Tao Zhao, etc., participated in the study, discussions, and proofreading of sections of this book. The book is the collective wisdom of CEEP. During the process of publication of this book, we have sought to update the relevant data. Although some studies were completed 2 or 3 years ago and some

data are not complete, the conclusions of the study and judgment have proved to be correct and have stood the test of time and practice.

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We take this opportunity to specially thank Prof. Changlu Zhao (Party Secretary of Beijing Institute of Technology), academician Haiyan Hu (President of Beijing Institute of Technology), and other school leaders. We would like to express thanks for the support and help of the leaders of school functional departments and colleagues of School of Management and Economics. Without their support and assistance, it would have been difficult to publish this book in such a short period of time, to adapt to the new working environment, to and concentrate on the completion of the follow-up study.

Thanks to all the authors of the documents referenced in this book!

Due to our limited knowledge of the style and norms of academic-level publications, the book may inevitably be flawed and inadequate in some instances (even wrong), and we are open to criticism and correction!

Beijing, China
July 2016

Yi-Ming Wei

Contents

1	Energy Development in the World and China	1
1.1	World Energy Development Review	2
1.1.1	World Economy and Energy Consumption Are Significantly Correlated When Taking a Statistical Perspective	2
1.1.2	Different Energy Demand Elasticities of GDP in Different Development Stages	3
1.1.3	Different Decreasing Rates of Energy Intensity Across Countries	4
1.1.4	There Is no Significant Improvement in the World's Unbalanced Energy Consumption	5
1.1.5	Energy Poverty and the Induced Health Issues Are Still Serious	6
1.1.6	World Energy Trade Increases Steadily and Natural Gas Emerges Progressively	6
1.1.7	Fossil Fuel-Based Energy Consumption Has Caused Serious Pollution Are Carbon Emissions	10
1.2	New Trends of World Energy Development from 2008 to 2010	12
1.2.1	Recent Changes in the World Economy and the Global Financial Crisis	12
1.2.2	Recent Changes in World Energy Development	14
1.3	Energy Structural Changes in the G7 and BRICs	18
1.4	Review of China's Energy Development	32
1.4.1	Rapid Economic Growth with a Lower Energy Consumption Growth Rate	32
1.4.2	Energy Supply Maintains a Rapid Growth Rate While the Energy Self-sufficiency Rate Has Declined	34

- 1.4.3 Less Carbon-Intensive and Cleaner Energy Structure and More Energy-Intensive Economic Structure 37
- 1.4.4 CO₂ Emissions Grow Rapidly and CO₂ Abatement Pressures Increase 38
- 1.5 New Changes and Trends in China’s Energy Development 39
 - 1.5.1 Reform of the Energy Management Mechanism Keeps Moving. 39
 - 1.5.2 Energy Demand Growth Rate Decreased Due to the Business Cycle 40
 - 1.5.3 Energy Supply Diversification Is Accelerating. 41
 - 1.5.4 Striking Advances in Energy Conservation Development 42
 - 1.5.5 China’s Energy Flow Analysis in 2008 44
- 1.6 Challenges and Reactions of China’s Energy Development 47
 - 1.6.1 Huge Energy Demand with Considerable Uncertainty 47
 - 1.6.2 Insufficient Per Capita Energy Resources, Especially High-Quality Ones 47
 - 1.6.3 New Challenges Facing Energy Development Due to Global Climate Change 48
 - 1.6.4 Global Climate Change Has Brought About New Energy Challenges. 48
 - 1.6.5 An Important and Effective Way of Facing Challenges: Improving Energy Efficiency 49
- References. 50
- 2 Relationship Between Energy Efficiency and the Economic System: Measuring Energy Efficiency 53**
 - 2.1 Reconsideration of Energy Efficiency and Its Relation to the Economic System 54
 - 2.1.1 Understanding Energy Efficiency. 54
 - 2.1.2 Measuring Energy Efficiency 55
 - 2.1.3 Energy Efficiency and the Economic System. 57
 - 2.1.4 Energy Efficiency and Energy Conservation 63
 - 2.2 Indicators and Measurement of Energy Efficiency 64
 - 2.2.1 Energy Macro-efficiency 65
 - 2.2.2 Energy Physical Efficiency 67
 - 2.2.3 Energy Thermodynamics Efficiency. 68
 - 2.2.4 Energy Value Efficiency 69
 - 2.2.5 Energy Allocation Efficiency 70
 - 2.2.6 Energy Utilization Efficiency 74
 - 2.2.7 Energy Economic Efficiency 76
 - 2.3 Summary 78
 - References. 80

3	Impact of Economic Structural Changes on Energy	
	Macro-efficiency	81
3.1	Linkages of the Industrial Structure and Energy Intensity.	82
3.1.1	Statistical Description of the Change in Energy Intensity	82
3.1.2	Impacts of Internal Industrial Structural Change on Energy Intensity	86
3.1.3	Further Discussion of the Decomposition Method.	96
3.2	Final Demand Structure and Energy Efficiency.	97
3.2.1	Marginal Energy Consumption of Different Final Demands	97
3.2.2	Study on the Expenditure Elasticity of Residual Energy Consumption	103
3.2.3	Analysis of the Elasticity of Energy Macro-efficiency to the Investment Ratio	105
3.2.4	Analysis of the Direct and Embodied Energy Exports	107
3.3	Impact of the National Income Distribution Structure on Energy Demand.	108
3.3.1	Analysis of the Income Elasticity of Household Energy Demand.	108
3.3.2	Changes in the Income Distribution Pattern and Its Impact on Energy Consumption	110
3.4	Research Methodology of the Influence of Urbanization on Energy Demand with Supporting Evidence	112
3.4.1	Research into Urbanization and Household Direct Energy Consumption Based on the Divisia Decomposition Method	112
3.4.2	Research into Urbanization and Household Indirect Energy Consumption Based on the Input–Output Analysis Method	114
3.4.3	Research into the Construction Industry and Energy Demand Based on the Input–Output Analysis Method	115
3.5	Conclusion	115
	References.	116
4	Residential Energy Consumption	119
4.1	Residential Energy Consumption Characteristics in Some Representative Countries.	120
4.1.1	Final Energy Consumption Structure by Sector in Some Representative Countries	120
4.1.2	Analysis of Trends in Residential Energy Final Demand for Some Representative Countries	122

4.1.3	Comparison of the Energy Consumption Structure Among Representative Countries.	124
4.1.4	Regional Comparison of Residential Energy Consumption	127
4.2	State of China's Residential Energy Consumption	127
4.2.1	Change in Residential Energy Consumption	128
4.2.2	Analysis of Different Kinds of Energy Consumption	130
4.2.3	Characteristics of the Residential Energy Consumption	133
4.3	Comparison Between Urban and Rural Residential Energy Consumption.	133
4.3.1	Differences Between Urban and Rural Residential Energy Consumption	134
4.3.2	Differences Between the Structure of Urban and Rural Residential Energy Consumption	137
4.4	Regional Comparison of Residential Energy Consumption.	140
4.4.1	Regional Comparison of Residential Energy Consumption	141
4.4.2	Regional Comparison of the Structures of Residential Energy Consumption	144
4.4.3	Impact Factors of Residential Energy Consumption: Examples from Three Regions	148
4.4.4	Characteristics of Regional Residential Energy Consumption	151
4.5	Impact Analysis of Urban Residential Energy Consumption.	152
4.5.1	Impact Factors of Urban Residential Energy Consumption	153
4.5.2	Accounting Methodology and Data Description	155
4.5.3	Results Analysis and Discussion	159
4.5.4	Conclusions	162
4.6	Summary	162
	References.	164
5	Energy Efficiency in Key Sectors	167
5.1	Transportation Sector	168
5.1.1	Energy Consumption Characteristics in China's Transportation Sector.	168
5.1.2	Systematic Analysis of the Impact of Energy Intensity on Transportation	180
5.1.3	International Comparison of Energy Consumption in Transportation	184
5.1.4	International Comparison of Energy Consumption and Emission Reductions.	199
5.1.5	Summary	202

- 5.2 Energy Consumption in Buildings 204
 - 5.2.1 Definition of Energy Consumption in China’s Public Buildings 205
 - 5.2.2 Development Tendencies and the Energy Consumption Situation of China’s Public Buildings . . . 207
 - 5.2.3 Characteristics of Energy Consumption in Large Public Buildings 212
 - 5.2.4 Geographical Differences of Energy Consumption Among Large Public Buildings 214
 - 5.2.5 Overall Features of Energy Consumption in Public Building 216
- 5.3 Energy Efficiency in the Electric Power Sector. 217
 - 5.3.1 Energy Efficiency of Electric Power Generation 217
 - 5.3.2 Energy Efficiency of Power Transportation and Distribution. 223
 - 5.3.3 Electricity Allocation Optimization and Economical Transmission 224
 - 5.3.4 Demand Side Management and Energy Efficiency 228
- 5.4 Summary 229
- References. 230
- 6 Empirical Research About the Effects of Price on Oil Demand 233**
 - 6.1 Introduction 233
 - 6.2 Research Method on the Demand Elasticity of China’s Crude Oil 235
 - 6.2.1 Variable Selections and Research Methods 235
 - 6.2.2 Data Sources and Processing 237
 - 6.2.3 Data Analysis and Bounds Test. 238
 - 6.3 Analysis of the Demand Elasticity of China’s Crude Oil 240
 - 6.3.1 Analysis of Crude Oil Demand Elasticity in the Long Run 240
 - 6.3.2 Analysis of Crude Oil Demand Elasticity in the Short Run 242
 - 6.4 Conclusions and Implications 245
 - References. 247
- 7 China’s Regional Energy Efficiency 249**
 - 7.1 Decomposition Study of Regional Energy Macro Efficiency . . . 250
 - 7.1.1 Theil Index Decomposition Method 250
 - 7.1.2 Data Sources and Processing 251
 - 7.1.3 Results and Discussion 252
 - 7.1.4 Econometric Analysis of Differences in Regional Energy Macro Efficiency. 254

7.2	Comparison of Regional Energy Utilization Efficiencies.	258
7.2.1	Data Sources and Processing	258
7.2.2	Results and Discussion	259
7.2.3	Econometric Analysis of the Regional Energy Utilization Efficiency Differences.	263
7.3	Evolution of Energy Physical Efficiency in the Regional Iron and Steel Sector	265
7.3.1	Introduction	265
7.3.2	Malmquist Index Decomposition Method	267
7.3.3	Data Sources, Results, and Discussion	272
7.4	Summary	274
	References.	275
8	Energy Efficiency in Developed Countries and Its Implications for China	277
8.1	International Comparison of Legal Mechanisms	277
8.1.1	Laws and Regulations	278
8.1.2	Energy Conservation Mechanisms.	279
8.2	International Comparison of Fiscal Policy	281
8.2.1	Japan	281
8.2.2	United States.	283
8.2.3	European Union	285
8.3	International Comparison of R&D Policy.	286
8.3.1	Japan	287
8.3.2	United States.	287
8.3.3	European Union	288
8.4	Other Policies to Promote Energy Efficiency	289
8.4.1	Japan	289
8.4.2	United States.	290
8.4.3	European Union	290
8.5	Implications	291
	References.	297
9	Energy Saving Potential from End-Use Efficiency Improvements and Its Socioeconomic Impacts	299
9.1	Energy Efficiency and Rebound Effects	299
9.2	Analytical Tool: China's Energy and Environmental Policy Analysis Model	302
9.2.1	Computable General Equilibrium Model	302
9.2.2	China's CEEPA Model	303
9.3	End-Use Efficiency Analysis Without Additional Energy and Environmental Policies.	306
9.4	Effects of Alternative Energy/Environmental Policies.	312
9.4.1	Policy Scenarios	312
9.4.2	Results and Analysis	313

9.5	Discussion of Policies on Energy Efficiency Improvement	315
9.6	Summary	316
	References.	317
10	Prospects of China's Energy Efficiency	319
10.1	Historic Opportunities for China's Energy Efficiency Improvement.	320
10.1.1	Solid Foundation for Energy Conservation Provided by Sustainable and Steady Economic Growth	320
10.1.2	Potential and Capacity to Realize Lower Energy Consumption Per Capita and Per Unit of GDP	321
10.1.3	Numerous Areas for Energy Conservation Provided by Low Energy-Intensive Industries	325
10.1.4	New Energy Conservation Opportunities Brought About by Industrial Structure Upgrading and International Technology Transfers Induced by Economic Globalization.	328
10.1.5	Broader Markets Facilitate Advanced Energy Conservation Technology	328
10.1.6	Energy Conservation Laws and Market Mechanisms Lead to Energy Efficiency Improvement	330
10.1.7	Properly Upgrading the Residential Consumption Structure Can Reduce Energy Consumption Growth Rate.	331
10.2	Prospects of Energy Efficiency in Developed Countries and in China.	332
10.2.1	Potential for Realizing Lower Energy Consumption Per Capita in China	332
10.2.2	Possibility of Realizing Lower Energy Consumption Per Unit of GDP in China	333
10.2.3	Potential for Gaining a Faster Decline of Energy Macro-efficiency	334
10.2.4	China's Energy Macro-efficiency Prospects.	334
10.3	Paths Leading to China's Low-Carbon Development	336
	References.	339

Abbreviations

CAAC	Civil Aviation Administration of China
CAAC-DPD	Department of Planning and Development, CAAC
CATS	China Academy of Transportation Sciences, MOT
CCYP	China Communications Yearbook Press
CEC	China Electricity Council
CGE	Computational General Equilibrium Modeling
CNMI	China Nonferrous Metals Industry Association
DEA	Data Envelopment Analysis
DEA-SBM	Slacks-Based Measure of Efficiency
DOT	Department of Transport, USA
EU	European Union
FNEC	The First National Economic Census
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GRP	Gross Regional Product
GWEC	Global Wind Energy Council
GWP	Gross World Product
ICP	International Comparison Program
IEA	International Energy Agency
IEEJ	Institute of Energy Economy of Japan
MER	Market Exchange Rate
MIC	Ministry of International Affairs and Communications
MOC	Ministry of Communications
MOR	Ministry of Railway
MOR-SC	Statistics Center, MOR
MOT	Ministry of Transport
MOT-DCP	Department of Comprehensive Planning, MOT
MOT-DPL	Department of Policy and Legislation, MOT
MPS	Material Product Balances
NBS	National Bureau of Statistics

NBS-DCS	Department of Comprehensive Statistics, NBS
NBS-DE	Department of Energy, NBS
NBS-DITS	Department of Industry and Transport Statistics, NBS
NBS-DNA	Department of National Accounts, NBS
NDRC	National Development and Reform Commission
NDRC-BE	Bureau of Energy, NDRC
NDRC-CTRI	Comprehensive Transportation Research Institute, NDRC
NDRC-ERI	Energy Research Institute, NDRC
NEN	Energy Terms of Subcommittee of National Committee for Energy Science and Administration Standardization
OECD	Organization for Economic Co-operation and Development
ONELG	Office of the National Energy Leading Group
ORNL	Oak Ridge National Laboratory
PPP	Purchasing Power Parity
RD&D	Research, Development and Demonstration
SNA	System of National Accounts
SNEC	The Second National Economic Census
UK-DT	Department for Transport, UK
UN	United Nations
WEC	World Energy Council
WTO	World Trade Organization

Chapter 1

Energy Development in the World and China

Financial crises, energy prices, climate change, and low carbon economies were among the hot topics of world development in the past several years. The outbreak of the financial crisis in late 2008 took a heavy toll on the world's economy and resulted in the most serious recession since World War II. The UN Climate Change Conference held in Copenhagen in December 2009 resulted in the Copenhagen Accord, a political agreement struck by world leaders. The year 2010 was the last year for the Chinese government to achieve its targets for energy savings related to the "Eleventh Five-Year Plan" and it was also the first year in the Chinese government's struggle to cut carbon dioxide emissions per unit of GDP by 40–50 % by 2020. At present, all levels of the Chinese government are developing the "Twelfth Five-Year Plan," in which the topics relevant to energy resources and climate change will have a more important place. Under the aforementioned situation, this chapter aims to answer the following questions:

- What are the basic statistical characteristics of global economic development and energy supply and demand?
- Are there any notable improvements in the lopsided distribution pattern of world energy consumption?
- What are the characteristics of the evolving energy consumption structure in the major countries?
- What have been the new trends in the worldwide economy and energy development since 2008?
- What are the basic characteristics of economic development and energy supply and demand in China?
- What progress in energy savings was made in the "Eleventh Five Year Plan?"
- What are the challenges faced by China in terms of energy development?
- How should China cope with these challenges?

1.1 World Energy Development Review

1.1.1 World Economy and Energy Consumption Are Significantly Correlated When Taking a Statistical Perspective

Energy resources are important in terms of both production and living standards; thus, energy consumption is always closely related to economic development. Ever since the industrial revolution, both economic development and energy consumption have experienced a relatively fast-increasing trend worldwide. The statistical data show that the gross world product (GWP) and gross energy consumption are positively related (Fig. 1.1). According to BP (2010), the World Bank (2010a, b), and our own analysis of the period from 1980 to 2009, the correlation coefficient between the two variables was 0.995; GWP increased from 17.8 to 39.4 trillion USD (at constant prices), an annual growth rate of 2.8 %; per capita GWP increased from 4000 to 5800 USD, an annual growth rate of 1.3 %; worldwide energy consumption increased from 6.6 billion tonnes of oil equivalent (toe) to 11.2 billion toe, an annual growth rate of 1.8 %; energy consumption per unit of GWP decreased from 3.73 to 2.84 toe/ 10^4 USD, a decrease of 23 %; and energy consumption per capita increased from 1.49 to 1.65 toe, an increase of 11 %. In general, while the world economy grew by 1 %, world energy demand increased by 0.64 % (Fig. 1.1).

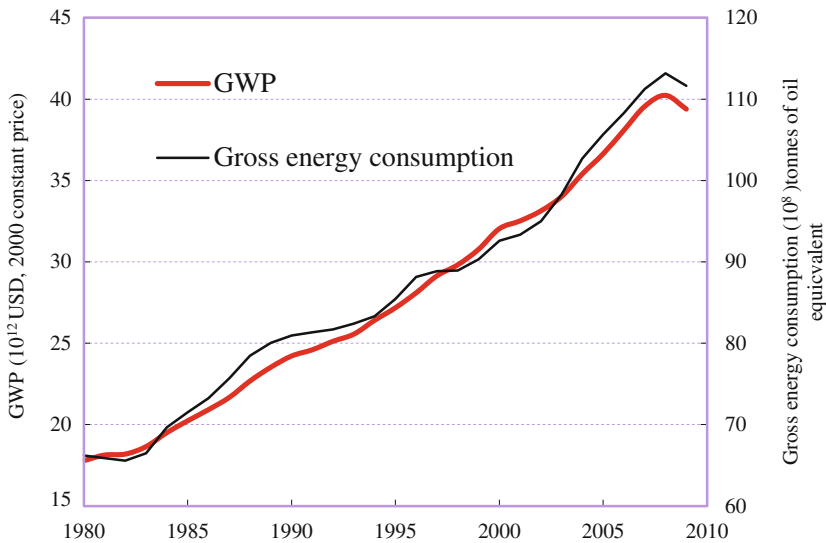


Fig. 1.1 Relationship between gross world production (GWP) and gross energy consumption (1980–2009). Data sources BP (2010), World Bank (2010b) and authors' calculations

Energy consumption in the OECD countries makes up a large percentage of the worldwide gross energy consumption, but it shows a decreasing trend. Energy consumption in the OECD countries in 1965 was 2.62 billion standard toe, which was 68.7 % of world aggregate consumption while energy consumption in 2009 was 5.22 billion standard toe, or 46.7 % of world aggregate consumption. The reasons are that (1) most OECD countries have turned into (or are already) industrialized countries, and they are steering towards low-energy industries and (2) some major developing countries have developed quickly, resulting in a sharper increase in their energy consumption while the OECD countries have been developing at a lower growth rate, resulting in a slower increase in their energy consumption.

The United States is the most developed country in the world, and it is also the country with the largest energy consumption. According to the data released by BP (2010), energy consumption in the United States was 2.18 billion standard toe or 19.5 % of world aggregate consumption. Among all energy sources, petroleum consumption was 0.84 billion tons (21.7 %), coal consumption was 0.50 billion tons (15.22 %) and natural gas consumption was 590 billion kiloliters (22.2 %).

Energy demand may experience a fast increasing trend in the future. According to the base scenario of the IEA (2009c), gross energy consumption worldwide could reach 16.8 billion standard toe in 2030, an average annual growth rate of 1.5 % from 2007 to 2030. Among all energy sources, petroleum demand would increase by 1.9 %, coal demand by 0.9 %, and natural gas by 1.5 or 35.6 %, 19.2 and 22.0 % of aggregate growth rate, respectively. According to the forecast, energy consumption in the OECD countries would increase slowly, with an annual growth rate of 0.2 % while the growth rate in the developing countries would reach 2.3 %. Growth in China and India would amount to 53 % of worldwide growth.

To satisfy energy demand and ensure energy supplies, investment in energy resources would keep increasing in the future. According to the IEA (2009c), the cumulative investment in the energy industry worldwide from 2008 to 2030 would reach 2.6 billion USD, approximately 1.4 % of the gross world product, where investment in the electricity industry would represent 53 % of total investment.

1.1.2 Different Energy Demand Elasticities of GDP in Different Development Stages

The relationship between energy consumption and economic development is significantly positive; in contrast, the aggregate economic elasticity of demand for energy has shown an ever-changing trend in past decades. Table 1.1 outlines the energy elasticity in different periods, including the first oil crisis, the second oil crisis, the Gulf War, and the “9/11” attacks as the cut-off points. Before the beginning of the first oil crisis, the energy elasticity was greater than 1.0, which was mostly caused by the fast-increasing demand for energy resources during the

Table 1.1 Aggregate economic elasticity of demand for energy at different periods (1965–2009)

Period	1965–1973	1973–1979	1979–1991	1991–2001	2001–2009
Elasticity of economic aggregate to energy demand	1.00	0.87	0.68	0.51	0.89
Economic annual growth rate in the developed countries	5.2	3.0	2.9	2.4	1.8
Economic annual growth rate in the developing countries	6.0	4.9	3.3	3.8	6.0

post-war reconstruction and industrialization. After the oil crisis, the developed countries had almost completed the industrialization process. They paid more attention to energy-saving and energy-efficiency improvements; thus, their demand for energy resources increased slowly.

In the late 20th century, the aggregate economic elasticity of demand for energy showed a decreasing trend. The major reason was that the economic growth rate in the developing countries was only slightly higher (1–2 %) than that in the developed countries in the last 50 years of the century. From the composition of world energy demand, we can see that the low growth rate in the developed countries somewhat softened the high growth rate in the developing countries, lowering the growth rate of world energy demand and reducing the energy elasticity. Since 2001, the sharp economic growth in the developing countries (almost 4 % higher than that in the developed countries) has driven the rapid increase in energy demand, which could not be completely offset by the lower growth rate of energy demand in the developed countries. Thus, the energy elasticity of demand showed an upward trend during this period (Table 1.1).

1.1.3 Different Decreasing Rates of Energy Intensity Across Countries

With economic restructuring and technological progress, most countries and regions in the world have shown a decreasing trend in energy consumption per unit of GDP since 1980 while some other countries have shown an increasing trend periodically. From 1980 to 2008, energy consumption per unit of GDP in the United States decreased by 44 % and that in Japan decreased by 23 %. For the developing countries, India decreased by 19 % and China decreased by 66 % (Fig. 1.2). The sharp decrease in China played a positive role in relieving global energy demand and greenhouse gas (GHG) emissions. The energy consumption per unit of GDP in South Africa and Brazil showed an increasing trend from 1980 to

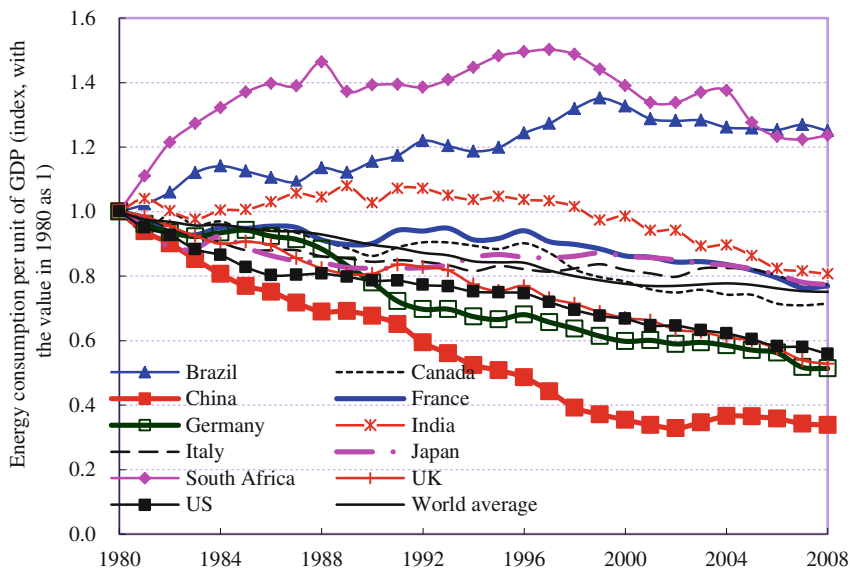


Fig. 1.2 Energy consumption per unit of GDP (index) in major countries (1980–2008). *Data sources* BP (2009), World Bank (2009) and authors’ calculations

2000 before slowing down after 2000. Some major developing countries have great potential in reducing their energy consumption, improving their technologies and shifting to less energy-intensive industries in the near future. To realize these objectives, more specific and enforceable strategic planning is needed.

1.1.4 *There Is no Significant Improvement in the World’s Unbalanced Energy Consumption*

Similar to global economic development, the energy consumption in different countries varies greatly (Fig. 1.3). The annual per capita energy consumption in the developed and OPEC countries was ranging from 3 to 10 toe and that in the State of Qatar exceeded 20 toe. According to the World Bank (2010b), the per capita energy consumption in most developing countries lags far behind than that in developed countries. For example, the per capita energy consumption in the United States is more than four times the world average. It is worth noting that the residential energy demand in most developing countries is still for basic living needs while that in the developed countries is for luxury or enjoyment. Similar to global energy consumption, the energy consumption within a country also differs greatly among regions, social classes, and income groups.

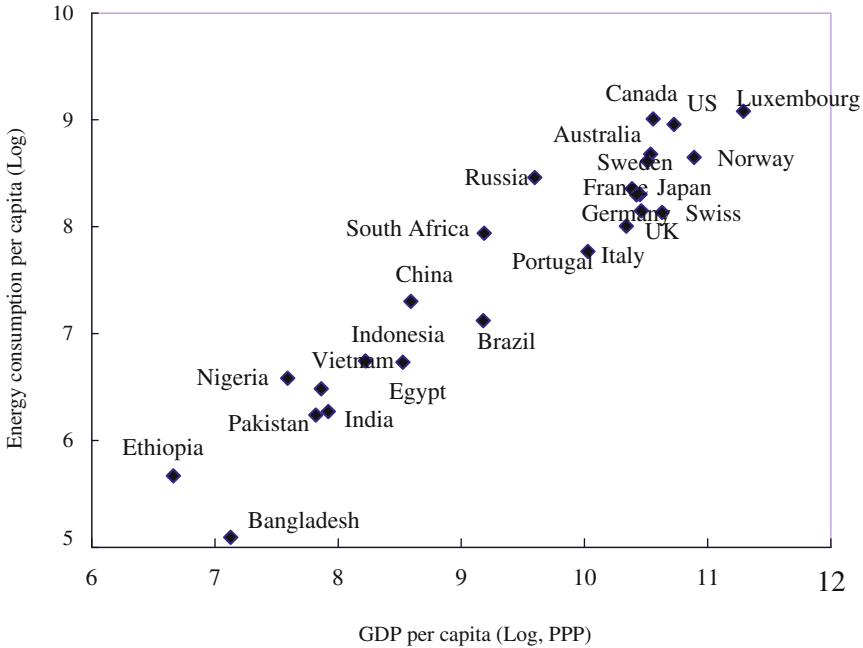


Fig. 1.3 Per capita energy consumption in major countries (2007). *Data source* World Bank (2010b)

1.1.5 Energy Poverty and the Induced Health Issues Are Still Serious

According to IEA (2009d), there are 2.5 billion people in the world who are still using traditional bio-energy and biomass to produce electricity for daily life and 1.5 billion people have no access to electricity services. The data from WTO (IEA 2009c) showed that 1.5 million people die from indoor air pollution every year because of their use of solid fuels (85 % of which is traditional bio-energy and biomass) and coal (15 %). If there are no new policies, electricity services will still be unavailable to 1.3 billion people in 2030. The data in the “2010 Millennium Development Goals” issued by the United Nations on June 23, 2010 (UN 2010) showed that more than 40 % of people in over 70 countries are still using solid fuels (Fig. 1.4).

1.1.6 World Energy Trade Increases Steadily and Natural Gas Emerges Progressively

Because the spatial distribution of energy resources and energy demand is unmatched, global energy trading has kept a quickly increasing trend since the

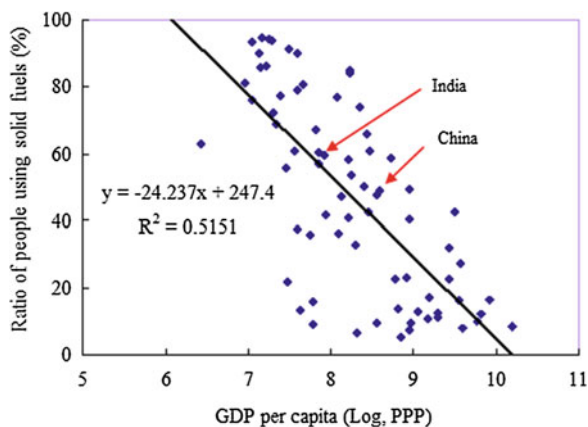


Fig. 1.4 Ratio of people using solid fuels in major countries (2007). *Data sources* World Bank (2010b) and UN {UN 2010#1135}. Includes data for the United States and another 76 countries (mostly developed countries and the oil-and-gas rich countries) where the ratio of people using solid fuels is less than 5 %. The data for Uganda and 19 other countries (mostly African countries) where the ratio is greater than 95 % are not included

1990s with the globalization and development of transport technology. World oil trade increased from 1.34 billion tons in 1990 to 2.54 billion tons in 2008, and the ratio of oil trade to oil consumption increased from 47 to 64 % (Table 1.2). Saudi Arabia and Russia are the world's leading crude oil producing and exporting

Table 1.2 World's top ten crude oil producers, net exports and imports

Country	Production (million tons, 2008)	Percentage of world total	Country	Net exports (million tons, 2007)	Country	Net imports (million tons, 2007)
Saudi Arabia	509	12.9	Saudi Arabia	339	United States	573
Russia	485	12.3	Russia	256	Japan	206
US	300	7.6	Iran	130	China	159
Iran	214	5.4	Nigeria	112	India	122
China	190	4.8	United Arab Emirates	105	Korea	118
Mexico	159	4	Norway	97	Germany	106
Canada	155	3.9	Mexico	89	Italy	94
Kuwait	145	3.7	Angola	83	France	81
Venezuela	137	3.5	Angola	82	Spain	59
United Arab Emirates	136	3.5	Iraq	81	Holland	58
Others	1511	38.4	Others	583	Others	515
World	3941	100	Total	1957	Total	2091

countries (approximately 25 % of the world's oil production and approximately 30 % of the world's net exports of oil). The United States, Japan, China, and India are the leading crude oil importing countries. The United States imported 0.57 billion tons of crude oil in 2007, 27.4 % of the world's total.

Natural gas plays an increasingly important role in global energy trading compared with crude oil resources, but the spatial distribution of natural gas resources is much more uneven. Natural gas reserves in Russia, the State of Qatar, and Iran amount to 56 % of the world's total. In the early stage of natural gas development, large-scale international/regional trading could not be achieved, and natural gas was generally consumed directly on site or transformed into electricity due to the limitations of storage and transportation technologies. Since the 1960s, international natural gas trading has grown. Before 1970, the leading natural gas importing country was the United States. With the outbreak of the first oil crisis, the crude oil supply in the developed countries was greatly challenged. To alleviate the energy shortage, some countries turned to importing natural gas as an important oil supplement. Since then, natural gas trading has attracted more and more attention from governments and enterprises and has played an increasing role in global energy trading.

With the development of storage and transportation technologies, there has been a swift expansion of natural gas pipelines, liquefied natural gas (LNG) carriers and receiving stations. Today, there are three natural gas trading markets based on European pipelines, Asia-Pacific LNG carriers and North American pipelines. In the early 1970s, natural gas trading accounted for only 5.5 % of total gas consumption, most of which was based on pipelines (only 6.2 % was LNG). In the past decades, however, natural gas trading has developed swiftly, especially LNG trading. By 2008, natural gas trading accounted for 29.7 % of total consumption, a quarter of which was LNG (Table 1.3).

The natural gas in Japan and Korea was mainly imported from southeastern Asia, Australia, and the Middle East and that in Europe was mainly imported from

Table 1.3 World's natural gas consumption and trading (1971–2008)

Year	1971	1990	2000	2006	2007	2008
Total natural gas consumption (10 ² million cubic meters)	11,000	20,721	25,280	29,338	30,632	31,542
Total natural gas trading (10 ² million cubic meters)	602	5352	6440	8808	9106	9373
Total LNG trading (10 ² million cubic meters)	40	740	1400	2159	2311	2256
Ratio of gas trading to gas consumption (%)	5.5	25.8	25.5	30.0	29.7	29.7
Ratio of LNG trading to gas consumption (%)	0.4	3.6	5.5	7.4	7.5	7.2
Ratio of LNG trading to gas trading (%)	6.6	13.8	21.7	24.5	25.4	24.1

Russia and North Africa. Since the 1980s, natural gas imports from both LNG carriers and pipelines have grown quickly in the OECD countries. Pipeline gas was mainly imported from the former Soviet Union and Eurasian countries/regions. LNG imports amounted to 30 % of total imports. With the development of gas storage and transportation technologies, natural gas trading will become part of the future global market. With the growing importance of LNG for satisfying natural gas demand, there are many countries and regions building or planning to build LNG import projects. Constructions of natural gas pipelines and LNG receiving stations are also developing very quickly, so natural gas imports are increasing dramatically.

At present, natural gas trading is centered in a few countries. According to BP (2010), Russia, Canada, and Norway are the world's leading export countries (natural gas exports in these three countries amounted to 58 % of the world's total in 2009) while the United States, Germany, and Italy are the leading gas pipeline import countries (gas pipeline imports in these three countries was approaching 40 % of world's total in 2009). The State of Qatar, Malaysia, and Indonesia are the leading LNG exporters (LNG exports in these countries amounted to 43 % of the world's total in 2009), and Japan, Korea, and Spain are the leading LNG importers (LNG imports in Japan were 85.9 billion cubic meters in 2009, 35 % of world's total imports¹ while LNG imports in Korea and Spain were 34.3 and 27.0 billion cubic meters, respectively). In the Asia-Pacific countries, China, India, and other emerging markets show great potential for natural gas imports.

Coal trading is primarily in hard coal, coking coal, and steam coal. The data from the IEA (2009a) and the results from our analysis show that global coal trading is growing fast in the 21st century, especially for hard coal and steam coal (Fig. 1.5). Transportation for coal trading is basically maritime transportation, which accounts for 90 % of total trading. Australia, Indonesia, and Russia are the world's leading coal export countries. China was also among the top coal exporters before 2006, but coal exports have decreased substantially since then because of growing domestic demand and the restrictions of resource-export policies. Data from Chinese Customs indicates that 2009 was the first year that China became a net importer of coal, importing 0.103 billion tons of coal that year. In terms of coking coal resources, China was a big exporting country for a long time in the past, when coking coal exports amounted to half of the world's total. Due to growing domestic demand and the resultant restriction in resource-export policies and the sluggish world coal demand, coking coal exports dropped substantially to 0.54 million tons in 2009.

¹Since the Great East Japan Earthquake and tsunami caused a nuclear accident on March 11, 2011, Japan has ceased to generate electricity from most of its nuclear reactors. To meet the electricity supply gap, Japan increased its electricity generation from oil and gas, which resulted in significant LNG imports in 2011 and 2012.

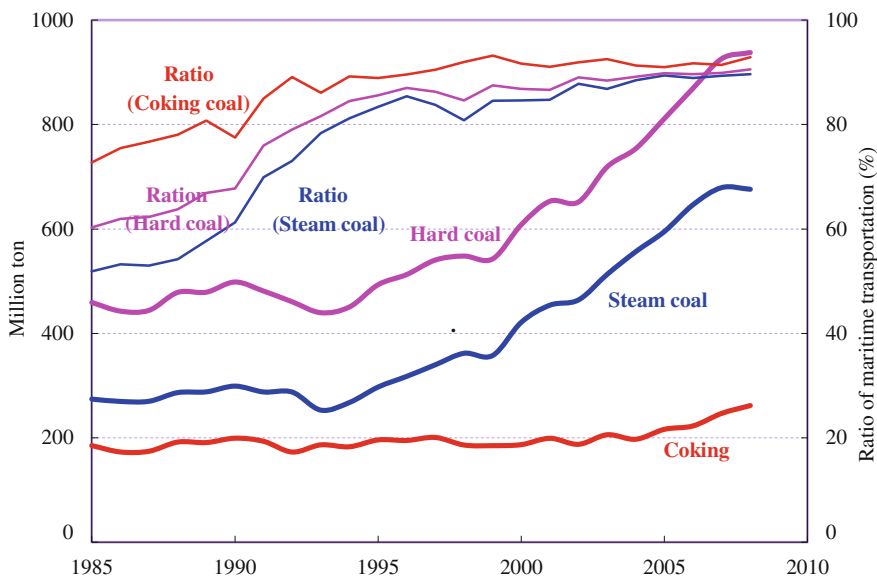


Fig. 1.5 World's coal trading and ratio of maritime transportation (1985–2010) IEA (2009b)

1.1.7 Fossil Fuel-Based Energy Consumption Has Caused Serious Pollution Are Carbon Emissions

While the volume of energy consumption was increasing rapidly, the structure of consumption was also changing continuously, motivated by the reserves of energy resources and the limitation of technologies. During the first industrial revolution, the ratio of coal to total energy consumption increased sharply and thus, the coal mining/consumption areas were always the world's industrial centers. But now the major primary energies worldwide include fossil fuels, such as oil, coal, and gas, even though different countries/regions have different structures due to different resource endowments. The IEA (2009b) suggests that the total energy consumption was 12 billion standard toe in 2007, with the ratio of coal at 26.5 %, oil at 34.0 % (a drop of 12.2 % compared with that in 1973), gas at 20.9 % (a rise of 4.9 %), nuclear energy at 5.9 % (a rise of 5.0 %), hydroelectricity at 2.2 %, bio-energy and waste at 9.8 %, and others at 0.7 % (Fig. 1.6). According to its base scenario prediction, the proportion of the different energies in 2030 will be coal at 29.1 %, oil at 29.8 %, gas at 21.2 %, nuclear energy at 5.7 %, hydroelectricity at 2.4 %, bio-energy and waste at 9.6 %, and others at 2.2 %.

The over-exploitation and combustion of fossil fuels to meet the energy needs are posing serious threats to the environment and contributing to environmental pollution, ecological damage, and global warming. According to IEA (2009a), there were 29 billion tons of carbon dioxide emissions from fossil fuels, 42.2 % of which was from coal, 37.6 % from oil, and 19.8 % from natural gas (Fig. 1.7). The

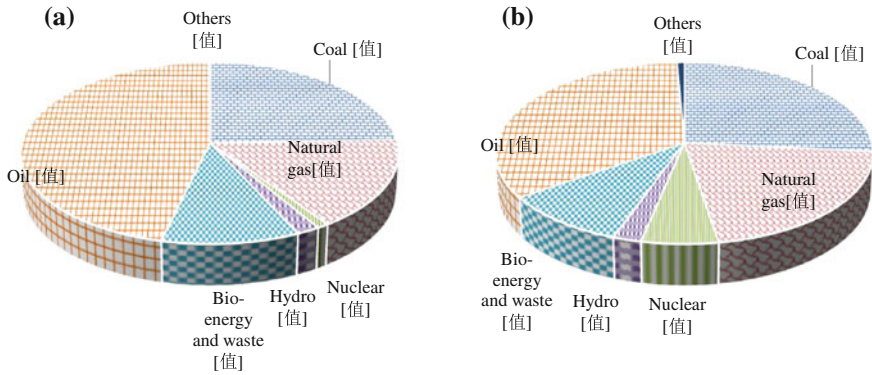


Fig. 1.6 a World energy consumption structure in 1973, b world energy consumption structure in 2007. Data source IEA (2009c)

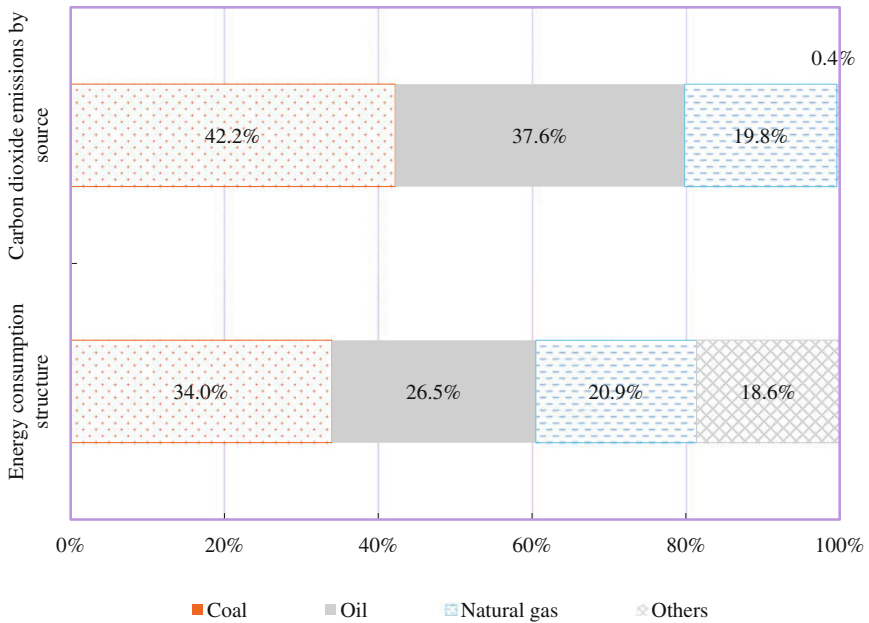


Fig. 1.7 World's energy consumption structure and carbon dioxide emissions. Data source IEA (2009a). Only carbon dioxide emissions from fossil fuel combustion were considered

leading carbon dioxide emission countries were China, the United States, Russia, India, and Japan, and the emissions from these countries accounted for 55 % of the world's total. The electricity sector at 41 % contributed the most to carbon dioxide emissions, followed by transportation sector at 23 %. The underlying reason was

that the carbon dioxide emission factors for coal and oil were the highest, and coal was mostly used in the electricity sector while oil was mostly used in the transportation sector.

1.2 New Trends of World Energy Development from 2008 to 2010

1.2.1 Recent Changes in the World Economy and the Global Financial Crisis

In recent years, the modern financial system has become more vulnerable and fragile as a result of complex financial securities, a dependence on short-term funding markets, international trade imbalances, and high corporate and consumer debt levels. Any shock or stimulus, such as the ongoing foreclosure crisis, the failure of key financial institutions, regulatory and market-based controls, or unhealthy stock and housing markets, could disrupt the delicate equilibrium of the system.

Since late 2008, the subprime mortgage crisis in the United States has spread worldwide. Both developed and developing countries have been adversely affected by the crisis. According to the World Bank (2010a), the world's economic growth rate in 2008 was 1.7 %, a drop of 2.2 % from the previous year, and the growth rate in 2009 was -2.2 %, the lowest since World War II, when growth in the developed countries was -3.3 % and that in the developing countries was 1.2 % (-2.2 % excluding China and India). Global trade decreased by 14.4 % in 2009 and the prices of the major commodities dropped substantially as well. The United States, Japan, European Union, and other developed countries suffered greatly during this crisis (Table 1.4).

Even though the crisis represented the most serious recession after World War II, the economic systems have been restored and even reinforced since late 2009, which is much earlier than expected due to the efforts of all governments, including the measures of government collaborations, the global economy is recovering and maintaining fast and stable growth. Despite the uncertainty, such as the high unemployment rate in the major economies and a serious debt crisis in a few countries, the global economy in 2010 was better than expected. Therefore, many international organizations have raised their economic growth rate expectations for the major economies since late 2009.

The global economic recession and the subsequent quick recovery have brought a great fluctuation in the world's energy prices (Fig. 1.8). The crude oil price for delivery in the New York Commodity Exchange dropped from a record high of 15 USD/barrel on June 3, 2008 to 34 USD/barrel (a drop of 77 %) on December 19, 2008. After March 2009, oil prices started to slowly rise. Generally speaking, the change in oil prices is a quarter earlier than the change in oil developments at the microeconomic level.