



Solar Energy Policies in China: Trajectory, Change and Drivers of China's Energy Transition

Melisande F. Liu
刘敏林

Shaker Verlag GmbH

Solar Energy Policies in China: Trajectory, Change and Drivers of China's Energy Transition

A dissertation presented by

Melisande F. Liu

to

Freie Universität Berlin

Fachbereich Politik- und Sozialwissenschaften.

In partial fulfillment of the requirements for the degree *doctor rerum politicarum*
(*Dr. rer. pol.*) – an equivalent of a PhD in Political Science.

Submitted in Berlin on July 28, 2016

First Supervisor

Prof. Dr. Miranda Schreurs,
Director of the Environmental Policy Research Centre and Professor of Comparative Politics,
Freie Universität Berlin

Second Supervisor

Prof. Dr. Manfred Fishedick,
Vice-President and Director of Future Energy and Mobility Structures,
Wuppertal Institut für Klima, Umwelt, Energie GmbH

Date of PhD Defense

February 10, 2017.

Photo Credit

Cover Photo by Raj Eiamworakul on Unsplash (www.unsplash.com).

Schriftenreihe der Reiner Lemoine-Stiftung

Melisande F. Liu

**Solar Energy Policies in China:
Trajectory, Change and Drivers of China's
Energy Transition**

D 188 (Diss. Freie Universität Berlin)

Shaker Verlag
Düren 2019

Bibliographic information published by the Deutsche Nationalbibliothek

The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data are available in the Internet at <http://dnb.d-nb.de>.

Zugl.: Berlin, Freie Univ., Diss., 2017

Copyright Shaker Verlag 2019

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, without the prior permission of the publishers.

Printed in Germany.

ISBN 978-3-8440-6732-3

ISSN 2193-7575

Shaker Verlag GmbH • Am Langen Graben 15a • 52353 Düren

Phone: 0049/2421/99011-0 • Telefax: 0049/2421/99011-9

Internet: www.shaker.de • e-mail: info@shaker.de

To my loving husband, Professor Dr. med. Francisco J. Martinez Portillo, and my beautiful daughter, Neyla Alegria Martinez Liu. Your unconditional love, encouragement and endurance have made this journey possible. I also dedicate this thesis to my parents and grandparents – Kosima, John, Eleanor and Liu Guoan – for nurturing my creative potential and paving the way for this academic achievement. Dearest Rosa and Rosita – thank you for your unreserved support. To Liberto whose wisdom and unquenchable thirst for knowledge will always inspire me.

Executive Summary (in German)

China befindet sich energiepolitisch an einem historischen Scheideweg. In den letzten Jahren erzielte China, trotz seiner Rolle als weltweit größter Umweltsünder und Treibhausgasverursacher, wichtige Fortschritte im internationalen Klimaschutz. Im Rahmen der UN-Klimakonferenz in Paris (COP21) kündigte der chinesische Staatschef Xi Jinping an, dass China seine CO₂-Emissionen bis zum Jahr 2030 um 60-65% senken werde. Dies stellt eine historische Absichtserklärung dar, die eine dramatische Kehrtwende des bisherigen Wachstumsmodells erahnen lässt und insbesondere einen raschen und effektiven Ausbau von erneuerbaren Energieträgern, vorwiegend im Bereich Solarenergie, erfordert. Wissenschaftliche Studien bezweifeln jedoch, dass China zu einer nachhaltigen und erfolgreichen Solarpolitik fähig sei und attestieren der chinesischen Solarpolitik eine regelmäßige „Sprunghaftigkeit“, „Inkohärenz“ und „Ziellosigkeit“. Als Beleg hierfür dienen der vermehrte Anstieg und die Änderung von politischen Vorgaben in den Jahren nach 2011 (beispielsweise die Zieländerungen der Kapazitäten für installierte Solarenergie der Jahre 2011, 2012 und 2013). Implizit schwingt hier die Annahme mit, dass es sich bei Chinas jüngsten Bemühungen um den raschen Ausbau von Solarenergie eher um einen kurzlebigen und ziellosen Prozess handelt, der anstelle einer grundlegenden Neuausrichtung vielmehr von opportunistischen und flüchtigen Interessen geleitet sei.

Die vorliegende Arbeit untersucht die Entwicklung und den Politikwandel der chinesischen Solarpolitik im Zeitraum 1980 bis 2013 und stellt in diesem Zusammenhang die Frage, wie sich die jüngsten und ambitionierten Gesetzesentwürfe in den historischen Verlauf von Solarpolitik in China einordnen lassen, zu welchem Zeitpunkt sich der *Policy Wandel* hin zu Solarenergie vollzogen hat und welche Auslöser hierzu beigetragen haben. Hierfür werden zwei analytische Theoriemodelle herangezogen, um den Strukturwandel und dessen Hintergründe umfassender zu verstehen. Das erste Theoriemodell (*Punctuated Equilibrium Theory* (PET)) dient dazu, Phasen der Stabilität und des Politikwandels zu unterscheiden, zu systematisieren und ermöglicht folglich eine genauere Betrachtung der Faktoren und Umstände, die den Politikwandel begünstigen bzw. auslösen: institutionelle Rahmenbedingungen, Auslöser sowie positive/negative Feedbackzyklen. Das zweite bei dieser Untersuchung benutzte Theoriemodell (*Fragmentierte Autoritätsmodell* (FA)) erweitert den analytischen Rahmen, in dem es die Besonderheiten und Strukturen von Chinas politischen Prozessen und fragmentierten Machtverhältnisse im Energiesektor hervorhebt. Eine Zusammenführung beider Theorien liefert dementsprechend Erkenntnisse, wie Chinas jüngste Solarpolitik zu interpretieren und einzuordnen ist, ob es sich hierbei um einen Paradigmenwechsel oder nur um inkrementelle Veränderungen handelt, in welchem erkennbaren Muster sich der Politikwandel vollzogen hat und welche Prozesse, Auslöser und Dynamiken dazu beigetragen haben.

Die Entwicklung der chinesischen Solarpolitik unterteilt sich in vier Phasen. In der ersten Phase (vor 1992) gab es weder spezifische Gesetzesentwürfe noch Ziele bezüglich Solarenergie, jedoch vereinzelte, vage Interessensbekundungen hin zu einem verstärkten Ausbau und Nutzung von Solarenergie (beispielsweise im Umweltgesetz von 1979, namentlich im sechsten Fünfjahresplan (1981-1985) und im siebten Fünfjahresplan (1986-1990)). In der zweiten Phase der Solarpolitik (1994-2003) lieferte China zum ersten Mal einen konkreten und landesweiten Strategieplan für den Solarsektor für den Zeitraum 1996 bis 2010 („*New and Renewable Energy Development Programm*“). Der Strategieplan für den Solarsektor beruhte ausschließlich auf Chinas Vision für das 21. Jahrhundert, festgeschrieben in der Agenda 2001. Das Programm diente als politische und strategische Richtlinie, die für den genannten Zeitraum 1996 bis 2010 zunächst den Ausbau einer Solarindustrie und entsprechender Infrastruktur vorsah, um noch nicht ausgereifte Technologien gezielt zu fördern und in einem zweiten Schritt (in den Jahren 2000 bis 2010) eine gezielte

Anwendung und Verbreitung von Solartechnologien auf das Niveau von Industrieländern anzuheben. In der dritten Phase der chinesischen Solarpolitik (2003-2008) wurde mit dem das Erneuerbaren Energien Gesetz („*Renewable Energy Law*“) das bis dato wichtigste Instrument zur Förderung erneuerbarer Energien entwickelt. Mit diesem Gesetz wurden konkrete Ziele vorgegeben und wichtige Maßnahmen geregelt, wie beispielsweise der Anschluss von Solaranlagen, die vorrangige Abnahme durch die Netzbetreiber, die Übertragung und Vergütung des Stroms durch die Netzbetreiber und die landesweite Finanzierung der durch den Solarenergieausbau verursachten Mehrkosten. Dies führte in den folgenden Jahren zu einem sprunghaften und intensiven Anstieg von politischen Vorgaben, um die weiteren Maßnahmen und Instrumente zu konkretisieren und auszuarbeiten. Die vierte und letzte Phase der chinesischen Solarpolitik (2009-2013) war zum einen durch einen weiteren Anstieg an Regelungen und Maßnahmen zur Anpassung der obengenannten Vorgaben gekennzeichnet, und zum anderen erfolgte eine ambitioniertere Abstimmung der geplanten Zielvorgaben für den Ausbau der Solarenergie.

Wie durch die vorliegende Arbeit gezeigt werden konnte, bestätigt die Anwendung der *Punctuated Equilibrium Theorie*, dass Chinas Solarpolitik des letzten Jahrzehnts vor allem einem Paradigmenwechsel geschuldet ist, der sich im Zeitraum 1994 bis 1996 vollzog und eine historische Kehrwende der bis dato existierende Kernziele, Priorisierungen sowie Policy Instrumente führte. Diese historische Kehrwende (oder *Punctuation*) war das Resultat zweier neuer Denkart (*Positive Feedbackprozesse*), nämlich die des *Environmental Paradigms* und die des *Scientific Development Paradigms*, welche das bis dahin dominante auf kohlebasierete Wachstumsmodell (*Policy Monopols*) entschieden in Frage stellte und stattdessen eine Neuausrichtung auf nachhaltige, soziale, umweltverträgliche sowie auf Innovation und Technologie-basierende Werte forderte. Die radikale Abkehr des bis dahin dominanten Denkmusters wurde letztendlich durch externe und interne Ereignisse (*Triggers, Window of Opportunity*) ausgelöst, allen voran wachsende energipolitische Bedenken, ausufernde Umweltzerstörung und die Sorge um Chinas Energiesicherheit. Das Eintreten dieser zwei neuen Denkart wurde zu den durch die schwach ausgeprägten formellen Institutionen (*Institutional Venues*) begünstigt.

Die Meilensteine in der chinesischen Solarpolitik, die in den Jahren nach 1996 folgten, insbesondere das im Jahr 2005 erlassene Erneuerbaren Energiegesetz und die darauffolgenden Regelungen und Policyänderungen, führten zwar zu einem rascheren Ausbau und der Initiierung neuer Handlungsweisen, waren aber letztendlich nur Teil eines *routinierten* und *inkrementellen* politischen Prozesses, ausgelöst und ermöglicht durch den Paradigmenwechsel im Zeitraum 1994-1996, und gelten somit als Modi eines *normalen* Policy-Zustandes (*First and Second Order Change*). Vor diesem Hintergrund ist die vermehrte Häufigkeit und Zunahme an politischen Vorgaben im Solarsektor insbesondere in den letzten Jahren nicht als „grüne Revolution“ aufzufassen, sondern vielmehr als die routinemäßige Anpassung eines relativ stabilen und schrittweisen Prozesses zu verstehen. Diese Annahme wird zusätzlich durch die Erkenntnis bekräftigt, dass sich das Thema Solarenergie bereits seit den 1970er auf der politischen Tagesordnung befand (*systematischen, institutionellen Agenda* und *Entscheidungsagenda*) und dass Solarenergie spätestens seit 1994 als nationale Priorität auf allen politischen Ebenen/Agenden wahrgenommen wurde. So lässt sich festhalten, dass die chinesische Solarenergiepolitik tief in Chinas langfristiger, allumfassender und kohärenter Energiestrategie für das 21. Jahrhundert eingebettet ist und diese damit auch in Zukunft weiterhin Priorität für politisches Handeln haben wird.

Executive Summary (in English)

China's energy sector is at critical crossroads. The country has recently committed itself to ambitious climate targets: In 2015, China's President Xi Jinping announced during the UN Climate Conference in Paris (COP21) that China would peak its carbon emissions by 2030. This constitutes a historical step for China and implies a dramatic shift away from of its heavy coal reliance towards a low-carbon path. This will require an unprecedented and highly ambitious promotion of renewable and clean energy sources particularly in the area of solar Photovoltaics. Despite these commitments, reasonable doubts remain as to whether China's policymakers are able to develop support mechanisms and policies that are necessary for an effective and sustained deployment of solar energies in the long run. Recent studies have described China's solar policies as *not ideal, highly erratic* and *unfocused*. This had led to recent *flare-ups* of solar regulations and measures as well as *frequent* and *dramatic* changes in solar energy targets, especially since 2011 (these include the solar target amendments in the years 2011, 2012 and 2013). It is implicitly assumed that China's efforts towards solar energy deployment are manifestations of an *ephemeral* and *unfocused* policy process that is predominantly guided by opportunistic maneuvering and short-term interest rather than the outcome of a long-term and consistent planning process.

This study sets out to understand *how* and *why* China's solar policies have emerged in recent past and how these seemingly sporadic flare-ups of contemporary solar policies fit into the overall trajectory of solar policy development. This study applies both the *Punctuated Equilibrium Theory* (PET) and the *Fragmented Authoritarianism* (FA) Model to examine China's policy transitions for the period 1980 to 2013. The PET pays particular attention to the disruptive phases and characteristics of political processes and is therefore highly conducive to understanding and identifying a general pattern of policy change and to understand why policymakers suddenly abandon a chosen path and explore new pathways and policy directions. The FA Model is considered the most durable heuristic through which to study contemporary politics in China and allows for a better understanding of the structures, processes and mechanism behind policy choices. A combination of the PET theory and FA Model allows for an improved understanding of the trajectory and rationale behind China's solar policy development.

The trajectory of solar policies in China can be distinguished into four phases. During the first phase (prior to 1990), solar policies included mostly official declarations of intent to encourage the use and development of solar technologies but lacked specific legislations or targets. A major milestone achieved during this time was the mentioning of solar energies in China's Sixth Five-Year-Plan (1981-1985). During the second phase (1994-2002), China released two landmark policies, namely the 1994 *White Paper on China's Population, Environment and Development in the Twenty-First Century* and the 1996 *New and Renewable Energy Development Program*, which elaborated on the general strategy for solar energy development for the following decade. It proposed to develop solar energies through a two-step process, whereby the first stage (period 1996-2000) should establish an industrial base for solar technology and the second stage (period 2000-2010) should scale-up solar energy technologies to the national level. During the third phase of solar policy development (2003-2008), China released another landmark policy in 2005 titled the *Renewable Energy Law*, which for the first time elaborated on concrete support measures for solar energy technologies including (i) a mandatory grid connection and full purchase agreements; (ii) a renewable energy fund to finance solar application and research; (iii) feed-in tariffs and remuneration schemes; and (iv) the specification of solar energy targets. Although the *Renewable Energy Law* remained rather vague, it established an essential guideline for lower levels of government to draft subsequent policies. The fourth and last phase of solar energy development (2009-2014) was marked by a sudden increase of new solar policies to specify and substantiate

existing support measures and to amend solar energy targets, including the solar target amendments since 2011.

By applying the PET and FA Model, this study shows that the recent proliferation of solar policies especially in recent years is mostly attributed to a paradigm shift (*Punctuation*) that took place during the period 1994 to 1996. This punctuation (*Third Order Change*) led to (i) a complete *new set of goals and priorities* (ii) a new *environment of instruments*, and (iii) a host of new *instruments themselves*. The large-scale departure from the past was the result of two new emerging paradigms (*Positive Feedback Forces*), namely the *Environmental Paradigm* and the *Scientific Development Paradigm*, that increasingly challenged the heretofore dominant “*pollute first, control later*” and “*getting rich first, clearing up later*” way of thinking (*Policy Monopoly* and *Negative Feedback Forces*) and offered instead new perspectives and interpretations on economic growth especially in terms of *sustainable, inclusive* and *innovative* parameters. The radical departure from the existing paradigm was finally prompted through internal and external events (*Triggers, Window of Opportunity*), most important of which were growing energy political factors, environmental degradation and emerging energy security concerns. New paradigms were able to enter the political arena due to weak institutional venues and boundaries. The solar policies that followed the first punctuation in the years after 1996, in particular the *Renewable Energy Law* in 2005 and the numerous policy changes and amendments in solar targets since then, have constituted important milestones for solar energy policy development that lead to a burgeoning of solar policies and an accelerated growth of solar energy capacities. However, they represent the type of routinized decision-making that is associated with the *normal* and *incremental* state of policy processes (*First and Second Order Change*). This conclusion aligns with the presumption that solar energy issues have been part of China’s national agenda (*agenda universe, systematic, institutional and decision agenda*) since the 1970s and since 1994 have been considered an issue of major national concern that is to be acted upon by the government body or ruling elite (*decision agenda level*). Therefore, China’s recent efforts and ambitious solar energy plans are not as much a “green revolution” or *new phenomenon* but instead constituents of a *routinized, incremental* and relatively *stable* policy process that is part of a more entrenched policy path that China began venturing in the mid 1990s and that builds upon a coherent and long-term energy strategy for the 21 centuries. Therefore, solar policies will likely continue to be a priority for energy policymaking in China’s mid- and long-term future.

Outline

EXECUTIVE SUMMARY (IN GERMAN)	4
EXECUTIVE SUMMARY (IN ENGLISH)	6
FIGURES, TABLES, ABBREVIATIONS, ACRONYMS, UNITS AND MAPS	10
ACKNOWLEDGEMENTS	16
PART 1 INTRODUCTION	17
1.1 PROBLEM DEFINITION: CHINA AT ENERGY CROSSROADS.....	17
1.2 CURRENT STATE OF RESEARCH: ARE CHINA'S SOLAR ENERGY POLICIES ERRATIC AND INCONSISTENT?.....	24
1.3 RESEARCH QUESTIONS AND PURPOSE	28
1.4 ANALYTICAL APPROACH, THEORETICAL FRAME AND RESEARCH PURPOSE.....	29
1.5 STRUCTURE OF THE STUDY.....	31
PART 2 RESEARCH DESIGN AND METHODOLOGY	33
2.1 RESEARCH PARADIGM: THE RATIONALE FOR QUALITATIVE RESEARCH AND CONSTRUCTIVISM	33
2.2 CASE STUDY: DEFINITION, TYPOLOGY AND SIZE	34
2.3 DATA SOURCES, DATA COLLECTION AND DATA ANALYSIS.....	36
2.4 LIMITATIONS AND SCOPE.....	39
PART 3 ANALYTICAL APPROACH AND THEORETICAL FRAMEWORK	41
3.1 POLICY ANALYSIS.....	42
3.2 POLICY CHANGE AND PUNCTUATED EQUILIBRIUM THEORY.....	50
3.3 CHINA'S POLICYMAKING, PROCESSES AND POLICY ARENA: AN ANALYTICAL FRAMEWORK	61
3.4 SUMMARY AND HYPOTHESIS.....	76
PART 4 SETTING THE STAGE: FRAMEWORK OF SOLAR ENERGY POLICY	80
4.1 SOLAR PV TECHNOLOGIES: CHARACTERISTICS, APPLICATION AND UTILIZATION.....	80
4.2 POLICY RATIONALE: OPPORTUNITIES, CHALLENGES AND CONSTRAINTS OF SOLAR PV IN CHINA.....	90
4.3 CHINA'S ENERGY SECTOR, INSTITUTIONS AND ACTORS.....	118
4.4 SUPPORT MECHANISMS AND INSTRUMENTS FOR SOLAR ENERGY.....	149
4.5 SUMMARY.....	152
PART 5 TRACING THE TRAJECTORY OF SOLAR POLICIES IN CHINA	155
5.1 FIRST PHASE: BEGINNING OF THE POLICY CYCLE (1970-1990)	155
5.2 SECOND PHASE: LAYING THE FOUNDATIONS FOR SOLAR ENERGY IN CHINA (1993 -2002).....	158
5.3 THIRD PHASE: ESTABLISHING A LEGISLATIVE FRAMEWORK FOR SOLAR ENERGY (2003-2008).....	167
5.4 FOURTH PHASE: ADJUSTING THE LEGISLATIVE FRAMEWORK FOR SOLAR ENERGY (2009-2013)	183
5.5 SUMMARY.....	197
PART 6 EXPLAINING CHINA'S SOLAR POLICY TRAJECTORY FROM THE PUNCTUATED EQUILIBRIUM THEORY AND FRAGMENTED AUTHORITARIANISM PERSPECTIVE	200
6.1 THE EMERGENCE OF SOLAR ISSUES ON CHINA'S NATIONAL AGENDA	200
6.2 POLICY DYNAMICS: PUNCTUATIONS AND TRIGGERS FROM THE PET PERSPECTIVE.....	204
6.3 INSTITUTIONAL VENUES	210
6.4 EMERGENCE OF NEW IMAGES AND PARADIGMS IN CHINA'S ENERGY SECTOR.....	215
6.5 TRIGGER AND WINDOW OF OPPORTUNITY	219
6.6 SUMMARY.....	220
PART 7 CONCLUSION AND OUTLOOK	225
7.1 SUMMARY OF ANALYSIS	225
7.2 EVALUATION OF ANALYTICAL CONCEPTS.....	229
7.3 POLICY IMPLICATIONS, OUTLOOK AND RECOMMENDATION	230
APPENDIX	232

ANNEX I: DIAGRAM OF POLITICAL-ADMINISTRATIVE SYSTEM OF PRC.....	232
ANNEX II: LIST OF INTERVIEWEES.....	233
ANNEX III: CHINA'S LEADER GENERATIONS: MEMBERS, IDEOLOGY AND VISION	234
ANNEX IV: ENERGY ACTORS IN CHINA: ABBREVIATIONS AND PROFILE DESCRIPTIONS.....	236
ANNEX V: ENERGY SECTOR REFORMS.....	239
ANNEX VI: MAJOR HISTORICAL EVENTS IN CHINA FROM CHINA'S COMMUNIST PARTY PERSPECTIVE.....	243
ANNEX VII: LIST OF FIVE-YEAR PLANS APPROVED BY NATIONAL'S PEOPLE'S CONGRESS (NPC)	247
ANNEX VIII: OVERVIEW OF SOLAR POLICIES IN CHINA FROM 1990-2013.....	249
ANNEX IX: REVIEW OF RECENT SCHOLARLY WORK ON SOLAR POLICIES IN CHINA.....	265
BIBLIOGRAPHY	272

Figures, Tables, Abbreviations, Acronyms, Units and Maps

List of Figures

FIGURE 1 MAP OF ADMINISTRATIVE LEVELS IN CHINA	14
FIGURE 2 DIAGRAM OF PET THEORY.....	51
FIGURE 3 LEVELS OF THE POLITICAL AGENDA.....	53
FIGURE 4 DOMINANT ANALYTICAL MODELS OF POLICYMAKING IN CHINA.....	64
FIGURE 5 DIAGRAM OF BARGAINING, CONSENSUS SEEKING AND BUREAUCRATIC RANK IN CHINA.....	71
FIGURE 6 DIAGRAM OF CHINA'S TWO-TIER POLICY ARENA	73
FIGURE 7 LEGISLATION CATEGORIES IN CHINA'S ADMINISTRATIVE AND POLITICAL SYSTEM	76
FIGURE 8 ANALYTICAL CONCEPT OF POLICY PROCESSES IN CHINA.....	79
FIGURE 9 SCHEME FROM SOLAR CELL TO SOLAR ARRAY.....	81
FIGURE 10 OVERVIEW SOLAR PV TECHNOLOGIES	82
FIGURE 11 LABORATORY BEST-CELL EFFICIENCIES FOR VARIOUS PV TECHNOLOGIES.....	85
FIGURE 12 DIFFERENCE BETWEEN MONO- AND MULTICRYSTALLINE SOLAR CELLS.....	86
FIGURE 13 DISTRIBUTION OF SOLAR RESOURCES IN CHINA	92
FIGURE 14 EXAMPLE OF SOLAR DISPATCH.....	98
FIGURE 16 THE LEARNING CURVE OF PHOTOVOLTAICS.....	110
FIGURE 17 APPROXIMATE ILLUSTRATION OF CHINA'S STATE	126
FIGURE 18 STAKEHOLDERS CONSTELLATION AND INTERACTION IN CHINA'S ELECTRICITY SECTOR.....	129
FIGURE 19 HIERARCHY OF COMMUNIST PARTY OF CHINA (CPC).....	132
FIGURE 20 CHINA'S POWER APEX: THE CPC'S POLITBURO STANDING COMMITTEE (2012-2017).....	133
FIGURE 21 TENTATIVE DIAGRAM OF POLICYMAKING PROCESS IN CHINA'S ENERGY SECTOR	144
FIGURE 22 TIMELINE OF SOLAR POLICY DEVELOPMENT (1970-1990).....	155
FIGURE 23 TIMELINE OF SOLAR POLICY DEVELOPMENT (1990-2002).....	158
FIGURE 24 TIMELINE OF SOLAR POLICY DEVELOPMENT (2003-2008).....	167
FIGURE 25 EVOLUTION OF THE LEGISLATIVE FRAMEWORK FOR SOLAR ENERGY IN CHINA.....	183
FIGURE 26 THE EMERGENCE OF SOLAR ENERGY ISSUES ON CHINA'S AGENDA.....	201
FIGURE 27 POLICY CHANGE AND POLICY PUNCTUATIONS FOR THE PERIOD (1970-1990).....	205
FIGURE 28 POLICY CHANGE AND POLICY PUNCTUATIONS FOR THE PERIOD (1993-2002).....	206
FIGURE 29 POLICY CHANGE AND POLICY PUNCTUATIONS FOR THE PERIOD (2003-2008).....	208
FIGURE 30 POLICY CHANGE AND POLICY PUNCTUATIONS FOR THE PERIOD (2009-2013).....	209

List of Tables

TABLE 1 CHINA'S ENERGY AND GHG EMISSION TARGETS.....	17
TABLE 2 OVERVIEW OF USED DATABASES AND SOURCES.....	37
TABLE 3 DEFINITIONS OF "PUBLIC POLICY"	42
TABLE 4 SELECTED INSTITUTIONS AND THEIR BUREAUCRATIC RANK	65
TABLE 5 SOLAR PV VALUE CHAIN, INDUSTRY AND ENVIRONMENTAL FACTORS.....	86
TABLE 6 OVERVIEW OF CATEGORIES OF PV APPLICATIONS.....	89
TABLE 7 SOLAR ENERGY RESOURCES IN DIFFERENT REGIONS OF CHINA.....	93
TABLE 8 THEORETICAL POTENTIAL AND INSTALLED CAPACITY OF SOLAR PV IN CHINA	93
TABLE 9 COMPARISON OF CHINA'S OIL, NATURAL GAS AND COAL RESERVES ON A PER CAPITA BASIS (BASED ON PROVEN RESERVES)	94
TABLE 10 COMPARISON OF GHG EMISSIONS BETWEEN COAL AND SOLAR POWER PLANTS (GLOBAL AVERAGE)....	106
TABLE 11 TYPICAL PV SYSTEM PRICES IN 2013 IN SELECTED COUNTRIES (USD).....	108
TABLE 12 ESTIMATES OF LCOES FOR SOLAR ELECTRICITY IN CHINA	112
TABLE 13 CHINA'S PRIMARY ELECTRICITY SUPPLY IN 2012.....	116
TABLE 14 OVERALL ENERGY BALANCE IN CHINA (INDICATED IN MIO TONS OF STANDARD COAL EQUIVALENT (SCE))	118

TABLE 15 CHINA'S COAL BALANCES IN 2012.....	121
TABLE 16 CHINA'S PETROLEUM BALANCES IN 2012.....	122
TABLE 17 CHINA'S NATURAL GAS BALANCES IN 2012	123
TABLE 18 NAMES AND ABBREVIATIONS OF ELECTRICITY SECTOR ACTORS.....	129
TABLE 19 OVERVIEW OF ENERGY-RELEVANT MINISTRIES	139
TABLE 20 OVERVIEW OF SELECTED SOLAR ENERGY SUPPORT MECHANISMS.....	149
TABLE 21 OVERVIEW OF RENEWABLE ENERGY PROMOTION SCHEMES IN CHINA (1970-1990)	155
TABLE 22 OVERVIEW OF RENEWABLE ENERGY PROMOTION SCHEMES IN CHINA.....	163
TABLE 23 OVERVIEW OF SOLAR ENERGY TARGETS (2003-2008)	168
TABLE 24 GENERAL PROVISIONS OF THE RENEWABLE ENERGY LAW	170
TABLE 25 CHINA'S FIRST SOLAR ENERGY TARGETS SPECIFIED IN THE MEDIUM AND LONG-TERM DEVELOPMENT PLAN FOR RENEWABLE ENERGY.....	171
TABLE 26 OVERVIEW OF SOLAR POLICIES ON GRID CONNECTION (2003-2008).....	172
TABLE 27 OVERVIEW OF RELEVANT POLICIES (2005-2008).....	175
TABLE 28 OVERVIEW OF RELEVANT POLICIES RELATED TO THE RENEWABLE ENERGY DEVELOPMENT FUND.....	178
TABLE 29 OVERVIEW OF RELEVANT POLICIES (2007-2008).....	182
TABLE 30 OVERVIEW OF SOLAR ENERGY TARGETS.....	184
TABLE 31 OVERVIEW OF RELEVANT POLICIES (2009-2013).....	186
TABLE 32 OVERVIEW OF RELEVANT POLICIES (2008-2013).....	188
TABLE 33 OVERVIEW OF AMENDMENTS TO THE RENEWABLE ENERGY FUND.....	191
TABLE 34 OVERVIEW OF AMENDMENTS TO DISTRIBUTED ENERGY POLICY	192
TABLE 35 OVERVIEW OF PILOT PROJECTS FOR SOLAR PV	194
TABLE 36 OVERVIEW OF MAJOR INSTITUTIONAL CHANGE (1980-1994).....	210
TABLE 37 OVERVIEW OF MAJOR INSTITUTIONAL CHANGE (2003-2007).....	212
TABLE 38 OVERVIEW OF MAJOR INSTITUTIONAL CHANGE (2008-2011).....	213

List of Abbreviations and Acronyms

AC	Alternating Current
BIPV	Building-integrated Photovoltaics
CAS	Chinese Academy of Sciences
CAE	Chinese Academy of Engineering
CDC	China Datang Corporation
CdTe	Cadmium-Telluride
CGC	China Guodian Corporation
CHDC	China Huadian Corporation
CHNG	China Huaneng Group
CIGS	Copper-indium-gallium-diselenide
CIS	Copper-Indium-Selenide
CNREC	China National Renewable Energy Centre
CO ₂	Carbon Dioxide
CPC	Communist Party of China
CPIC	China Power Investment Corporation
CPP	China's Communist Party
CPV	Concentrating Photovoltaics
CREIA	Chinese Renewable Industry Association
CSG	China Southern Power Grid Cooperation
CSP	Concentrated Solar Power
CSR	Corporate Social Responsibility

DC	Direct Current
EPIA	European Photovoltaic Industry Association
ERI	Energy Research Institute
EU	European Union
FA	Fragmented Authoritarianism
FYP	Five-Year Plan
GDP	Gross Domestic Product
GHG	Greenhouse Gas
IAD	Institutional Analysis and Development
IEA	International Energy Agency
IMG	Inner Mongolian Power Grid Cooperation
INC	International Negotiating Committee
IPCC	Intergovernmental Panel on Climate Change
LCOE	Levelized Cost of Energy
MEP	Ministry of Environmental Protection
MIIT	Ministry of Industry and Information Technology
MLP	Multi-level Perspective
MLR	Ministry of Land and Resources
MOE	Ministry of Education
MOP	Ministry of Personnel
NSFC	National Natural Science Foundation of China
MOF	Ministry of Finance
MofCom	Ministry of Commerce
MoHURD	Ministry of Housing, Urban and Rural Development
MOST	Ministry of Science and Technology
MOC	Ministry of Commerce
MOF	Ministry of Finance
Mtce	Metric tons of coal equivalent
NDRC	National Development and Reform Commission
NEA	National Energy Administration
NEC	National Energy Commission
NGO	Non-governmental organization
NIMBY	Not in my back yard
NIS	National innovation system
PM	Particulate Matter
PRC	People's Republic of China
PV	Photovoltaic
R&D	Research and Development
RD&D	Research, Development and Demonstration
RE	Renewable Energy
REL	Renewable Energy Law
RES	Renewable Energy Sources
RPS	Renewable Energy Portfolio Standard
SASAC	State-owned Assets Supervision and Administration Commission
SDPC	State Development Planning Commission (since 2003 NDRC)
SETC	State Economic and Trade Commission
SGCC	State Grid Cooperation of China
SSTC	State Science and Technology Commission

STC	Standard Testing Conditions
TT	Technological Transitions
UHV	Ultra-high Voltage
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change
US / USA	United States of America
USD	United States Dollar
VAT	Value Added Tax
WECD	United Nations World Commission on Environment and Development
WHO	World Health Organization

List of Units

a-Si	Amorphous
mc-Si	Multicrystalline
sc-Si	<i>Monocrystalline</i> / single crystalline
μc-Si	Micromorphous Silicon
μm	Microns

Currency Equivalents

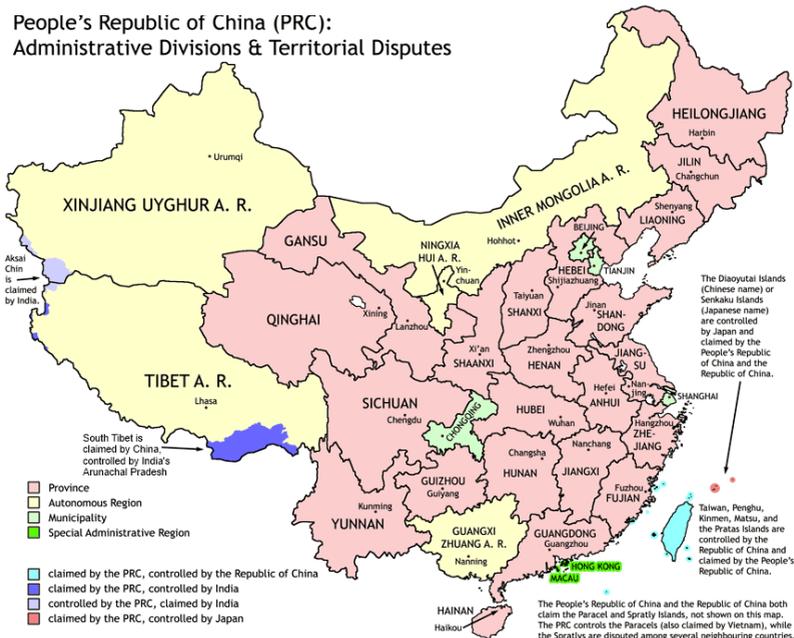
(as of July 18, 2016)
Chinese Renminbi (CNY)
Euro (EUR)
CNY 1.00 = EUR 0.135
EUR 1.00 = CNY 7,422

Physical Units and Conversion Factors

Name	Abbreviation	Conversion Calculation
Nanometer	nm	$1 \times 10^{-9} \text{ m}$
Kilo	k	10^3
Mega	M	10^6
Giga	G	10^9
Tera	T	10^{12}
Peta	P	10^{15}
Watt	W	1 J x s^{-1}
Kilowatt	kW	1 000 W
Megawatt	MW	$10^6 \text{ W} = 1\,000 \text{ kW}$
Gigawatt	GW	1 000 MW
Terawatt	TW	1 000 GW
Kilowatt-second	kWs	$3\,600 \text{ J} = 3,6 \text{ kJ}$
Wattpeak	Wp	
Kilowatt Peak	kWp	
Megawatt Pek	MWp	
Watt-hour	Wh	$3\,600 \text{ J} = 3,6 \text{ kJ}$
Kilowatt-hour	kWh	$3,6 \times 10^6 \text{ J} = 3\,600\,000 \text{ J} = 3\,600 \text{ kJ} = 3,6 \text{ MJ}$

Megawatt-hour	MWh	$3,6 \times 10^9 \text{ J} = 3\,600\,000 \text{ kJ} = 3\,600 \text{ MJ} = 3,6 \text{ GJ}$
Gigawatt-hour	GWh	$3,6 \times 10^{12} \text{ J} = 3\,600\,000 \text{ MJ} = 3\,600 \text{ GJ} = 3,6 \text{ TJ}$
Terawatt-hour	TWh	$3,6 \times 10^{15} \text{ J} = 3\,600\,000 \text{ GJ} = 3\,600 \text{ TJ} = 3,6 \text{ PJ}$
Joule	J	1 kW ^s
Kilojoule	KJ	
Megajoule	MJ	
Gigajoule	GJ	
Terajoule	TJ	
Petajoule	PJ	
Ton/tonne	Ton	1 000 kg
BTU		1,054.615 joules
1 barrel of crude oil		6.193 gigajoules
1 tonne oil equivalent (TOE)		41.9 GJ
1 tonne coal equivalent (TCE)		29.3 GJ

**People's Republic of China (PRC):
Administrative Divisions & Territorial Disputes**



Source: Wikipedia, www.wikipedia.com

China has four levels of formal administration under the central government. The first level is officially made up of 34 provincial-level governments. This includes 23 provinces; five

geographic entities that China calls “autonomous regions,” which have large ethnic minority populations (Guangxi, Inner Mongolia, Tibet, and Xinjiang); four municipalities that report directly to the central government (Beijing, Chongqing, Shanghai, and Tianjin); and the two special administrative regions of Hong Kong and Macau. The PRC’s count of 23 provinces includes Taiwan, the island of 23 million people that the PRC does not control, but over which it claims sovereignty. The second level of administration includes more than 300 prefectural-level administrative units, including prefectures and prefectural-level cities. The third level of administration includes nearly 3,000 counties and county-level cities. The lowest tier of official administration is made up of approximately 40,000 townships and towns. The first, third, and fourth levels of administration all have political structures that mirror the central government, with parallel Party and government organizations and people’s congresses. At the second administrative level, prefectural-level cities and autonomous prefectures also have government organizations and people’s congresses, but regular prefectures do not. Instead, they have administrative agencies. Villages are not considered part of the formal administrative structure, but are rather considered “mass organizations of self-management at the grass-roots level.” Their status outside the government hierarchy allowed China to introduce direct elections at the village level in the 1980s without setting a precedent for direct elections at higher levels.¹

¹ Saich, T. (2011). Governance and Politics of China. In *Governance and Politics of China (review)* (3rd ed., pp. 1–448). New York, USA: Palgrave Macmillan.

Acknowledgements

This thesis has benefited greatly from the contributions of many interviewees, practitioners and scholars in China and Germany, who participated and generously devoted their time and efforts to make this study possible. To them, I express my sincere gratitude. A number of reviewers made constructive suggestions during the revision and writing of this thesis. Special thanks go to Annie Liu for sharing her insights into the Chinese energy sector. I also wish to thank the Tsinghua University for hosting me as visiting scholar and providing me with three memorable semesters and courses at their historical university campus. I would like to express my very great appreciation to Prof. Dr. Miranda Schreurs and Prof. Dr. Manfred Fishedick for their input and patience during this thesis. This thesis would not have existed without the financial support from the Reiner Lemoine Foundation, the German Academic Exchange Service (DAAD) and the China Scholarship Council (CSC). Last but not least, I am extremely grateful for the incredible support, encouragement and patience from my family. This is especially true for my loving husband, Professor Dr. med. Francisco J. Martinez Portillo and mother-in-law Rosa Portillo Marin, who made it possible for me to pursue and reconcile research, motherhood and a career abroad. I am indebted to my parents and grandparents, John D. Liu, Kosima Weber Liu, Guo An Liu and Eleanor Liu who have always encouraged and inspired me.