



Energy Science, Engineering and Technology

JIAHAI YUAN · GUOLIANG LUO
JIANGUO CHEN
EDITORS

RENEWABLE ENERGY IN CHINA

NOVA

ENERGY SCIENCE, ENGINEERING AND TECHNOLOGY

RENEWABLE ENERGY IN CHINA

JIAHAI YUAN
GUOLIANG LUO

AND

JIANGUO CHEN

EDITORS



 **nova**
publishers
New York

Copyright © 2014 by Nova Science Publishers, Inc.

All rights reserved. No part of this book may be reproduced, stored in a retrieval system or transmitted in any form or by any means: electronic, electrostatic, magnetic, tape, mechanical photocopying, recording or otherwise without the written permission of the Publisher.

For permission to use material from this book please contact us:

Telephone 631-231-7269; Fax 631-231-8175

Web Site: <http://www.novapublishers.com>

NOTICE TO THE READER

The Publisher has taken reasonable care in the preparation of this book, but makes no expressed or implied warranty of any kind and assumes no responsibility for any errors or omissions. No liability is assumed for incidental or consequential damages in connection with or arising out of information contained in this book. The Publisher shall not be liable for any special, consequential, or exemplary damages resulting, in whole or in part, from the readers' use of, or reliance upon, this material. Any parts of this book based on government reports are so indicated and copyright is claimed for those parts to the extent applicable to compilations of such works.

Independent verification should be sought for any data, advice or recommendations contained in this book. In addition, no responsibility is assumed by the publisher for any injury and/or damage to persons or property arising from any methods, products, instructions, ideas or otherwise contained in this publication.

This publication is designed to provide accurate and authoritative information with regard to the subject matter covered herein. It is sold with the clear understanding that the Publisher is not engaged in rendering legal or any other professional services. If legal or any other expert assistance is required, the services of a competent person should be sought. FROM A DECLARATION OF PARTICIPANTS JOINTLY ADOPTED BY A COMMITTEE OF THE AMERICAN BAR ASSOCIATION AND A COMMITTEE OF PUBLISHERS.

Additional color graphics may be available in the e-book version of this book.

Library of Congress Cataloging-in-Publication Data

ISBN: 978-1-63117-610-4

Published by Nova Science Publishers, Inc. † New York

ENERGY SCIENCE, ENGINEERING AND TECHNOLOGY

RENEWABLE ENERGY IN CHINA

ENERGY SCIENCE, ENGINEERING AND TECHNOLOGY

Additional books in this series can be found on Nova's website
under the Series tab.

Additional e-books in this series can be found on Nova's website
under the e-book tab.

ACKNOWLEDGMENTS

This book is partly supported by Beijing Higher Education Young Elite Teacher Project and the Fundamental Research Funds for the Central Universities. The authors are also grateful to Nadya Gotsiridze-Columbus, whose invitation lead us to discuss and work out the idea of publishing a book on China's renewable energy, to Carra Feagaiga, whose kind reminders helped to finish the preparation of the manuscript in due time, and to the editorial team of Nova, whose editorial services largely improved the manuscript. The errors which remain in the book belong to the authors, certainly.

CONTENTS

Table List		vii
Figure List		xi
Acknowledgments		xiii
Chapter 1	Renewable Energy in China: Introduction <i>Jiahai Yuan and Huiming Xu</i>	1
Chapter 2	The Wind Power Supply Chain in China <i>Jiahai Yuan, Shenghui Sun and Jiakun Shen</i>	25
Chapter 3	Solar Power Industry in China <i>Jianguo Chen</i>	53
Chapter 4	The Development of Biomass Energy Industry in China <i>Jianguo Chen</i>	71
Chapter 5	Development and Utilization of Marine Renewable Energy Resources in China <i>Guoliang Luo</i>	93
Chapter 6	Smart Grids in China <i>Jiahai Yuan, Jiakun Shen and Huiming Xu</i>	109
Chapter 7	Successes and Failures of China's Golden-Sun Program <i>Guoliang Luo</i>	131
Chapter 8	Exploitation and Utilization of Renewable Energy Resources in Rural Areas of Western China <i>Guoliang Luo</i>	149
Chapter 9	Transition to Renewable-Based Energy System in China <i>Jiahai Yuan</i>	181
Editors' Contact Information		203
Index		205

TABLE LIST

Table 1-1. Renewable Energy Sources in China	13
Table 1-2. Renewable Energy Planning in China	15
Table 1-3. China's divergences from the "best practice" of renewable energy deployment	18
Table 2-1. The upstream stakeholders in China's wind power supply chain.	31
Table 2-2. The downstream stakeholders in China's wind power supply chain.	32
Table 2-3. The upstream policies for wind power in China.	34
Table 2-4. The downstream policies for wind power in China.	35
Table 2-5. Top 20 wind turbine suppliers in China in 2011.	37
Table 2-6. The trend of wind power technology development	38
Table 2-7. Top 10 wind farm developers in China in 2011.	43
Table 2-8. Cumulative grid-connected wind capacity in China in 2011.	43
Table 2-9. Statistical data of wind power curtailment in China, 2010.	44
Table 3-1. PV industry chain	57
Table 3-2. Key producers in China's PV industry	58
Table 3-3. Stakeholders in China PV industry	59
Table 3-4. The planning related to China's PV industry	60
Table 3-5. National PV power price	62
Table 3-6. Subsidies policy for China's solar power generation	64
Table 3-7. Strategic objectives of China's PV generation cost	65
Table 3-8. Strategic objective of China's solar power generation capacity (unit: GW)	66
Table 3-9. Investment estimation of China's solar power generation market	67
Table 4-1. The amount of field crop straw in China in 2010 (unit: Mt)	74
Table 4-2. China's agricultural residue resources (unit: Mt)	75
Table 4-3. Amount of residue of forestry resources in China	76
Table 4-4. Total amount of forestry residue resources in China and its energy potential (unit: Mt)	76
Table 4-5. The feeding quantity of livestock in China by the end of 2011(Million)	76
Table 4-6. The amount of faeces from poultry and livestock in 2009	77

Table 4-7. Total amount of poultry and livestock manure in China and its energy potential (Unit: Mt)	77
Table 4-8. The amount of the 2008 biomass liquid fuel resources and the amount can be obtained (Unit: Mt)	78
Table 4-9. The output of fuel ethanol in China (unit: Mt)	79
Table 4-10. Stakeholders in the development of biomass energy industry in China	81
Table 4-11. Planning system of biomass energy in China	82
Table 4-12. Laws and regulations for biomass energy in China	84
Table 4-13. Strategic goals of biomass development during the 12th Five-Year period	86
Table 4-14. Strategic goals on biomass development in rural areas and agriculture bio-energy	87
Table 4-15. The overall goals on national forestry development	88
Table 4-16. Investment demand in the functional field of biomass energy	89
Table 5-1. Tidal energy in China's coastal provinces, municipalities and autonomous regions	95
Table 5-2. Distribution of wave energy in part of China	96
Table 5-3. Distribution of tidal current energy in part of China	96
Table 5-4. Main projects for wave technologies funded by S&T program since 2001	102
Table 5-5. Main tidal current energy projects supported by the Chinese government since 2001	103
Table 6-1. Stakeholders and their concerns on SG	112
Table 6-2. Comparison of smart grid and traditional grid	113
Table 6-3. Key aspects of developing smart grids in China	114
Table 6-4. Policies relevant to smart grid development in China	116
Table 6-5. Progress in generation sector	120
Table 6-6. Progress in transmission sector	121
Table 6-7. Progress in transformation sector	121
Table 6-8. Progress in distribution sector	122
Table 6-9. Progress in utilization sector	123
Table 6-10. Progress in dispatch sector	124
Table 6-11. Estimated investment on power grid in China, 2011-2020	126
Table 6-12. Estimated investment on smart grid in China, 2011-2020	127
Table 7-1. Roles of different incentives for the PV power generation industry at various stages	134
Table 7-2. China's laws and policies regarding renewable energy (2005-2011)	135
Table 7-3. China's PV market share (%)	136
Table 7-4. China's main PV subsidy policies	136
Table 7-5. Main conditions, supported areas and measures for implementing the Golden Sun Program, 2009-2012	140
Table 7-6. Approved projects under the Golden-Sun Program	141
Table 7-7. Shares of PV module export in China, 2006-2012	142
Table 7-8. Capacity of projects under the Golden-Sun Program, 2009-2012	143

Table 7-9. Standards and codes related to distributed PV power generation	144
Table 7-10. Comparison between PV module costs and PV subsidies (yuan/W)	146
Table 8-1. Renewable energy resources in rural areas of Western China	151
Table 8-2. Profile of eastern, central and western regions of China (2010)	151
Table 8-3. Household energy consumption structures and changes in rural areas of eastern, central and western China (Unit: 10, 000 kg ce)	152
Table 8-4. Cooking fuels consumption proportion in different rural areas in 2006 (Unit: %)	153
Table 8-5. Living electricity consumption in rural areas of Western China in 2006 (Unit: kWh)	154
Table 8-6. Rural households without power access in Western China in 2007	155
Table 8-7. Per capita living energy consumption changes in rural areas of eastern, central and western China (Unit: kg ce/a)	155
Table 8-8. Proportion and ranking of respiratory disease-caused death of China's rural residents	157
Table 8-9. The subsidy scale of "Demonstrative Building Integrated Solar PV Project" and "Golden Sun Project" during 2009 -2012	159
Table 8-10. Comparison of renewable energy development modes	161
Table 8-11. Costs for power access to non-electric households in rural areas of Western China during 2006-2009	162
Table 8-12. Investment of biogas in China	163
Table 8-13. Rural electricity consumption in Tibet	168
Table 8-14. Major durable goods owned by every 100 rural households	168
Table 8-15. Electricity consumption of rural residents in China in 2006 (unit: kWh)	169
Table 8-16. Composition of rural residents according to the major use of cooking energy (unit: %) [7]	169
Table 8-17. Solar energy resource distribution in Tibet [7]	170
Table 8-18. Power-access rate of rural areas in the Tar in 2005 (unit: %)	172
Table 8-19. Power supply by isolated small hydropower and solar power in Tibetan rural areas in 2005	172
Table 9-1. Energy technology options analysis	185
Table 9-2. Pathways for energy system transition in China	188
Table 9-3. Summary of integration characteristics for selecting renewable energy technologies	190
Table 9-4. Policy packages for energy system transition and illustrations	198

FIGURE LIST

Figure 1-1. GDP and its growth in China, 1980-2011.	2
Figure 1-2. Energy consumption and growth rate in China, 1980-2011.	2
Figure 1-3. CO ₂ emissions and growth rate in China, 1980-2010.	3
Figure 1-4. Per capita energy consumption vs. GDP per capita in the world, 1971-2010.	3
Figure 1-5. Per capita CO ₂ emissions vs. GDP per capita in the world, 1971-2010.	4
Figure 1-6. Energy intensity of the economy in the world, 1971-2010.	5
Figure 1-7. Primary energy consumption structure in China, 1980-2011.	6
Figure 1-8. Growth of renewable power generation capacity in China, 1980-2011.	6
Figure 1-9. Power generation structure in China, 1980-2011.	7
Figure 1-10. The proportion of renewable power generation in some countries.	7
Figure 1-11. Regional distribution of hydropower resources in China.	8
Figure 1-12. Regional distribution of wind power resources in China.	9
Figure 1-13. Regional distribution of solar power resources in China.	10
Figure 2-1. Annual installed and cumulative wind power capacity in China, 2001-2011.	26
Figure 2-2. Wind turbine system.	28
Figure 2-3. Wind power generation and utilization.	29
Figure 2-4. Wind power supply chain.	30
Figure 2-5. Upstream wind power supply chain.	36
Figure 2-6. Market concentration of wind turbine manufacturing in China.	37
Figure 2-7. Mating among electronic control and wind turbine companies.	39
Figure 2-8. Patent application in wind turbine industry.	40
Figure 2-9. Patent application of foreign applicants in China.	41
Figure 2-10. Patent application of domestic applicants in China.	41
Figure 2-11. Downstream supply chain of wind power.	42
Figure 7.1. Formation of solar PV development policies and the effects	133
Figure 7.2. Process for implementing the Golden-Sun Program	138
Figure 7.3. Subsidies to the Golden-Sun Program (2009-2012)	141

Figure 7.4. Increased capacities under the Golden-Sun Program in provinces (municipalities and autonomous regions)	142
Figure 7.5. Changes in the prices of China’s PV modules and PV systems	143
Figure 9.1. An interactive framework for managing energy system transition in China.	195

Chapter 1

RENEWABLE ENERGY IN CHINA: INTRODUCTION

Jiahai Yuan^{1} and Huiming Xu²*

¹School of Economics and Management, North China Electric Power University

²Information and Telecommunication Branch,
State Grid Corporation of China, People's Republic of China

ABSTRACT

Renewable energy (RE) has grown rapidly in China ever since the publication of the *Renewable Energy Law* in 2006. As the introduction of the book, this chapter begins with an overview of economic growth, energy consumption and CO₂ emissions in China, with a purpose to justify the urgent requirement to develop RE in China's overall picture of social-economic growth. Then the resource endowment of various forms of renewable energy in China is briefly analyzed, and China's legislation and overall plan to develop RE is presented. Finally, with an institutional perspective, the social-political factors of energy system (with an emphasis on power system) development in China are briefly addressed. The chapter concludes with the scope and layout of the entire book.

Keywords: Renewable energy resource, legislation, planning, institutional analysis, China

1. ECONOMIC GROWTH, ENERGY CONSUMPTION AND CARBON EMISSIONS IN CHINA

1.1. Historical Trend

Since implementing the reform-and-open-up policy in 1978, China has successfully realized the economic take-off and sustained a growth miracle of successive GDP growth at nearly 10% for more than three decades (Figure 1-1). In 2010, China became the second largest economy with a total GDP of 5878.6 billion US\$ (in 2012-year exchange rate and hereafter in this chapter) [1].

* Corresponding author: Email: yuanjh126@126.com.

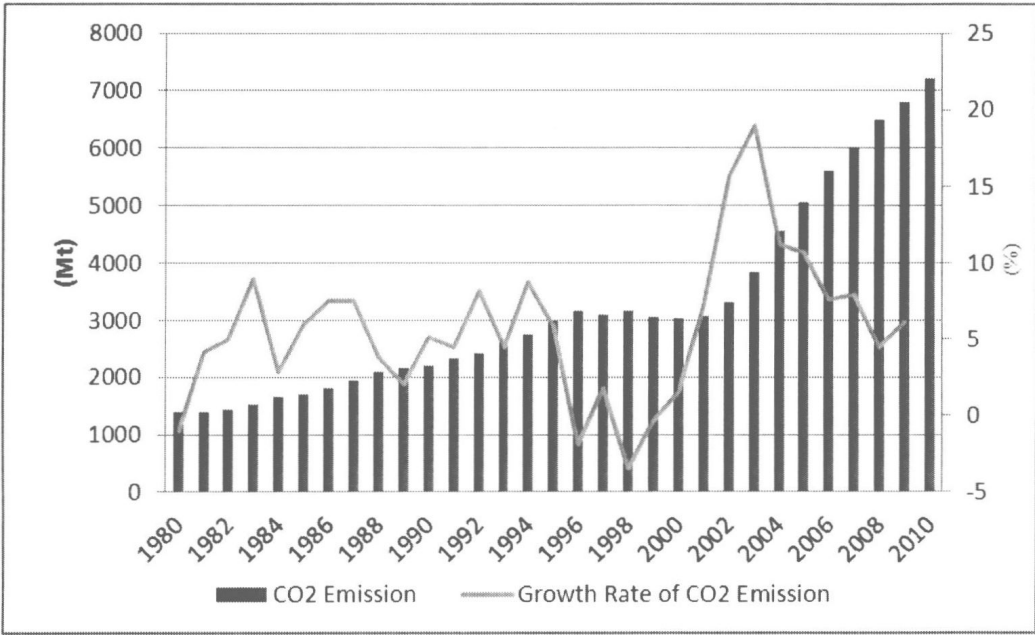


Figure 1-1. GDP and its growth in China, 1980-2011.

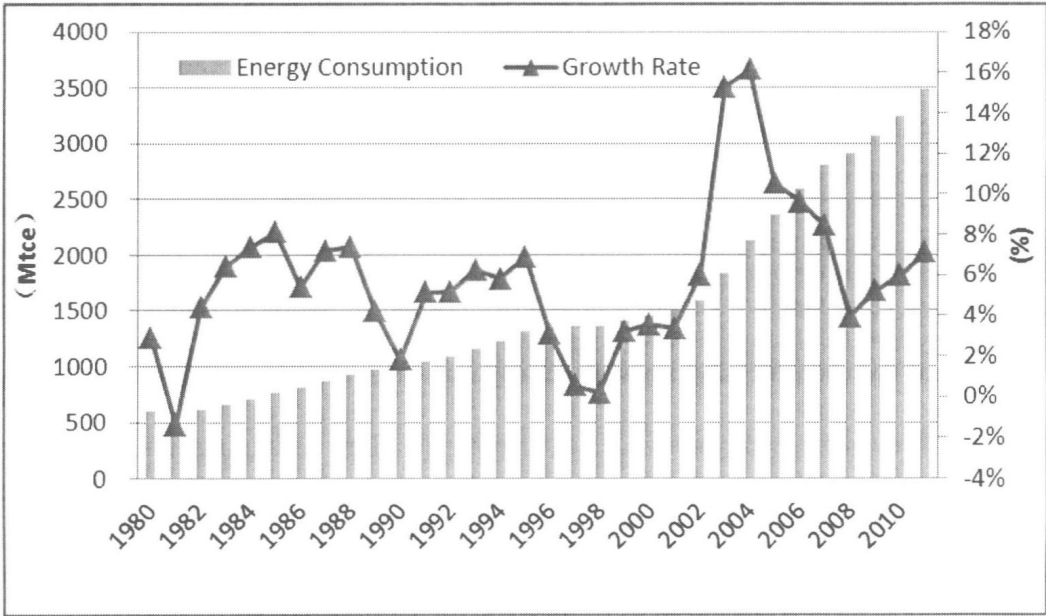


Figure 1-2. Energy consumption and growth rate in China, 1980-2011.

Economic growth is accompanied by rapid energy consumption. Various empirical studies have revealed strong evidences that Chinese economy is energy-dependent [2]. As is indicated in Figure 1-2, growth of energy consumption is almost synchronous with China’s economic growth during 1980-2011. It is worth noticing that China has made huge progress in energy efficiency in the first two decades of reform-and-opening-up. From 1980 to 2000, China managed to fuel fourfold GDP growth with just double energy consumption growth. However, energy consumption experienced rapid growth in the early of 21st century when