Katrin Jordan-Korte

Government Promotion of Renewable Energy Technologies

Policy Approaches and Market Development in Germany, the United States, and Japan

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Preface

I have made it! My PhD thesis is finally published. There were many moments when I doubted this would ever happen. I would like to dedicate this book to all PhD students still struggling to finish their projects.

The interest in my research topic certainly was the single most important factor that kept me motivated to finish this work. The future of our energy system affects all of us every day. This book presents the first comprehensive comparison of renewable energy promotion instruments in Germany, the United States and Japan. If my work contributes to a better understanding of how governments can promote renewable energy use more effectively and efficiently, then I will have achieved what I set out to do.

This research project would not have been possible without the help and support of many individuals and institutions. I am particularly grateful to the German Institute for International and Security Affairs (Stiftung Wissenschaft und Politik, SWP) for granting me a scholarship through the Forum Ebenhausen. I have immensely benefited from the stimulating environment at the SWP and various opportunities to present and discuss my research results. I would also like to express my deep gratitude to Mr. Joseph C. Fox and the Fox International Fellowship Program, which allowed me to pursue my research for one year at Yale University. This experience has been extremely fruitful and rewarding. Most importantly, however, I want to thank Professor Carl-Ludwig Holtfrerich, the supervisor of my thesis, for his advice and guidance. I would also like to thank Professor Moritz Schularick for his support.

I owe my deepest gratitude to my family and friends, who helped me to stay committed to this work. I want to thank my parents Inge and Dirk Jordan for their moral support. I will forever be indebted to my husband Immo Korte, who has been a great help through the ups and downs. My beautiful children Svea and Vito gave me the motivation and determination to finish this project.

Katrin Jordan-Korte

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List of Abbreviations

AHKs	German Chambers of Commerce Abroad
ANRE	Agency for Natural Resources and Energy
APEC	Asia Pacific Economic Co-operation
BAU	Business as usual
bfai	German Office of Foreign Trade
BMU	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
BMWI	Federal Ministry of Economics and Technology
C and C	Command and control
CFC	Chlorofluorocarbon
CO_2	Carbon Dioxide
CORECT	Committee on Renewable Energy Commerce and Trade
dena	German Energy Agency (Deutsche Energie Agentur)
DoC	Department of Commerce
DoE	Department of Energy
DSIRE	Database of State Incentives for Renewables and Efficiency
EC	European Commission
ECA	Export credit agency
EEG	Renewable Energy Sources Act
EEX	European Energy Exchange
EFL	Electricity Feed-In Law
EIA	Energy Information Administration, US Department of Energy
EPA	Environmental Protection Agency
ETA	Energy Tax Act
EU	European Union
Ex-Im Bank	US Export Import Bank
FERC	Federal Energy Regulatory Commission
GDP	Gross domestic product
GHG	Greenhouse Gas
GW	Gigawatt
HS	Harmonized System
IEA	International Energy Agency
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency

ITA	International Trade Administration
ITC	Investment Tax Credit
ITCS	International Trade by Commodities Statistics
JBIC	Japan Bank for International Cooperation
JETRO	Japan External Trade Organization
JICA	Japan International Cooperation Agency
KfW	Credit Institute for Reconstruction
kWh	kilowatt-hour
METI	Ministry of Economy, Trade and Industry
MFN	Most-favoured nation
MITI	Ministry of International Trade and Industry
MNE	Multinational Enterprises
Mtoe	Million Tons of Oil Equivalent
MW	Megawatt
NEDO	New Energy Industrial Technology Development Organization
NEXI	Nippon Export & Investment Insurance
ODA	Official Development Assistance (Japan)
OECD	Organisation for Economic Co-operation and Development
OEEI	Office of Energy and Environmental Industries
OPEC	Organization of the Petroleum Exporting Countries
PBF	Public Benefits Funds
PTC	Production Tax Credit
PURPA	Public Utility Regulatory Policies Act
PV	Photovoltaic
p.y.	Per Year
R&D	Research and Development
RCA	Revealed Comparative Advantage
REPI	Renewable Energy Production Incentive
RPS	Renewable Portfolio Standards
SPD	Social Democratic Party
toe	Tonne of Oil Equivalent
TPED	Total Primary Energy Demand
TPES	Total Primary Energy Supply
TWh	Terawatt hour
UNFCC	United Nations Framework Convention on Climate Change
US CAP	United States Climate Action Partnership
USITC	United States International Trade Commission
WTO	World Trade Organization

1 Introduction

1.1 Motivation

The expected growth of the world population to 9 or 10 billion towards the second half of the century and renewed economic growth after the current economic crisis will immensely increase the demand for energy. At the same time, the carbon dioxide emissions inherently linked to current fossil fuel use need to be reduced substantially over the century to "prevent dangerous anthropogenic interference with the climate system."[1] As a consequence, there will be a tremendous need for the development and large-scale diffusion of a range of new technologies for conversion, storage, transport and efficient use of energy. Scenarios by the International Energy Agency (IEA) suggest an increase of 87% of electricity demand from 19,014 TWh in the year 2006 to 35,400 TWh in the year 2030.[2]

Renewable energies such as wind, water, solar, biomass and geothermal energy are increasingly regarded as important energy sources to provide sufficient energy in an economically efficient and sustainable way in the next decades and centuries. Against the background of (a) rising energy demand worldwide, (b) the concentration of the remaining fossil fuel reserves in relatively few and mostly volatile countries and the associated risks of energy supply disruptions as well as (c) the challenges posed by climate change, renewable energy will increase its importance and its share in the energy mix worldwide. Accordingly, countries and sub-national governments around the world are increasingly investing in renewable energy technologies. Today, virtually all industrialized countries and many developing countries promote renewable energy use.[3] However, the degree of government involvement and the instruments used in promoting renewable energy technologies vary greatly between countries. Germany, Japan and the United States exemplify different approaches to renewable energy use and governmental promotion of renewable energy. Germany is considered as a forerunner in renewable energy policy and likes to view itself as a "*Klimaschützer*" (engl. climate protector).[4] The German Renewable En-

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[1] United Nations (1992), *Framework Convention on Climate Change*, Article 2.

[2] International Energy Agency (2007), *World Energy Outlook 2007*, p. 539.

[3] See the Global Renewable Energy Policies and Measures Database of the International Energy Agency at http://www.iea.org/textbase/pm/grindex.aspx (access date: 08/05/2008).

[4] Setzer (1998), *Wirtschaftliche Entwicklung und Energieintensität. Zur Theorie und Empirie der Determinanten der Energieintensität*, p. 9.

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ergy Sources Act (EEG) is generally praised as unequivocal success.[5] In contrast, the United States is still regarded as a laggard, unwilling to commit to carbon emission reductions and to implement federal standards on the share of renewable energy in its energy mix, even if a few states (such as California) pursue a more progressive strategy. Japan holds a position in between. The country concentrates on the promotion of solar photovoltaic (PV) and relies heavily on voluntary measures.

Despite their different approaches to renewable energy policy Japan, Germany, and the United States have all played a pioneering role in initiating and supporting various programs for renewable energy promotion, which makes them important players influencing the renewable energy policy decisions in many other countries. Still, the different approaches to renewable energy policy in Germany, Japan and the United States are puzzling since all three countries share similar interests, are confronted with similar challenges and have comparable industrial structures.

The aim of this research endeavor is, thus, to answer two broad questions:

- How are renewable energy instruments to be evaluated in the three countries?
- How can differences in the policy approaches be explained and what are their implications?

The detailed analysis of these two questions is pertinent and topical. Governments will continue to promote renewable energy in the future due to the great challenges in the energy sector. Even though the current economic downturn resulted both in a massive reduction of fossil fuel prices and in decreased energy demand, the need to make the world economy less dependent on fossil fuel use remains vital. Renewable energy sources will not supersede fossil fuels in the near future, but they will play a rapidly growing and increasingly important role in meeting global energy demand in the years to come.

Further, with the increasing saturation of the domestic renewable energy market, international trade in renewable energy technologies will also continuously gain in importance. Trade in renewable energy technologies has experienced above average growth rates and presents a very dynamic trade sector. Especially for countries such as Germany and Japan but also the United States this sector will even gain in importance in the future because of the limitations of the domestic market for renewable power generation. In some cases, the areas that can be efficiently harvested for renewable energy sources (such as on-shore wind or hydro power generation) are becoming increasingly scarce. If high growth rates in the renewable energy industry are to be maintained, international trade in renewable energy technologies becomes vital. Governments have realized the great poten-

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[5] Weber (2008), *Das Erneuerbare-Energien-Gesetz - eine Erfolgsgeschichte*, p. 71. See also a speech by the German Minister for the Environment, Sigmar Gabriel, http://www.bmu.de/english/current_press_releases/pm/39678.php (access date: 10/25/2008).

tial of renewable energy trade and started to implement policies to directly further such exports on international markets. However, the economic efficiency of such instruments is at least questionable and requires a careful examination. Therefore, this analysis includes both promotion instruments aimed at the deployment of renewable energies on the national market as well as measures geared towards increasing exports of renewable energy technologies.

This research is relevant and expedient because the conclusions from the experiences in the three examined countries make patterns for renewable energy promotion and the developments on renewable energy markets recognizable. To understand renewable energy markets and instruments better is especially important with more and more countries implementing renewable energy policies in the coming years.

1.2 Research Questions and Aims

The purpose of this study is to analyze renewable electricity policies in Japan, Germany and the United States. The intention of this work is to evaluate national and, to some degree, sub-national policies promoting renewable energy technologies, to explain the different policy strategies, and to identify advantages and disadvantages of different types of instruments.

Breaking down the two broad research aims stated above, this dissertation aims to answer four specific questions:

- What are the economic arguments for and against governmental intervention in renewable energy markets? Should governments promote renewable energy technologies?
- Which instruments are used in Germany, the United States and Japan to promote renewable energy technologies on the domestic and on international markets?
- How is the promotion of renewable energy technologies to be evaluated with regard to three economic criteria? These criteria are:
    1. the deployment of renewable energy sources in the national electricity mix
    2. the capacity to induce technological improvement
    3. renewable technology exports and economic competitiveness
- Which factors explain the different approaches in the three case countries to promote renewable energy technologies?

Existing literature in this field lacks a systematic comparison of renewable energy policy and markets in Germany, the United States and Japan. Moreover, the literature on Japanese experiences in this area is surprisingly limited, compared to the works on Germany and the United States. Thus, the analysis of renewable energy policies and markets in the three countries is an open field of research. Moreover, the existing analyses have neglected both government instruments to promote renewable energy technology exports as well as the international market for renewable energy technologies which is a thriving sector.

My research complements and expands previous research in three important ways: First, the systematic comparison of the three case countries help to understand the risks and chances, the dynamics and the explanatory factors of governmental market involvement in renewable energy markets. Second, the inclusion of an analysis of renewable energy export promotion measures is an understudied field of research. Third, the systematic analysis of international trade in renewable energy technologies in this research endeavor is new, reveals unpublished data and helps to understand the dynamics of these markets. Moreover, this analysis is very relevant since international trade in renewable energy technologies will continuously gain in importance with the increasing saturation of domestic renewable energy markets.

1.3 Literature Review

This study relates to several existing strands of the economics literature. In the following section, the most important research areas for the purpose of this study are outlined. First, the theoretical chapter of this study examines the economic reasons for governmental policy intervention in renewable energy markets and thus relates to theories of market failure and economic regulation.[6] Second, this study is more specifically shaped by literature on renewable energy policies and markets in various countries and the question of efficiency of different renewable energy instruments. Third, this study builds upon comparative environmental policy literature in order to explain why and how countries, here Germany, Japan and the US, promote renewable energy in such different ways and to such different degrees.

This research study analyzes and evaluates government intervention in renewable energy markets. Therefore economic theories dealing with market intervention and economic regulation frame this study. The academic debate on economic issues connected to renewable energy has long been dominated by a discussion on the role of governments in promoting renewable energy.[7] The majority of researchers today present the correction of market failure (most notably external costs of fossil fuel consumption) as a justification

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[6] See chapter 2 for a discussion on the relevant theoretical concepts of government intervention in (renewable) electricity markets.

[7] See for some of the earlier studies Nogee (1999), *Powerful Solutions* and Rader/Norgaard (1996), *Efficiency and Sustainability in Restructured Electricity Markets*.

for government intervention.[8] Still, other authors point to the risks of government failure and a resulting misallocation of resources because of imperfect information or political capture. These authors stress the necessity of allowing the dynamics of markets to determine the outcomes on energy markets in order to prevent government failure.[9] A further set of theories focuses on the possibility of governments to determine international trade patterns from an industrial policy perspective. These theories are being necessary to structure the analysis of policies to promote renewable energy trading (international trade theories, infant industry theory and first-mover advantages).

A second strain of studies concentrates on the evaluation of different instruments to promote renewable energy.[10] These studies present a guideline for the methodology for my own evaluation of instruments used in the three case countries. The success or failure of certain instruments (such as price-based and quantity-based systems) is analyzed with regard to different criteria such as: increase in electricity generation from renewable energy sources, political enforceability, cost efficiency, the level of competitive structures and the complexity of instruments.

Even though there is a wealth of literature comparing different promotion instruments, there is still no agreement on which policies are more effective and/or efficient in promoting renewable energy use, but two main forms of renewable energy promotion have emerged: feed-in tariffs (price-based system) and renewable portfolio standards (quantity-based systems).

One of the first comparative studies was conducted by Espey (2001). The author analyzes which instruments are available for governments to promote renewable energy use and discusses renewable energy policies in eight industrial countries. The main conclusion

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[8] See for example Nogee (1999), *Powerful Solutions*, p. 16, Diekmann/Kemfert (2005), *Erneuerbare Energien: Weitere Förderung aus Klimaschutzgründen unverzichtbar* and Bergmann/Nick/Wright (2006), *Valuing the Attributes of Renewable Energy Investments*.

[9] See Taylor/Doren (2002), *Evaluating the Case for Renewable Energy. Is Government Support Warranted?*, p. 2.

[10] See for comprehensive studies evaluating promotion measures Ackermann/Andersson/Söder (2001), *Overview of Government and Market Driven Programs for the Promotion of Renewable Power Generation*, Langniss (2003), *Governance Structures for Promoting Renewable Energy Sources*, Bräuer (2002), *Ordnungspolitischer Vergleich von Instrumenten zur Förderung Erneuerbarer Energien im Deutschen Stromsektor*, US Energy Information Administration (2005), *Policies to Promote Non-Hydro Renewable Energy in the United States and Selected Countries*, Espey (2001), *Internationaler Vergleich energiepolitischer Instrumente zur Förderung regenerativer Energien in ausgewählten Industrieländern*, Fraunhofer Institute (2005), *Zusammenfassende Analyse zu Effektivität und ökonomischer Effizienz von Instrumenten zum Ausbau der Erneuerbaren Energien im Strombereich*, Finon/Menanteau/Lamy (2003), *Prices Versus Quantities: Choosing Policies for Promoting the Development of Renewable Energy*, Finon/Menanteau (2003), *The Static and Dynamic Efficiency of Instruments of Promotion of Renewables*.

is that the conditions under which political actors implement policies are more important than the forms of instruments implemented for a successful renewable energy policy.[11]

Langniss (2003) analyzes different types of renewable energy regulation on the basis of a partial equilibrium model and finds that with perfect competition and complete information all types[12] potentially lead to the same result. Under incomplete information, however, minimum price standards such as the German feed-in tariff are preferable if the supply of renewable electricity is highly price-inelastic, since then the overall costs of regulation can be minimized. By contrast, a price-elastic supply favors renewable portfolio standards.[13]

Reiche/Bechberger (2004) also find that neither instrument is generally superior, but that the success of instruments to promote renewable energy use depends on four conditions: 1) long-term planning security, 2) technology-specific remuneration of green energy, 3) investment in infrastructure (grid reinforcement or extension, fair access to the grid) and 4) steps to reduce local resistance against renewable energy projects.[14] This study thereby combines specific characteristics of instruments (planning security and specific remuneration) and general conditions (infrastructure and low local resistance).

Finon/Menanteau (2003) compare the static and dynamic efficiency of renewable energy instruments. The authors conclude that feed-in tariffs make it possible to achieve a high additional renewable output while also promoting technical progress.[15] The capacity to stimulate innovation of quota systems still has to be confirmed.

Haas/Huber/Langniss et al. (2004) show in an empirical study of renewable energy instruments, that well-designed feed-in tariffs had been more effective and cost-efficient than other promotion schemes so far. Several studies in the past years confirm the finding that feed-in tariffs can be very cost efficient. Held (2006) concludes that a well-designed (dynamic) feed-in tariff system, such as enacted under the German EEG ensures the fastest deployment of power plants using renewable energy sources at the lowest cost to society. Sensfuß/Ragwitz/Kratzat et al. (2007) support this finding, but argue that the major disadvantage of feed-in tariffs is the low level of competition between renewable energy

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[11] Espey (2001), *Internationaler Vergleich energiepolitischer Instrumente zur Förderung regenerativer Energien in ausgewählten Industrieländern*.

[12] Langniss compares minimum price standards, renewable portfolio standards and tender systems, see Langniss (2003), *Governance Structures for Promoting Renewable Energy Sources*, p. 88-138.

[13] Langniss (2003), *Governance Structures for Promoting Renewable Energy Sources*, pp. 86-87.

[14] Reiche/Bechberger (2004), *Policy Differences in the Promotion of Renewable Energies in the EU Member States*, p. 843.

[15] Finon/Menanteau/Lamy (2003), *Prices Versus Quantities: Choosing Policies for Promoting the Development of Renewable Energy*, p. 3.

generators.[16] A comparative study of European countries shows that all countries experiencing fast growth in renewable energy diffusion use feed-in tariffs.[17]

However, van Rooijen/van Wees (2006) show that the introduction of a feed-in tariff in the Netherlands did not result in a significant expansion of renewable energy development and targets have not been generally met.[18]

All these studies relate the success of instruments applied to domestic data for renewable energy use and do not systematically look at developments on international markets for renewable energy technologies. In the very recent years, only few studies have dealt with international markets for renewable energy technologies. However, those studies that exist concentrate on either barriers for market entry of certain technologies or regions or exclude the possible effects of national support schemes on international markets.[19] In sum, there are no studies which systematically compare and analyze international trade data for renewable energy technologies over time, for different renewable energy sectors and countries.

The third main strain of literature relevant for the purpose of this study constitutes comparative energy and environmental policy literature. In this literature, three main arguments are proposed to explain the differences in the shape, aims and activities of environmental and renewable energy policy.

(1) A reflection of cultural differences

Cultural differences in terms of how countries see the environment certainly exist, but as Schreurs (2002) has pointed out, if cultural differences would provide a dominant explanation of the evolvement of environmental policy, there should be considerable continuity over time in this field.[20] This has clearly not been the case, as can be shown in the case of the United States. Whereas the United States has been a frontrunner in the 1960s and 1970s and implemented major environmental legislation in this period, since the beginning of the 1980s the US has been considered a laggard and clearly lost the vigor of previous decades. Consequently, cultural arguments are limited in their explanatory power.

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[16] Sensfuß/Ragwitz/Kratzat et al. (2007), *Fortentwicklung des Erneuerbaren Energien Gesetzes (EEG) zur Marktdurchdringung Erneuerbarer Energien im deutschen und europäischen Strommarkt*, p. 5.

[17] German Institute for Economic Research (DIW) et al. (2008), *Economic Analysis and Evaluation of the Effects of the Renewable Energy Act*, p. 27.

[18] Rooijen/Wees (2006), *Green Electricity Policies in the Netherlands: An Analysis of Policy Decisions*, p. 60.

[19] These studies include Wiser/Lewis (2007), *Fostering a Renewable Energy Technology Industry: An International Comparison of Wind Industry Policy Support Mechanisms*, Connor (2003), *National Innovation, Industrial Policy and Renewable Energy Technology*, Kamp (2004), *Notions on Learning Applied to Wind Turbine Development in the Netherlands and Denmark*, Barton (2003), *Social and Technical Barriers and Options for Renewable Energy on Remote Developed Islands*, Marbek Resource Consultants (2004), *Case Study on Renewable Grid-Power Electricity.*

[20] Schreurs (2002), *Environmental Politics in Japan, Germany and the United States*, p. 22.

(2) Differences in geographical conditions and natural resource endowments

Some authors argue that the level of engagement in renewable energy policy can be explained by geographical conditions and natural resource endowment. Hansen/ Jensen/Madsen (2003) argue that Denmark is so successful in wind energy because Denmark is "very abundant in wind energy due to its geographical position."[21] Similarly, other authors argue that one reason Americans appear to be less concerned with environmental protection and sustainability than the Japanese or Germans is simply because the geographical expansion of the United States offers a lot more space to live in.[22] Japan and Germany are certainly more densely populated. Moreover, these two countries are more dependent on energy imports than the US. Still, both environmental degradation and resource scarcity do not explain why the United States was an environmental leader in the past. In the 1970s, the US implemented some of the most stringent environmental regulations worldwide, most importantly air and water pollution laws. Similarly, these arguments do not help to illuminate why Japanese environmental standards in the 1970s were not more stringent given that Japan at that point of time was the most polluted of the three countries. Also, the United States so far was hardest hit by environmental phenomena such as hurricanes, whose intensities as well as frequencies are believed to have increased due to global climate change.[23] Nevertheless, the US government still refuses to commit to binding greenhouse gas reduction targets.

If geographical conditions were of central importance then Germany and Japan should not produce significantly more solar power despite having far less land area and lower solar insolation than the United States. Reiche/Bechberger (2004) come to a similar conclusion and argue that favorable geographical conditions are a necessary but not sufficient condition for successful renewable energy development.[24]

(3) Differences in institutional structures and political driving forces

Schreurs (2002) offers a third argument to explain the evolution and changes in environmental policy in Germany, Japan and the United States. She argues that the stronger the environmental movement in a country, the stronger the environmental regulations are likely to be.[25] However, this approach also only holds limited explanatory power. Environmental movements have been strongest when there was almost no new environmental

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[21] Hansen/Jensen/Strojer Madsen (2003), *The Establishment of the Danish Windmill Industry - Was It Worthwhile?*, p. 324.

[22] See for this argument Lafferty/Meadowcroft (2002), *Implementing Sustainable Development: Strategies and Initiatives in High Consumption Societies*, pp. 273-302 and for the Japanese case Calder (2001), *Japan's Energy Angst and the Caspian Great Game*, p. 9.

[23] Nordhaus (2006), *The Economics of Hurricanes and Global Warming*.

[24] Reiche/Bechberger (2004), *Policy Differences in the Promotion of Renewable Energies in the EU Member States*, p. 844.

[25] Schreurs (2002), *Environmental Politics in Japan, Germany and the United States*, p. 23.

legislation, such as in the 1980s in the United States. Also, the so-called environmental decade in the US in the 1960s, which saw a flux of stringent environmental regulation, occurred before such movements became powerful and influential in the late 1970s and 1980s. Moreover, Japan signed the Kyoto Protocol despite a weak environmental community, while the US did not ratify the protocol even with relatively strong environmental groups. The Kyoto process is also a fitting example to show that political affiliation does not present a satisfactory explanation. In the United States, the Democratic Party is considered to be environmentally-friendly, while the Republicans embody the more business-friendly counterpart. Still, in July 1997, the US Senate voted unanimously against the Kyoto Protocol in the Byrd-Hagel-Resolution and any climate agreement that would hurt US industry or which did not also include binding reduction targets for developing countries.[26]

Still, political driving forces clearly play a role. Lauber/Mez (2004) provide an historical account of German renewable energy policy since 1974 and argue that not geographical conditions but strong political pressure has made Germany a leading country in renewable energy production.[27]

Suck (2008) analyzes renewable energy policy in the United Kingdom and in Germany.[28] The author describes and explains different regulatory approaches. The focus is on examining the impact of different institutional structures (federalist versus unitary system) on renewable energy regulation. Suck argues that different starting points for the liberalization of the electricity sector added different weight to the emphasis on efficiency criteria with regard to the instrumental design of renewable energy policy. In Germany, at the time that renewable energy policy was first developed in the late 1970s and 1980s, the electricity sector was not yet liberalized and privatized. Therefore, renewable energy instruments were less oriented by efficiency criteria towards achieving a competitive renewable energy industry. In contrast, Suck argues that the sectoral liberalization in the late 1980s in the UK resulted in significant barriers to the implementation of comprehensive regulations for promotion renewable energy sources. Suck further argues that the federal system in Germany was better suited to the requirements of decentralized energy generation than the unitary states in the UK: “The co-existence of policy-making competencies and concurrent legislation in the German energy policy at the federal and state levels provided for additional access point, which proved to be susceptive and permeable to the interest of specific renewable energy technologies”.[29]

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[26] Vig/Kraft (2000), *Environmental Policy: New Directions for the Twenty-First Century*, p. 98.

[27] Lauber/Mez (2004), *Three Decades of Renewable Electricity Policies in Germany*, p. 599.

[28] Suck (2008), *Erneuerbare Energien und Wettbewerb in der Elektrizitätswirtschaft: Staatliche Regulierung im Vergleich zwischen Deutschland und Großbritannien*.

[29] Suck (2002), *Renewable Energy Policy in the United Kingdom and in Germany*, p. 40.

However, this argument cannot be generalized. In the United States, competencies in renewable energy policy are shared between the federal and the state level creating – according to Suck's argument – more access points. Still, renewable energy policy in the US is far less comprehensive than in Germany despite a less federalistic German structure.

Moreover, the arguments developed so far cannot help to explain why the United States as the birthplace of many renewable energy technologies has increasingly lost its competitive advantage to Germany and Japan and other countries.[30] Hence, there is a lack of convincing alternative explanations of the determinants of renewable energy approaches in Germany, Japan and the United States.

This study proposes a new argument: the aim of government involvement in renewable energy markets is not only to foster a greater share of renewables in their countries' energy mix because of environmental reasons, but also to develop and strengthen renewable energy technology industries in order to further exports in this strongly growing world-market segment and to create a competitive advantage for these industries on international markets. This argument is not entirely new.[31] However, authors who have used this line of argument in the context of renewable energy did not support their conclusion by a comprehensive analysis of international data for trade in renewable energy technologies, but rather looked at domestic market data.

The central arguments developed in this study are:

- Government promotion is important and is warranted to secure a sufficient diffusion of renewable energy sources.
- The success of government instruments to promote renewable energy technologies depends on the specific design and implementation of the respective instrument.
- The success of countries in international trade of renewable energy technologies depends on domestic market development not export promotion measures.
- The greater the emphasis on economic opportunities of renewable energy use, the more likely is a comprehensive promotion policy. Actors in the political sector and the industrial sector must have a common interest to promote renewable energy, so there has to be a combination of political will driven through public opinion and industry support.

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[30] Mohiuddin (2004), *How America Lost Its Clean Technology Edge*, p. 1.

[31] See for the few studies that promote this argument Agnolucci (2007), *Wind Electricity in Denmark: A Survey of Policies, Their Effectiveness and Factors Motivating Their Introduction*, Wiser/Lewis (2007), *Fostering a Renewable Energy Technology Industry: An International Comparison of Wind Industry Policy Support Mechanisms* and Brandt/Svendsen (2004), *Switch Point and First-Mover Advantage: The Case of the Wind Turbine Industry*.

1.4 Definition of Renewable Energy

The definition of renewable energy differs both in the academic debate as well as among countries.[32] The most important differences in the definition between countries exist over the question whether large hydro power plants[33] and biomass from waste should be included in the definition of renewable energy.[34]

The International Energy Agency defines renewable energy as "energy that is derived from natural processes that are replenished constantly. In its various forms, it derives directly or indirectly from the sun, or from heat generated deep within the earth." Consequently, the IEA classifies energy generated from solar, wind, biomass, geothermal, hydropower and ocean resources, and biofuels and hydrogen derived from renewable resources as renewable energies.[35]

Germany's EEG defines renewable energy as "hydropower including wave power, tidal power, salt gradient and flow energy, wind energy, solar radiation, geothermal energy, energy from biomass including biogas, landfill gas and sewage treatment plant gas as well as the biodegradable fraction of municipal and industrial waste."[36]

In this definition biomass from non-biodegradable parts as well as hydropower plants with a capacity of over 5 megawatt (MW) are excluded. Large hydro power is in fact excluded from most governmental support programs in developed countries, because of its possible adverse effects on nature and wildlife and its strong competitive stance, which reduces the need for governmental support.

In Japan, the term "new energy" is more common than the term renewable energy.[37] The New Energy Law (1997)[38] defines new or renewable energy as an "an oil alternative energy for either manufacture, generation, or use" and includes photovoltaic power generation, wind power generation, solar thermal utilization, temperature difference energy, waste power generation, thermal utilization of waste, waste fuel manufacturing, biomass power generation, thermal utilization of biomass and biomass fuel manufacturing in its definition.

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[32] Compare Reiche (2004), *Rahmenbedingungen für Erneuerbare Energien in Deutschland: Möglichkeiten und Grenzen einer Vorreiterpolitik*, pp. 25-28 and Hoogwijk (2004), *On the Global and Regional Potential of Renewable Energy Sources*, p. 16.

[33] Hydro power plants with a capacity of 10 MW or more are considered "large" by the International Energy Agency, see http://www.iea.org/Textbase/stats/defs/rdd.htm (access date: 08/05/2008).

[34] For a discussion on the definition of renewable energy in the European Union see Rowlands (2005), *The European Directive on Renewable Electricity. Conflicts and Compromises*.

[35] International Energy Agency (2005), *Renewables Information 2005*, p. 29.

[36] Renewable Energy Sources Act (EEG), §2.

[37] Ohira (2006), *Measures to Promote Renewable Energy and the Technical Challenges Involved*, p. 98.

[38] Law Concerning Special Measures for Promotion of the Use of New Energy.

Another current discussion focuses on the question whether nuclear energy should also be considered a renewable form of energy. This debate was sparked by former US President George W. Bush and politicians in the United Kingdom. In a speech in September 2006 President Bush said: “Nuclear power is safe; nuclear power is clean; and nuclear power is renewable.”[39] The British politician Lord David Sainsbury also declared nuclear energy to be renewable.[40] The World Bank has called nuclear energy a “clean” source of energy, but not a renewable form of energy.[41] The Economist proclaims a nuclear revival.[42]

It is misleading, however, to call nuclear power renewable energy. Uranium, which is used in the process to produce nuclear energy, is an exhaustible resource. The debate on how long the uranium reserves will last are as diverse and complex as they are on the question how long fossil fuels will remain the dominant fuel source in energy supply.[43] Still, to label nuclear energy as renewable is clearly not correct and is done for political reasons. By terming nuclear power a renewable energy, it may be rendered more acceptable in the public debate. It is possible, too, that the term is simply confused with “alternative energy”, referring to alternatives to conventional fossil fuels such as oil, natural gas and coal. It is at least questionable, whether nuclear energy can play a vital part in answering the challenges posed by climate change. It is true that the operation of a nuclear power station produces almost no carbon dioxide (CO_2) emissions, which are largely responsible for global warming and climate change. However, when the whole life cycle of a nuclear power plant is considered, nuclear power plants do emit large amounts of greenhouse gases and the produced energy is not “clean”, because the mining, milling and enrichment of uranium into nuclear power are very energy intensive and environmentally degrading.[44]

For the purpose of this study, I follow the definition of the International Energy Agency of renewable energy. This means that renewable energy in this study refers both to traditional biomass and new renewable energy sources from solar, wind, modern biomass, geothermal, and hydropower.[45] To focus my study, I make an important restriction,

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[39] US White House (2006), *President Bush Honors American Work Force on Labor Day*.

[40] Times Online (2005), *Minister Declares Nuclear 'Renewable'*.

[41] Frankfurter Rundschau (2006), *Weltbank rückt von Privatisierung ab*, p. 10.

[42] Economist (2007), *Nuclear Power's New Age*, p. 11.

[43] See International Atomic Energy Agency (2008), *Uranium 2007: Resources, Production and Demand* for the latest edition of an annual report on uranium supply and demand of 40 countries worldwide.

[44] See Fthenakis/Kim (2007), *Greenhouse-Gas Emissions From Solar Electric- and Nuclear Power: A Life-Cycle Study*, p. 2549.

[45] This dissertation includes only renewable energy technologies that are in commercial application on a significant global scale today. Other technologies that show great potential in the future or that are used in limited quantities are not covered. Such technologies include active solar cooling, concentrated solar electric power, ocean thermal energy conversion, tidal power, wave power, and hot dry/wet rock geothermal.

however. This research solely deals with the electricity sector. Renewable energy is used in all three energy sectors; the electricity sector (renewable power), the transportation sector (biofuels) and the heating sector. This means biofuels used in the transport sector and renewables used in the heating sector are excluded from the focus of this study. Since the statistics often do not differentiate between large and small scale hydro, this studies includes both forms of hydro power.

1.5 Research Design and Methodology

This research study is primarily an empirical work with a theoretical and conceptual basis which is important to guide the methodology and to sharpen the focus of my research interest.

The research methods include an intensive literature review and the compilation and analysis of empirical data, government publications and trade statistics as primary sources. Interviews with governmental officials, researchers and energy industry experts helped to test the arguments elaborated in this study. Finally, the participation in energy conferences and the presentation of parts of this work in Germany as well as in the United States guaranteed that the research presented here withstood the scrutiny of an international research community.

A combination of qualitative and quantitative methods is employed to answer the research questions outlined above. In the more qualitative part on the use of different renewable energy instruments and the differences in the approaches the main sources comprise research papers, government publications and grey literature such as technical reports, patent documents, conference papers and internal reports. In the more quantitative part on national and international market development, statistical methods are used to analyze the different data sets.

The part on national and international renewable energy markets uses data for Germany, Japan and the United States for the period from 1996 until 2007. Due to the restriction on the electricity sector, only data relevant to power generation are analyzed. The transportation and heating sector are not the research objective of this study. Whereas, access to data on renewable power generation and generation capacity is relatively easily available through the International Energy Agency and national statistics offices, compiling the relevant data to analyze international trade in renewable energy technology is quite difficult since the relevant goods are not identified in a set list with specific trade codes.

In fact, the international trade database for most renewable energy technologies is relatively poor. One reason for this is that international renewable energy markets are still comparably small even though they are growing at a high rate. Also, the markets are very heterogeneous. Moreover, there has been little effort to create a continuing and well-defined database for specifying renewable energy goods.

The trade data are taken from COMTRADE of the United Nations Statistics Division. This database contains values and to a limited extent quantities of exports and imports for 184 countries, capturing 95% of world trade in goods in over 5.000 products. Trade data from 1996 to 2007 for OECD member countries and China and Russia are examined. The data used is based on the 6-digit-level of the Harmonized System (HS), 1996 and 2002 edition, an international commodity classification system (with six-digit codes) of export and import statistics. This study contributes to the research on trade in renewable energy technologies by creating an original trade code basis for renewable energy technologies goods according to the 6-digit harmonized system. The list of trade codes has been developed through the intense review of the discussion processes in this context in the World Trade Organization (WTO) and the Organization for Economic Co-operation and Development (OECD) as well as previous studies on this topic such as by the European Commission (EC), the United States International Trade Commission (USITC) and the German Umweltbundesamt.[46]

The units-of-analysis in these empirical cases are Germany, the United States and Japan. These countries have been chosen because they fulfill three main criteria: (1) They are not only regional leaders but are among the worlds' five largest economies, (2) all three countries implemented innovative renewable energy promotion schemes and (3) they produce a significant share of so-called “new” renewables.

In 2007, renewable sources already provide 11.7% of the electricity in Germany. The United States produces 9.2% of its electricity from renewable sources, and Japan 9.8%.[47] The greatest potential for future use of renewable energy sources lies in the *new* renewables: modern wind energy, solar energy, modern biomass and geothermal energy. China, for example, even though increasing its share in renewables considerably and being the second largest economy worldwide, still focuses largely on traditional renewable energies, mostly biomass. China’s share of new renewables without hydro in total renewables is still very limited (1.4%), compared to 16.3% for Germany, 11.1% for the United States and 20.9% for Japan (see Table 1-1).

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[46] See ECOTEC (2002), *Renewable Energy Sector in the EU. Its Employment and Export Potential*, US International Trade Commission (2005), *Renewable Energy Services: An Examination of U.S. and Foreign Markets* and Legler (2006), *Wirtschaftsfaktor Umweltschutz: Leistungsfähigkeit der deutschen Umwelt- und Klimaschutzwirtschaft im internationalen Vergleich*.

[47] International Energy Agency (2007), *Renewables Information 2007*, p. 17.

Tab 1-1: Renewable indicators by country, 2007

	Share of the Main Fuel Categories in Total Renewables (%)		
	Hydro	Geothermal, Solar, Wind, Tide	Combustible R. and Waste
Germany	8.5	16.3	75.2
United States	22.6	11.1	66.3
Japan	43.2	20.9	35.9
China	14.1	1.4	84.5
India	5.7	0.5	93.8

Source: International Energy Agency (2008), *Renewables Information 2008*. Paris, pp. 23-25.

How can the two main research interests (evaluation of the success of renewable energy policy and relevant factors to explain its evolvement in the three countries) be operationalized more specifically? Which indicators can be used to answer the posed research questions?

The three criteria applied in this study are derived from the methodology developed in the literature and the theoretical discussion of government intervention in renewable energy markets. Most studies evaluating renewable energy policy instruments differentiate between effectiveness and efficiency.[48]

Effectiveness: Effectiveness generally refers to an increase in renewable energy use. Lienert/Wissen (2006) differentiate between the efficiency to increase market deployment and the efficiency to meet targets, such as a certain share of renewables in the electricity mix by a certain time.[49] Van Dijk/Beurskens/Kaal et al. (2003) doubt that the efficiency to meet targets is a relevant indicator since less ambitious targets are more achievable than ambitious ones.[50] Therefore, the authors suggest that the deployment of renewable energy sources in the national electricity mix should be evaluated.[51] The success of any industrial sector, such as the renewable energy industry, however, can be evaluated in two contexts; the domestic marketplace and the international marketplace. In terms of renewable energy this refers to (a) the physical generation of energy from renewable sources and its share in the domestic energy mix (domestic marketplace) and (b) the trade in renewable energy

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[48] Compare Held/Ragwitz/Haas (2006), *On the Success of Policy Strategies for the Promotion of Electricity from Renewable Energy Sources in the EU*, p. 850.

[49] Lienert/Wissen (2006), *Bewertung von Fördersystemen für Erneuerbare Energien: Eine kritische Analyse der aktuell geführten Diskussion*, p. 134.

[50] van Dijk/Beurskens/Kaal et al. (2003), *Renewable Energy Policies and Market Developments*, p. 16.

[51] This indicator is in fact the most often used criterion for effectiveness, compare Menges (2003), *Supporting Renewable Energy on Liberalised Markets: Green Electricity Between Additionality and Consumer Sovereignty*, p. 584.

technologies (such as wind turbines) on the international marketplace. Such an analysis has, to my knowledge, not been systematically carried out so far.

Efficiency: Efficiency generally refers to the capacity to generate electricity from renewable sources at competitive costs. Lienert/Wissen (2006) further differentiate between static and dynamic efficiency, where static efficiency refers to the definition just mentioned (generation of renewable power at competitive costs) and dynamic efficiency refers to the optimal growth in renewable power output through *decreasing* generation costs.[52] One basic assumption of this study is that renewable energy promotion can only be deemed successful when it functions as short to medium term initial support (until the technologies become competitive) and not long-term market support. Thus, the setting of incentives for technological improvement which reduce costs and thus increases competitiveness is extremely important and dynamic efficiency is the more relevant indicator. The development of generation costs over time therefore constitutes the third criterion analyzed.

Hence, the success of renewable energy policy is evaluated by (a) the deployment of renewable energy sources in the national electricity mix, (b) the development of renewable technology exports and competitiveness and (c) the development of generation costs (see Table 1-2).

Tab 1-2: Criteria to evaluate renewable energy policy

Effectiveness		***Efficiency***
Deployment of renewable energy sources nationally	**International Trading of Renewable Technologies**	**Development of Generation Costs**
all data absolute and per capita • Renewable power generation • Renewable power capacity • Renewables share in electricity output in %	• Annual growth rates • Net exports • Exports per capita • Share in national exports (imports) • World market share • Revealed Comparative Advantage (RCA)	• Specific generation costs of wind and solar power

Source: Own

The deployment of renewable energy sources in the national electricity mix is determined by looking at different indicators such as change in renewable electricity generation in absolute and per capita numbers as well as the renewables share in electricity output in percent and the development over time. The development on international renewable energy markets is analyzed with the help of indicators such as growth in renewable energy trading, destinations of exports and sources of imports, world market shares, share in national exports and revealed comparative advantages. The development of generation costs

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[52] Lienert/Wissen (2006), *Bewertung von Fördersystemen für Erneuerbare Energien: Eine kritische Analyse der aktuell geführten Diskussion*, p. 136.

is analyzed by looking at the development of costs from wind power and solar power in the three countries respectively.

Other aspects such as the reduction of greenhouse gas emissions or job effects are not at the focus of this study and are only touched upon when necessary. These factors as well as many others (costs for basic and reserve energy, grid expansion due to the integration of renewable power, administrative costs, costs of displaced fossil fuel imports etc.) would be relevant if this study was to do a complete cost-benefit analysis of renewable energy policy in all three case countries.[53] The main research interest of this study remains, however, a comparison of the success of renewable energy policy in terms of the three criteria stated above and an explanation of the evolvement of renewable energy policy in the three countries.

The second main research interest (explaining the evolvement of different renewable energy policy approaches) reviews the literature and examines the factors discussed so far in the literature. The literature review shows that one aspect has received relatively little attention so far, even though it is very relevant to explain the different approaches to renewable energy policy in the three countries. That is the emphasis on economic opportunities. Therefore, this aspect is presented and discussed in more detail in this study.

1.6 Outline

This research study is organized as follows: Chapter 2 reviews the most important theoretical concepts in the context of governmental regulation and renewable energy. These include theories on market failure (monopolistic or cartel-like structures, externalities, and information asymmetry) in the context of the normative theory of regulation. Theories on government failure in the tradition of the positive theory of regulation shape this part. The second main part of the second chapter discusses industrial policy approaches. The intention of countries to increase the competitiveness of certain industries is illuminated. Here the most important theoretical arguments can be drawn from the literature on strategic trade theory, the infant industry argument, first-mover advantages and the newer lead market theory. This chapter ends with concluding remarks on the validity of the different concepts and theories and on the necessity of governments to promote renewable energy technologies.

Chapter 3 starts with a discussion on the key drivers of increased renewable energy use (economic, environmental and security issues) and the development of generation costs of renewable electricity and externals costs in electricity production. Subsequently,

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[53] See for example German Institute for Economic Research (DIW) et al. (2008), *Economic Analysis and Evaluation of the Effects of the Renewable Energy Act* for a comprehensive study on the economic effects of the Renewable Energy Act.

the chapter focuses on a theoretical discussion of the two main forms of renewable energy promotion: price- and quantity-based systems.

Chapter 4 provides an overview of policies to promote renewable energy in Germany, Japan and the United States. The main instruments used are contrasted. Since sub-national actors are relevant especially in the United States, the analysis is broadened at this point to include the experiences in US states as well. The second main part of chapter 4 explores the empirical data on national renewable energy markets (power generation, generation capacity). The data are presented in absolute numbers and for the purpose of better comparison in per capita numbers. The analysis of the development of power generation costs for wind and solar PV serves as an indicator for the efficiency of the respective renewable instruments. The fourth chapter ends with a discussion on the most important criteria of effective and efficient renewable energy promotion.

Chapter 5 starts with a discussion of measures aimed at the promotion of exports of renewable technologies in the three countries. The chapter then proceeds to present a new approach to the analysis of international trade in renewable energy technologies. First, the methodology of this analysis is explained, presenting the indicators computed, the necessary restrictions for the analysis and the relevant trade codes. Following this methodological part, the empirical data are presented, focusing first on the different renewable energy sectors analyzed (wind, solar, hydro, geothermal and biomass) and second on the country perspective. Here growth in renewable energy trading, destinations of exports and sources of imports, world market shares, share in national exports and revealed comparative advantages are computed and analyzed.

Chapter 6 asks for the reasons of different approaches to renewable energy policy in the three countries. This chapter, thus, aims to explain different approaches to renewable energy promotion and different levels of governmental involvement. Such factors include geography, political will, public opinion and institutional factors. While these factors surely help to explain the approaches and market developments, another factor must be highlighted; the emphasis on economic opportunities in the context of renewable energy use.

Chapter 7 summarizes the findings, presents the lessons learned from the experiences in Germany, Japan and the United States and develops conclusions for the design and implementation of future instruments and the further improvement of current policies to promote renewable energy use in industrialized countries. Areas are indicated where more research is needed.

2 Government Intervention in Renewable Electricity Markets

The energy sector is a fruitful case for a study of the costs and benefits of government market intervention since it has been regulated, deregulated and re-regulated for decades in almost all industrialized countries. The energy sector, as one of the most vital sectors of any economy, has been seen as a strategic area since at least the first oil price hikes in the 1970s. The reliance on oil and other forms of fossil fuels became especially obvious with the skyrocketing energy prices in the 1970s after the Organization of the Petroleum Exporting Countries (OPEC) cut its production levels. With lower energy prices in the early 1980s, concerns of energy shortages decreased but were supplemented by new challenges posed by first evidence of global warming and climate change.

This chapter analyzes economic reasons of government intervention in renewable electricity markets. In the first section, I outline the most important characteristics of (renewable) electricity markets to create a basis on which to judge the promotion of renewable energy. The following analysis of government intervention is divided into two parts. First, theories of economic regulation will provide the main theoretical framework to evaluate the promotion of renewable energy use domestically. Second, the promotion of renewable energy exports will be discussed in the context of industrial policy approaches.

The literature on economic regulation[54] can be divided into a normative theory of economic regulation as part of the neoclassical school of thought, and a positive theory of economic regulation as part of rational choice theory.[55] According to the normative theory of regulation government intervention in markets is justified because of market failure which prevents an efficient allocation of goods and services by a market. There are three main forms of market failures: monopolistic or cartel-like structures, the existence of externalities and information asymmetry. The normative theory of economic regulation seeks to define what economic functions should be performed by the government to correct for market failure and to develop policies to achieve the stated goals. In contrast to this concept, economists in the tradition of the positive theory of regulation, such as George J. Stigler, Richard A. Posner or Sam Peltzman, do not see market failures, even if they exist, as compelling arguments for government intervention. These economists argue

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[54] See Joskow (2000), *Economic Regulation* and Viscusi/Harrington/Vernon (2005), *Economics of Regulation and Antitrust* for an in-depth overview of regulation theory, both from a normative and a positive stance. Medema/Boettke (eds.) (2005), *The Role of Government in the History of Economic Thought* also offer an excellent analysis of the changing perceived roles of government in economics over time.

[55] See Musgrave (1959), *The Theory of Public Finance: A Study in Public Economy* for one of the early texts on rational choice. Rational choice theory became the predominant theory on human behaviour only in the 1960s, but Musgrave's work as well as Anthony Downs (1957), *An Economic Theory of Democracy* was published in the late 1950s.

K. Jordan-Korte, *Government Promotion of Renewable Energy Technologies,* DOI 10.1007/978-3-8349-6587-5_2,

that government intervention through taxes or subsidies may also lead to an inefficient allocation of resources due to political capture or imperfect information (government failure).

The analysis of export promotion refers to different theoretical concepts; industrial policy approaches. These are theoretically highly disputable, nevertheless industrial policy goals, such as the promotion of certain “champion” industries, often determine government market intervention. In the context of renewable energy and specifically the promotion of renewable energy technology exports, industrial policy plays a central role. The theories relevant here are strategic trade theory, the infant industry argument, first-mover advantages and the newer lead market theory.

The term regulation is used in a very broad sense in this chapter. Regulation in general refers to the state’s power to limit the behavior of firms or individuals.[56] The definition used in this study includes all forms of government market intervention that affect the economic freedom and freedom of contract of firms or individuals.

In this chapter, I develop the argument that economic theory points to significant market barriers and market failures that will limit renewable energy generation unless special policy measures are enacted. The theoretical justification for government export promotion or import restriction of renewable energy technologies is less clear. The risks here are greater that government intervention distorts trade and market outcomes, resulting in a misallocation of scarce resources.

2.1 Characteristics of Electricity Markets and Renewable Energy Technologies

The aim of this section is to describe characteristics of electricity markets and specifics of renewable energy technologies. The analysis is restricted to those attributes that are relevant for an economic judgment of renewable energy promotion measures.

The most important characteristics of electricity are:

- Electricity cannot be stored. This implies that supply and demand of electricity have to be balanced instantaneously by an operating system and the grid has to withstand peak load demand.
- Electricity markets are characterized by high and long-term investment necessities and great uncertainty due to the difficulty to forecast the development of these markets. This together with long adjustment times to new developments often leads to too little or excess capacity and important barriers to market entry.
- Demand for and supply of electricity is inelastic in the short run. Demand responsiveness of consumers is limited because of the difficulties and constraints to substi-

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[56] See Joskow (2000), *Economic Regulation*, p. xiv.

tute electricity with other energy sources. The high installation costs of electric power plants account for the low price-elasticity of electricity supply.

- Electric power markets display a high level of market dominance even in liberalized electricity markets.

Several of these characteristics pose great challenges especially for renewable energy technologies:

- Inability to produce energy on a continuous basis: Several renewable energy technologies are dependent on certain conditions to produce electricity, e.g. solar photovoltaic (PV) generation requires sunlight and wind power generation is limited during calm weather. Because of the need of real-time balancing of supply and demand, this is a great problem for the electric grid.
- Status of technological development: large scale power generation from renewable sources has been introduced later than fossil fuel or nuclear power plants. Fossil fuels have been used for power generation for more than a century and nuclear power has been produced for more than 40 years. Therefore, the operational time spans of renewable power technologies are much shorter and the technological development through learning by using is generally less mature.
- Generation costs: Even though the generation costs of most renewable technologies have seen impressive reductions in the past ten years and some are only cost-competitive under favorable conditions, renewable generation costs are on average still higher than from conventional technologies (see section 3.3 for more detail and empirical data).
- Capital-intensive installation: The installation of new renewable energy power stations is very costly. The payback period[57] for example for solar PV installations in Connecticut (USA) is about 12 years.[58] Operating costs, however, are generally lower than for conventional technologies since no fuel costs have to be considered (except for biomass power plants).

Moreover, the main advantage of renewables is that they contribute to the sustainment of public goods, most importantly clean air and climate stability. Since public goods can be acquired for free due to their characteristics (non-excludability and non-rivalry) private actors are not willing to pay for the preservation of public goods. Thus, these characteristics reduce the incentive of the private sector to engage in renewable energy production, which results in less than optimal diffusion. This in turn hinders the process of learning by

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[57] In economics, the payback period refers to the time needed to recover the costs of investments.

[58] This information was acquired from a non-representative survey of owners of solar panels in Connecticut (USA) during the year 2006/2007. The length of the payback period depends on many factors such solar insolation and varies greatly. These results are supported by more comprehensive studies, see e.g. Langniss (2003), *Governance Structures for Promoting Renewable Energy Sources*, p. 36.

using or learning by doing.[59] Hereby, the process of price reduction and increasing reliability is slowed.[60] Thus, in the early stages of development, renewable energy technologies, just like any new technology, are characterized by certain disadvantages compared to the established technologies.

Due to the characteristics of electricity, such as no storage, instantaneous balancing, high investment costs and long lead times, it cannot be assumed that "electric markets should work because other markets work."[61] The same is true for the development of renewable energy technologies, whose characteristics, including generation costs, status of technological development and market deployment, hinder an efficient working of the price mechanism to create equilibrium of supply and demand. This demands government guidance in order to profit from the advantages of renewable energy technologies such as environmental benefits and other positive externalities (see section 2.2.2). The following section describes the three most important market failures in renewable electricity markets in greater detail.

2.2 Main Justification for Intervention: Market Failure

Economic theory deals with the efficient allocation of resources and so can be suitably employed to explore environmental and energy questions.[62] The assumption that markets can have inefficient outcomes due to market failures is the most common justification for government intervention in markets.[63] The economic debate of electricity markets and more specifically renewable energy markets is also dominated by the question of market failures, which lead to market outcomes that are not Pareto-efficient.

The three most important market failures in electricity markets are (1) imperfect competition which can take the form of monopolies or oligopolies, (2) the existence of externalities and (3) information asymmetry. These market failures will be discussed in the following section.

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[59] See Arrow (1962), *The Economic Implications of Learning by Doing* for a general discussion of learning by doing and learning by using.

[60] Finon/Menanteau/Lamy (2003), *Prices Versus Quantities: Choosing Policies for Promoting the Development of Renewable Energy*, p. 7.

[61] Budhraja (2003), *Harmonizing Electricity Markets with the Physics of Electricity*, p. 51.

[62] See Banks (2000), *Energy Economics: A Modern Introduction* and Erdmann/Zweifel (2007), *Energieökonomik: Theorie und Anwendungen* for two of the few comprehensive newer books on energy economics.

[63] See Gravelle/Rees (2004), *Microeconomics*, pp. 314-320 for a general discussion of market failures. For a general discussion on assessing the effectiveness of governmental regulation see Baldwin (1995), *Rules and Government*, pp. 260-263.

2.2.1 Monopolistic Competition and Cartels

The existence of natural monopolies, a situation where supply costs are lower when the supply is provided by a single firm rather than in competing firms, has long been used to justify a strong state presence in electricity supply. In the 1980s and 1990s, technological changes in this sector have lessened the importance of economies of scale and scope, and created opportunities for new companies to enter the electricity market. Subsequently, state monopolies have been restructured and competitive markets have been created in many countries. The hope was that the need of government involvement due to imperfect competition would be reduced.[64] However, as experience has shown, electricity markets are in most cases not perfectly competitive. Even after deregulation and liberalization in most industrialized countries, electricity sectors are still mostly controlled by monopolies or display cartel like conditions. As the electricity sector in Germany shows, for example, the liberalization of the German electricity market did not lead to a situation of perfect competition, but to the creation of cartels with great market power as a result of market restructuring by mergers and acquisitions.[65] In Germany, four companies alone (E.ON, RWE, Vattenfall and EnBW) own about 85% of all installed electric capacity in Germany. The need for governments to control whether these companies do not misuse their market power remains.

2.2.2 Externalities

The most common and most acknowledged justification of government intervention into energy markets is external costs of fossil fuel and nuclear energy production which are not internalized in their prices. These external costs create a strategic disadvantage for the use of renewable energy sources, whose external costs are much lower or nonexistent.

Externalities are benefits or costs generated by an economic activity that do not accrue directly to the producer of the externalities. Externalities can be divided into positive externalities and negative externalities. Investment in research and development and the spillover effects to other parties than the investor itself represent positive externalities. An example for a negative externality is environmental damage whose costs are not borne by the party responsible for the damage but are passed on to society or a third-party.[66] The originator of the negative externalities is thus not forced to consider them in his economic calculations.

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[64] Joskow (2000), *Economic Regulation*, p. xiii.

[65] Market power is generally defined as: “the ability to alter profitably prices away from competitive levels.”, Mass-Colell/Whinston/Green (1995), *Microeconomic Theory*, p. 383.

[66] View Fritsch/Wein/Ewers (1993), *Marktversagen und Wirtschaftspolitik: Mikroökonomische Grundlagen staatlichen Handelns*, p. 115, who see negative externalities as a justification for redistribution measures in order to increase Pareto-efficiency.

Historically, the concept of externalities goes back to the work of the British economist Arthur Pigou (1920). Pigou argued that externalities represent a form of market failure. The market fails to create an equilibrium of demand and supply since the price mechanism does not take into account the full social costs and benefits of consumption and production. In the case of negative externalities, too much of a good will be produced because not all costs are internalized in its price. In the case of positive externalities, too little of a good will be produced. In both cases a welfare loss results.

Fig 2-1 exemplifies that the output of fossil fuels will be too high (Q_1) at too low prices (P_1) if market prices prevail and external costs are not internalized. Society benefits and market outcomes are efficient if the price for fossil fuel reflects their total costs (market price + external costs), resulting in lower output (Q_2) and higher prices (P_2).

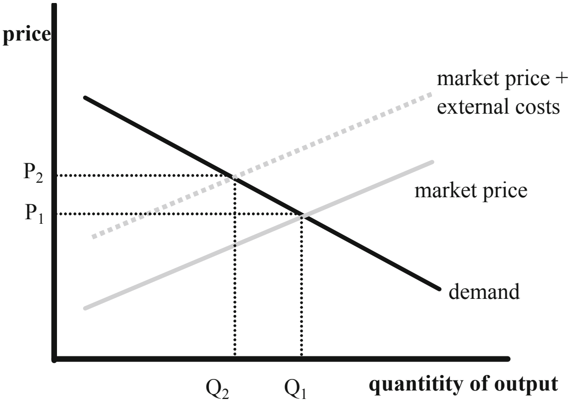

Fig 2-1: Prices and output at market prices and market prices + external costs

2.2.3 Forms of Externalities

In the context of renewable energy, two main forms of externalities have been identified. Finon/Menanteau/Lamy (2003) focus on environmental externalities; that is costs from the extraction, processing, or transport of fossil fuel and other energy sources. Examples include land degradation, air pollution, leaching of mine drainage from coal mining, spills and leaks from off-shore oil extraction and transport. The combustion of fossil fuels is the most important single factor for the accumulation of carbon dioxide and other greenhouse gases in the atmosphere and thus largely responsible for climate change. Renewable energy technologies have less but are not without environmental impact. For example, the effects of hydropower facilities on water levels and marine life can be damaging and wind power plants may affect the habitats of birds.

Especially since the 1990s, national security risks posed by a strong dependence on imported energy resources have been highlighted as another external cost of fossil energy resources.[67] The dependence of many countries on imported fossil fuels creates a significant risk to economic development in the case of supply disruption. These risks are not accurately reflected in today's fossil fuel prices. Security risks have long served as a justification for government involvement in energy markets, e.g. the coal subsidies in Germany during the cold war have been justified by the risks of supply disruptions.

A third form of externalities which should be considered when thinking about energy use has received much less attention but is equally important. A higher share of renewable energy can serve as a hedge against the volatility of oil and natural gas prices.[68] Studies have shown that it is not higher energy prices per se that affect economic growth and investments negatively, but their volatility and the uncertainty about their future development.[69] Fig 2-2 and Fig 2-3 show the increased price volatility of oil and natural gas prices since the turn of the century.

Accordingly, a higher share of renewable sources increases energy price security, which in turn enhances economic planning reliability. The advantage of using wind or solar energy lies in the fact that the costs for these forms of energy do not include fuel costs, which could be volatile. I argue that the economic evaluation of renewable energy also has to take into account these economic security advantages.

All three forms of external costs of fossil fuel use (environmental, national security and economic security) are not generally internalized in their prices yet. One main reason for that is that externalities are very difficult to quantify (see section 3.3.2 for studies attempting to quantify the external costs of electricity generation).

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[67] See Menz (2005), *Green Electricity Policies in the United States: Case Study*, p. 2408 and Neuhoff (2005), *Large-Scale Deployment of Renewables for Electricity Generation*, p. 91.

[68] Berry (2005), *Renewable Energy as a Natural Gas Price Hedge: The Case of Wind* also stresses economic externalities of renewable energy use.

[69] See International Energy Agency (2004), *Analysis of the Impact of High Oil Prices on the Global Economy*, p. 14 and Harks (2004), *Der hohe Ölpreis: Anzeichen einer neuen Ölkrise?*, p. 6.

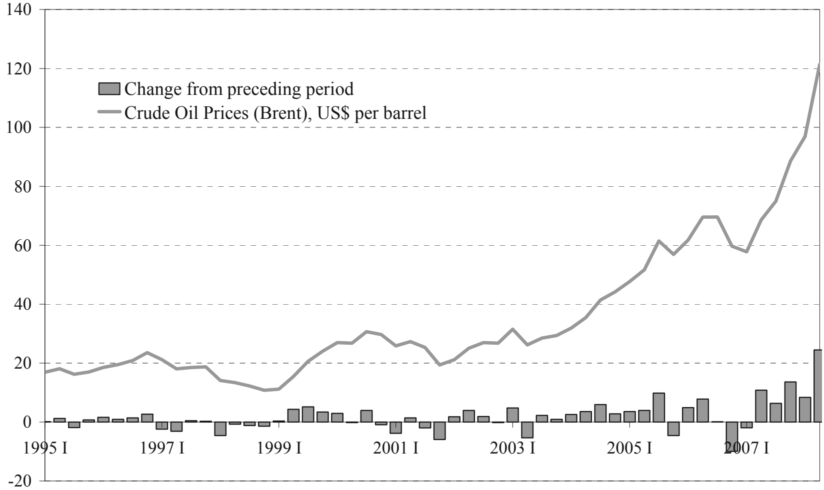

Fig 2-2: Crude oil spot prices (Brent, US$/bbl), 1995-2008
Source: Energy Information Administration (2008), Petroleum Navigator, (access date: 07/22/2008).

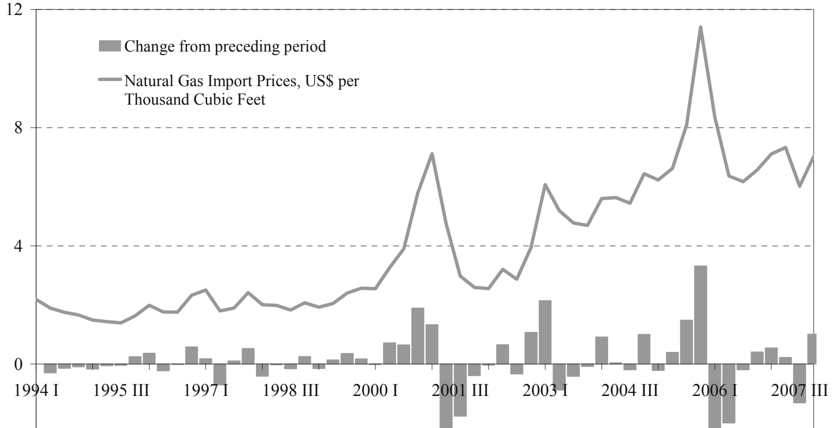

Fig 2-3: US average natural gas import prices (US$/MBtu), 1992-2006
Source: Energy Information Administration (2008), Natural Gas Navigator, (access date: 07/22/2008).

2.2.3.1 Pigovian Taxes

Arthur Pigou was first to develop the idea that the external costs of economic activity not represented in the prices of the goods have to be internalized in order to create efficient market outcomes.[70] The measure he proposed to achieve this end is a tax on the activity creating the negative externality. Consequently, it would be efficient for the producer of the externality to reduce external costs (e.g. emissions) to the point where its marginal abatement cost is equal to the tax rate. In the case of a positive externality, a subsidy should be used to compensate the producer for the external benefit. The concept of Pigovian taxes became the core of the "polluter pay principle"; those responsible for a negative externality have to pay for this damage.[71]

In contrast to traditional command and control (C and C) regulation that imposes fixed standards of environmental performance that are enforced by law, Pigovian taxes are market-based instruments. Market-based instruments are generally more flexible than C and C approaches, since they give companies the choice to either pay the taxes or to reduce its external costs which creates an incentive to make use of innovations in order to decrease their tax burden.[72]

However, two main objections are formulated against the use of Pigovian taxes to internalize external costs:

Governments do not have precise information on the size of costs from negative externalities and thus are unable to decide on the "optimal" tax rate. The size of the effect of a tax will also depend on the price elasticity of demand. If demand is inelastic, a tax will only lead to a small decline in consumption. Also, the producer might be able to pass the costs on to consumers.

Related to the first restriction of incomplete information of governments in setting the tax level is the possibility of government failure. Even if external effects can be accurately quantified, the extent to which they should be internalized will be highly politicized. Neuhoff (2005) argues:

> "Where impacts have previously been tolerated, seeking to change what are perceived to be existing rights is even more difficult. The same holds for those energy producers whose commercial viability has relied on a variety of financial and social subsidies. Not surprisingly, operators want to protect any benefits they have been granted and avoid any new constraints that would limit environmental impacts".[73]

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[70] See Pigou (1920), *The Economics of Welfare*.

[71] Owen (2004), *Environmental Externalities, Market Distortions and the Economics of Renewable Energy Technologies*, p. 128.

[72] See Baldwin (1997), *Regulation: After 'Command and Control'* for a discussion on market-based instruments.

[73] Neuhoff (2005), *Large-Scale Deployment of Renewables for Electricity Generation*, p. 93.

Thus, regulators will be confronted with high pressure from interest groups not to adversely affect their economic activities.

2.2.3.2 Coase Theorem

In the 1960s, Ronald Coase's article "The problem of social cost" influenced the economic debate on how best to internalize externalities significantly.[74] Coase argued that the existence of externalities does not necessarily justify taxes or subsidies. More efficient reresults would be achieved when individuals (such as consumers or private firms) bargain in order to negotiate an efficient outcome which eliminates externalities. The government should restrict its role to facilitating bargaining among the affected groups or individuals and to enforcing any contracts that result. This is known as the "Coase Theorem"[75] or contracting theory. This theorem basically states that under the condition of (a) perfect competition, (b) clearly assigned property rights and (c) negligible transactions costs, private parties that either generate or are affected by externalities will negotiate voluntary agreements that lead to the socially optimal resource allocation.

All three assumptions have been heavily criticized for not representing the real world, but the assumption of transaction costs is the most problematic.[76] This is especially true for the environmental context since many parties are involved in most cases. For example, a firm polluting a river transfers the damage to many third parties along the river and it is unrealistic that these parties can negotiate an efficient outcome that entails an adequate compensation for those suffering from the damages produced by the firm.

A further limitation to the Coase theorem is the existence of public goods where property rights are not clearly assigned. Public goods, such as clean air are characterized by non-rivalry in consumption and non-excludability. This implies that consumption of the good by one individual does not reduce the amount of the good available for consumption by others and no one can be effectively excluded from using that good. In such a situation it is economically rational on an individual basis to use as much of the good as possible without charge, which leads ultimately to the destruction or at least to a severe damage of the good. Since no property rights are assigned for public goods, no party will be willing to pay for the damage of this good. This gives rise to the free-rider problems, which refers to a situation when everybody benefits from the efforts of others to use less

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[74] Coase (1960), *The Problem of Social Cost.*

[75] This term goes back to George Stigler (1966), *The Theory of Price*, p. 113.

[76] It should be mentioned that Coase himself was extremely frustrated with most economists' understanding of the assumption of zero transaction costs. Coase clarified later that this assumption was purely hypothetical and was intended to highlight problems with standard assumptions of neoclassical theory, see Coase (1998), *The Firm, the Market and the Law*, pp. 187-213.

of the public good or to internalize external effects while not undertaking any efforts themselves.

2.2.4 Information Asymmetry

Besides imperfect competition and externalities, asymmetric information is the third main cause for market failure. Asymmetric information refers to a situation where access to relevant knowledge is unevenly distributed.[77] One party of a transaction has more or better information than the other party, which results in an inefficient outcome of transactions. Especially the work of the economists George Akerlof (1970), Joseph E. Stiglitz (1986) and Oliver Williamson (1971) studied the effects of information asymmetry on markets.[78]

There are two basic cases of information asymmetry; one refers to a situation of hidden action (moral hazard) and the other to hidden characteristics (adverse selection).

In the case of hidden action, information asymmetries most commonly occur in the context of principal-agent problems, which can result in moral hazard. Moral hazard describes a situation where the agent is imperfectly monitored by the principal and thus delivers less desirable behavior than the principal deems necessary. Such problems are most often studied in the context of employment relations.

For electricity markets and renewable energy use, information asymmetries resulting from hidden characteristics are more relevant. Adverse selection because of hidden characteristics occurs when the seller has better knowledge of the characteristics of the good on offer than the buyer.[79] A classical example of such a situation is described by the “lemon problem” of Akerlof (1970). Akerlof uses the markets for used cars to exemplify how unevenly distributed information on the characteristics of used cars leads to inefficient market outcomes because bad risks will probably dominate the market. The seller of the car has better information on the quality of the car than the buyer and the buyer runs the risk of being sold a low quality car (a “lemon”). The informed parties (the buyers) determine their willingness to pay according to the average quality of used cars. Such behavior penalizes the sellers of higher quality cars, which will be driven out of the market. The withdrawal of good quality cars reduces the average quality of used cars on the market. This further reduces both the willingness to pay and the expected quality of any used car on the part of the buyers. Ultimately only low quality cars will be on offer.[80] The market would be more efficient, however, if also cars of high quality would be traded, since the

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[77] Mankiw (2004), *Principles of Microeconomics*, pp. 480-484.

[78] See Akerlof (1970), *The Market for Lemons*, Stiglitz/Greenwald (1986), *Externalities in Economies with Imperfect Information and Incomplete Markets* and Williamson (1971), *The Vertical Integration of Production: Market Failure Considerations*.

[79] See Wilson (1989), *Adverse Selection*, p. 31.

[80] Akerlof (1970), *The Market for Lemons*, pp. 489-492.

buyers' willingness to pay would be higher if they had perfect information on the quality of the offered cars.

Information asymmetry presents a significant problem for renewable energy use.[81] First of all, the competitiveness of renewable sources is always determined in comparison to conventional energy sources. As the past years have shown, prices for fossil fuels fluctuate greatly. This uncertainty regarding both market developments for conventional fossil fuels and also the level of future generation costs of renewable energy sources reduces the willingness to invest in renewable energy technologies. More information on the characteristics of renewables serves to heighten transparency in the renewable energy markets, and helps to reduce the risk premiums for investments in renewable energy technologies.

Asymmetric information either due to hidden behavior or hidden characteristics seems to require government action to increase market outcomes. However, there are several reasons that call the need for government intervention into question. First, private actors may be better able to reduce the effects of information asymmetry through either signaling or screening. Through signaling the informed party (firms or third-party labeling institutions) reveals information to an uninformed party.[82] For example, staying in the context of used cars, sellers of used cars commit to reveal information on damages or previous accidents. Screening refers to an action pursued by the less informed party to receive information by the better informed party (such as certain tests on the car).[83] Second, the government also has only limited access to information and may not be better equipped to reduce information asymmetries. Third, the government is an imperfect institution and might base its decision on other motivations than the creation of perfect markets. These factors will be discussed in more detail in the following section.

2.3 The Risk of Government Failure

Starting in the 1970s, the academic debate increasingly highlighted that market failure as such does not necessarily call for government involvement, since the government itself can produce mistakes and hence suboptimal outcomes. The influential Chicago School of Regulatory Theory with its most important proponents Stigler (1971), Posner (1974) and Peltzman (1976) and were among the first to criticize the dominant understanding in the 1960s of economic regulation.

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[81] See Jordan (2007), *Barrieren für den Ausbau erneuerbarer Energie* for a discussion of the greatest barriers to an increased use of renewable energy such as lacking energy infrastructure and reduced access to capital markets because of information asymmetries.

[82] Mankiw (2004), *Principles of Microeconomics*, p. 482.

[83] Mankiw (2004), *Principles of Microeconomics*, p. 483.

The positive theory of regulation suggests that regulation does not protect the public at large but only the interests of individuals or groups.84 Accordingly, positive theories see regulation more as an instrument for redistributing income rather than as an instrument for ameliorating market imperfections. This perspective, which is part of the rational choice theory, seeks to explain "why existing policies are pursued and … predict which policies will be pursued in the future."85 It explores how the range, scope and form of state action is influenced by the behavior of self-interested citizens, organized interest groups, politicians, and bureaucrats, who deal with each other in political institutions. Proponents of the positive theory of regulation criticize that normative theory does not take into account the dynamics of political and economic institutions and claims that the benevolent, omnipotent, and omniscient dictator would aim to maximize the social welfare under the condition of Pareto-efficiency. In contrasts, positive theory states that redistributions rarely are Pareto-optimal, since individuals and groups would try to capture the benevolence of regulators and thus to influence redistribution according to their interests and not to the interest of the general public.

2.3.1 Capture Theory

Capture theory argues that the regulators of an industry (bureaucrats or politicians) might not act to the benefit of the country as a whole but might pursue the interests of certain industries. Stigler states it drastically: "As a rule, regulation is acquired by the industry and is designed and operated primarily for its benefit."[86] There are different explanations for capture: the life cycle approach states that after a certain period of regulation, regulators and industries become increasingly intertwined and more and more the regulation serves the interest of industry. The interest-group explanations stress the extent to which regulators can be influenced by the claims and political influence of different groups for which it is easier to organize than for the public at large. This mechanism has been explored by Olson (1965) in his seminal work „The Logic of Collective Action“. Olsen showed how small, well-organized groups manage to push their interest through against diverse groups for which high transaction costs are involved to organize themselves.[87] Finally, the private-interest approach sees regulation as a commodity liable to fall under the influence of

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[84] See Stigler (1971), *The Theory of Economic Regulation*, Posner (1974), *Theories of Economic Regulation* and Peltzman (1976), *Toward a More General Theory of Regulation* as the most well-known representatives of the positive theory of regulation.

[85] Musgrave (1959), *The Theory of Public Finance: A Study in Public Economy*, p. 4, quoted after Cordes (1997), *Reconciling Normative and Positive Theories of Government*, p. 169.

[86] Stigler (1975), *The Citizen and the State: Essays on Regulation*, p. 114.

[87] Olson developed in this work the theoretical basis for the theory of collective action and public choice, see Olson (1965), *The Logic of Collective Action: Public Goods and the Theory of Groups*.

the economically powerful. The outcome in all cases is a transfer of income to well-organized groups from those with less political power.

Accordingly, proponents of the capture theory deny that regulation is the attempt to correct market failures according to the normative theory of regulation, but see it as the result of a "market for regulation"[88]. In this market firms demand and politicians and bureaucrats supply regulation. In this view, politicians act rationally. They are seen as political firms aiming to maximize votes to secure re-election.

2.3.2 Imperfect Information of the Regulator

The Chicago School argues that even if it would be possible for regulators to act independently and without being influenced by certain interest, economic regulation of the market will still lead to undesirable outcomes because governments do not possess the necessary information to regulate efficiently. The government has to decide which industry to promote, which instruments to use and to what degree to promote. Especially command and control (C and C) regulation using set standards requires information on the appropriate level of a standard that is difficult to acquire and might produce unwanted outcomes if the standard is set too low or too high.

In the environmental context, however, several studies have shown that many of the problems associated with C and C can also occur under market-based systems.[89] Incentive approaches also require a complex system of rules and the control of the right use and enforcement of incentives. Moreover, the outcome of such market-based systems is less predictable and might be lower than the socially desirable level (e.g. a higher level of pollution than desirable).

2.4 Industrial Policy Approaches

In the past years, industrial policy approaches, that is government policies intended to provide a favorable economic climate for the development of industry in general or specific industrial sectors, seem to experience a comeback. In fact, it seems that both within policy-making and academic circles, state intervention in general and industrial policy in particular are regarded in a more positive light.[90] The new industrial policy is distinctively different, however, both from traditional horizontal industrial policy of the 1980s and 1990s as well as vertical industrial policy of the 1960s and 1970s. An example of sectoral

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[88] Trunkó (2000), *Regulierung der US-Elektrizitätswirtschaft. Demokratische Partizipation versus ökonomische Effizienz?*, pp. 240-244.

[89] See e.g. Bauman (2004), *Free-Market Incentives for Innovation: A Closer Look at the Case of Pollution Control*, pp. 13-15.

[90] See Lau (2007), *Viel Sehnsucht, viel Angst* for an interesting article on the political move to the left in Germany and Economist (2007), *Is America Turning Left?*, p. 9.

or vertical industrial policy is infant industry protection or the “picking of winners”. Typical instruments of horizontal industrial policy are oriented to enhance both hard (roads, bridges) and soft (administrative capacity, human capital, schools or retraining facilities) infrastructure. While this certainly is important for economic development, this approach is also very expensive and very slow to yield results.

New, so called pragmatic industrial policy aims to resolves the problems of vertical and horizontal industrial policy.[91] Picking winners or the build-up of infrastructure is not intended, rather the creation of a dynamic environment, which helps to accelerate exciting sectors and to create innovation clusters and networks. The assumption here is that human capital development and technological innovation are the engines of productivity growth which lead to long-term growth of a country or a sector of the economy. Even though innovation and technological advancements are produced by the private sector, the private sector depends on state incentives since the fixed costs and risks of entering new market niches are significant. Rodrik (2007) demands that the debate on industrial policy should be “normalized” and that the academic discussion whether there should be industrial policy is not productive, since state intervention is a fact.[92] The question of “how” to design industrial policy measures is more fruitful.

The promotion of renewables is seen by many governments as a strategic investment to be better prepared for the energy challenges of the future. Besides the positive environmental effects of a higher share of renewables in the energy mix, economic interest and the government intention to create strategic industries with a comparative advantage on international markets are important motivations.

While the previous sections discussed state intervention in the context of market and government failure, the next section deals with industrial policy approaches of states. Since the stated aim of many governments is the creation or the strengthening of a competitive renewable energy industry on international markets, the concept of competitiveness and comparative advantage will be discussed first. These terms have been interpreted very differently in the literature in both traditional and new (strategic) trade theory. Both perspectives as well as the understanding of Porter (1990) of competitive advantage will be briefly analyzed. Subsequently, two specific arguments which are most prominently raised when discussing industrial policy will be analyzed and will be applied to renewable energy markets: the aim of export promotion which are theoretically either based on the infant-industry arguments or first-mover advantages and the related concept of lead markets.

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[91] See the World Bank Initiative “New Industrial and Innovation Policy”, http://go.worldbank.org/GY9Y0WIGD0 (access date: 10/05/2007).

[92] Rodrik (2007), *Normalizing Industrial Policy*, pp. 38-39.

2.4.1 The Competitiveness "Problem"

The origins of the concept of 'competitiveness' can be traced back to the first half of the nineteenth century. Still, the concept of competitiveness is ambiguous and in the academic debate the term competitiveness is often used for different meanings and in different contexts.[93]

In general, the most important distinction is between microeconomic and macroeconomic concepts of competitiveness.[94] At the firm level, competitiveness generally refers to the ability of the firm to compete, grow and be profitable in the marketplace.[95] The macroeconomic perspective on competitiveness asks how a country rates versus a partner country in terms of desirable economic goals such as productivity, employment and equality. Generally, most measure of competitiveness at the national level "refer to the ability of a country to produce goods and services that meet the test of international markets, while simultaneously maintaining and expanding the real income of its citizens".[96] Perhaps the most well-known of the macroeconomic indicators of competitiveness is the Global Competitiveness Index published in the annual Global Competitiveness Report by the World Economic Forum.[97] Macroeconomic concepts of competitiveness, though very popular, are controversial in the economic literature. Paul Krugman denounces the term competitiveness as 'meaningless' when applied to national economies and referred to international competitiveness concerns as a 'dangerous obsession'.[98] Michael Porter's influential study on the „Comparative Advantage of Nations" acknowledges that it is not nations that compete against each other on the international markets but firms and branches.[99] Some authors use the term "competitive advantage" when referring to the international competitive position of countries to demonstrate the difference to comparative advantage.[100]

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[93] See Lee (2001), *Competitiveness of Nations*, p. 224 for a historical survey of the debate on competitiveness.

[94] For reviewing discussions on the concept of international competitiveness in the economic literature see Siggel (2006), *International Competitiveness and Comparative Advantage: A Survey and a Proposal for Measurement*, Preuße (2003), *Konzeptionelle Überlegungen zur internationalen Wettbewerbsfähigkeit: Unternehmen oder Länder*, Porter (1990), *The Competitive Advantage of Nations*, Dosi/Pavitt/Soete (1990), *The Economics of Technical Change and International Trade* and Fagerberg (1988), *International Competitiveness*.

[95] Bristow (2005), *Everyone's a 'Winner': Problematising the Discourse of Regional Competitiveness*, p. 287.

[96] US Commission on Industrial Competitiveness (1985), *Report of the President's Commission on Industrial Competitiveness*, p. 6.

[97] World Economic Forum (2007), *Global Competitiveness Report*.

[98] See Krugman (1994), *Competitiveness: A Dangerous Obsession*, p. 28.

[99] See Porter (1990), *The Competitive Advantage of Nations*, p. 2.

[100] See Neary (2003), *Competitive Versus Comparative Advantage*, pp. 9-11.

The following section will look at the concepts of competitiveness and comparative advantage in trade theory.[101] Analytically, trade theory can be classified into two categories: traditional trade theory and new trade theory. Traditional trade theories encompass the theories of Smith, Ricardo, Heckscher and Ohlin and the modifications of the Heckscher-Ohlin theory such as the Stolper-Samuelson theorem. The new trade theories on the other hand were developed most prominently by Krugman (1979) and (1988) and Brander/Spencer (1985).

2.4.1.1 The Perspective of Traditional Trade Models

In the classic trade theory of Adam Smith, the concept of international competitiveness had no relevance. The concept of competitiveness only entered international trade theory with Ricardo's theories of comparative advantages.[102]

Conventional trade theory assumes perfect competition, homogenous goods and constant returns to scale in production. Given these basic assumptions, traditional trade theories developed predictions on trade patterns and origins of comparative advantage, which will be presented in this section.

David Ricardo's comparative advantage theory focuses on the relative cost of goods within and across countries.[103] Unlike the theory of absolute advantage of Adam Smith, Ricardo argues in his main work "On the principle of political economy and taxation" that it will always be beneficial for all countries to trade since every country has a comparative advantage in one good even if the competitor has an absolute cost advantage in the production of all traded goods. This implies that countries should export those goods which they can produce better – not in comparison to other countries, but in comparisons to all domestically produced goods.[104] International trade would then lead to a specialization in production; each country would specialize in what they are relatively more adept at producing and thus have a comparative advantage. Ricardo explained the differences in comparative advantage with differences in technology. By definition, each country has a comparative advantage in the production of some products – those which it produces at lower relative cost than its competitors. No country can have a comparative advantage for all products.

The two Swedish economists Eli Heckscher and Bertil Ohlin argued that not technological differences, but differences in factor endowments of labor, land and capital ex-

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[101] See Markusen/Melvin/Kaempfer et al. (1995), *International Trade: Theory and Evidence*, pp. 84-240 and Krugman/Obstfeld (1997), *International Economics: Theory and Policy*, p. 275-296 for two very good overviews over the genesis of trade theory.

[102] See Lee (2001), *Competitiveness of Nations*, p. 224.

[103] Frieden (2006), *Global Capitalism: Its Fall and Rise in the Twentieth Century*, pp. 29-33.

[104] Case/Fair (1999), *Principles of Economics*, pp. 812-818.

plained comparative advantage. These differences in endowments of the factors of production translate into relative cost differences, which explain trade flows. Thus, a country has a comparative advantage in and will export those goods which use the relatively more abundant resource.

The Stolper-Samuelson theorem[105] is a derivative of the Heckscher-Ohlin model. It is not so much concerned with explaining comparative advantage, but with the distributional effects of trade on returns and incomes. The theorem states that trade will increase the incomes of some industries and lower the incomes of other industries within countries. More specifically, the producers of goods which intensively use the scarce factors of a country loose when an economy opens up for trade, while the national owners of an abundant factor of production will be better off. In autarky, goods which use the scarce factor intensively will be relatively expensive. If the country opens up, the price for those goods will be under pressure from the lower world market prices and will fall. This results in a lower return for the scarce factor.

In 1953, Wassily Leontief presented the Leontief paradox, which showed that the United States as a capital-abundant country exported labor-intensive goods and imported capital-intensive products; a clear contradiction of the Heckscher-Ohlin theorem. Following the publication of Leontief's study, the Heckscher-Ohlin model was increasingly criticized for not explaining the real world. New trade theories were developed to offer alternative explanations of trade patterns and comparative advantage.

2.4.1.2 The Perspective of New Trade Theory

The Leontief paradox spurred a new wave of research in international trade theory. Moreover, several authors found that trade patterns between developed countries reveal that a considerable amount of trade consists of intra-industry trade; that is trade of products which are close substitutes for each other in terms of factor inputs and consumption.[106] Such trade patterns are contrary to the Heckscher-Ohlin-model which predicts that a nation's imports and exports consist of very different goods. Consequently, the "new"[107] trade theory questioned many of the assumptions of the traditional trade theory.[108] It emphasizes that international trade cannot be explained by different factor endowments without negating the concept of comparative advantage. New trade theories rather claim

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[105] For the original publication see Samuelson/Stolper (1941), *Protection and Real Wages*.

[106] Krugman (1981), *Intra-Industry Specialization and the Gains from Trade*, pp. 959-960.

[107] The term „new" becomes increasingly inappropriate since it dates back to the late 1970s and early 1980s.

[108] Further pioneers of new trade theory are Markusen/Svensson (1985), *Trade in Goods and Factors With International Differences in Technology*, Dixit/Norman (1980), *Theory of International Trade: A Dual, General Equilibrium Approach* and Lancaster (1980), *Intra-Industry Trade Under Perfect Monopolistic Competition*.

that trade flows are characterized by (a) imperfect competition, (b) increasing returns to scale, (c) product differentials, and (d) the timing of innovation.[109]

(a) The new trade theorists disputed that resource allocation between production activities is instantaneous and costless as traditional trade theorists assumed. Moreover, new trade theories are based on monopolistic and oligopolistic market models, which imply that large companies can influence the prices of internationally traded goods and are not simply price takers. Thus, *imperfect competition* is a more realistic description of markets than perfect competition models, which provide the base of traditional trade theory.

(b) The assumption of monopolistic or oligopolistic competition is closely related to the second main difference from traditional trade theory: *increasing returns to scale*.[110] When a market size expands through trade, it allows firms to reap higher returns to scale, either through specialization and a greater product variety or simply increased sales. Krugman differentiates two main forms of increasing returns to scale: those internal to firms (the average production costs of a firm fall with its output) and those external to firms. External returns to scale mean that the average production costs of all firms of an industry fall, either because of access to inputs, technology and information or spatial concentration of firms.

(c) Contrary to traditional trade theory, new trade theory presumes the existence of *product differentials* and differences in technological capabilities. Product differentiation refers to the practice of making close substitutes appear different in order to avoid or to lessen ruinous price competition. The influence of technological differences on the patterns of trade has been documented in the economic literature since the mid-1980s.[111] As mentioned earlier, the new trade theory did not dismiss the concept of comparative advantage altogether. In new trade theory, comparative advantage can explain inter-industry trade, while increasing returns to scale can explain intra-industry trade, which is due to specialization within industries.

(d) The importance of intra-industry trade also became obvious with the success and the rapid expansion of the European Common Market. The exchange between the European countries could not be explained by differences in factor endowments as the standard trade model maintained. Vernon developed the product cycle model to explain the European trade patterns and which exemplifies how both factor endowments and economies of

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[109] See Helpman/Krugman (1985), *Market Structure and Foreign Trade: Increasing Returns, Imperfect Competition, and the International Economy*, p. 261-263.

[110] Already Adam Smith was aware of the importance of increasing returns, but only with the new trade theory were the concept of increasing returns and imperfect competition linked and other limitations of the concept overcome.

[111] See Markusen/Svensson (1985), *Trade in Goods and Factors With International Differences in Technology*, p. 175-176 for a review of the literature.

scale have relevance.[112] The essence of the Vernon's product cycle theory is that products and its production methods go through three stages of maturation and that comparative advantage in the production of new products that change over the life cycle of the products. In the first stage, a new product is invented in one country and exported. Comparative advantage is based on the first-mover advantage of the country in which the product was developed. In the second stage, the maturing stage, the innovator looses export market share to other countries who imitate the innovation. The source of comparative advantage lies in cost advantages in lower cost countries, which are likely to come from Heck-Heckscher-Ohlin-type factor abundance. In the third and final stage, the former innovator ends up importing the now standardized product and comparative advantage in the production of the good is likely to result from scale economies and learning effects. Thus, Vernon put emphasis on the *timing of innovation* to explain trade patterns with the assumption that diffusion of new technology occurs with a time lag which generates temporary differences between countries in available production technology. In fact, innovation in general is increasingly seen as *the* primary driver of competitiveness and trade patterns between developed countries.[113]

The main assumptions of new trade theory (imperfect competition, increasing returns to scale, product differentials, the timing of innovation) are also the starting points for the analysis of the effects of government involvement in international markets, as part of strategic trade theory. The use of different policies by governments to gain a competitive advantage in international markets has been analyzed by the literature on international trade. This literature shows that in imperfect competitive markets governments have incentives to subsidize exports of domestic firms to shift profits to the domestic economy at the expense of their rival partners.[114] Esser et al. (1996) for examples argue:

> “The most competitive countries are those that do not put all their bets on competition between isolated firms, unconditioned free trade, and the state as an institution of regulation and supervision. Rather, the most successful countries are those that actively shape locational and competitive advantages.”[115]

Even though Paul Krugman is closely related to strategic trade theory[116], he later emphasized three main problems with strategic trade theory and its possible effects on international trade: The first two arguments refer to the general risk of government failure:

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[112] Vernon (1966), *International Investment and International Trade in the Product Cycle*.

[113] See e.g. OECD (2002), *Dynamising National Innovation Systems*, p. 9 and Gries (1998), *Internationale Wettbewerbsfähigkeit: eine Fallstudie für Deutschland*, pp. 63-64.

[114] See among many Krugman (1987), *Is Free Trade Passé?*, Brander/Spencer (1985), *Export Subsidies and International Market Share Rivalry* and Eaton/Grossman (1986), *Optimal Trade and Industrial Policy Under Oligopoly*.

[115] Esser (1996), *Systemic Competitiveness: New Governance Patterns for Industrial Development*, p. 1.

[116] See Krugman (1987), *Is Free Trade Passé?* for one of the most well-known publications on strategic trade theory.

information asymmetry and political capture. The government does not possess the relevant information in most cases on all economic sectors to efficiently decide which industry to promote and how. Powerful interest groups will also aim to influence the decisions of the government, which will further lead to inefficient market outcomes and lower overall welfare. The third main problem of strategic trade theory refers to the protectionists nature of trade measures to promote domestic industries, which can result in retaliation measures of the trading partners and reduce international trade altogether.

2.4.1.3 Porter's Diamond Model

Research from the management field also added to the analysis of the determinants of competitiveness. Especially, Harvard management strategy professor Michael Porter launched an attack on the dominant factor endowment theory to explain comparative advantage. Porter argued that competitive advantage is not gained through relative factor abundance. Instead it is gained through non-price factors such as the ability to innovate, which creates technological advantages or greater output per unit of input. In this 1990 book "The Competitive Advantage of Nations, Porter created a new paradigm in order to understand why a nation succeeds in some industries but not in others. Hence, his framework combines macroeconomic and microeconomic concepts of competitiveness: through focusing on the competitiveness of clusters, which present the core prerequisite of competitiveness, Porters explains the development of the competitiveness of nations. Porter's analytical framework is determined by the diamond model, which captures four major determinants of competitive advantage (factor conditions, demand conditions, related and supporting industries and strategy, structure and rivalry, see Fig 2-4).

Factor conditions refer to the production factors required for a given industry, such as labor, capital and infrastructure. Contrary to conventional theory, Porter insists that the dominant factors of production are created, not inherited.[117] Porter divides production factors into two categories: basic production factors (unskilled labor, natural resources, climate etc.) and specialized factors (such as narrowly skilled labor and a high education level).[118] Whereas basic factors do not generate sustained competitive advantage, specialized factors require large investments to obtain and are more difficult to duplicate. Hence, those factors are valuable and can materialize in competitive advantages.

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[117] See Messner (1995), *Die Netzwerkgesellschaft: wirtschaftliche Entwicklung und internationale Wettbewerbsfähigkeit als Probleme gesellschaftlicher Steuerung*, pp. 7-28 for an interesting discussion of Porter's arguments. Messner's main argument in his influential book "Die Netzwerkgesellschaft" is that the most successful countries at the end of the twentieth century in term of economic, social, and ecological success will not be unleashed market economies but "active and learning societies". They will address their problems on the basis of an organizational and governance-related pluralism, see Messner (1995), *Die Netzwerkgesellschaft: wirtschaftliche Entwicklung und internationale Wettbewerbsfähigkeit als Probleme gesellschaftlicher Steuerung*, p. IX.

[118] Porter (1990), *The Competitive Advantage of Nations*, pp. 77-80.

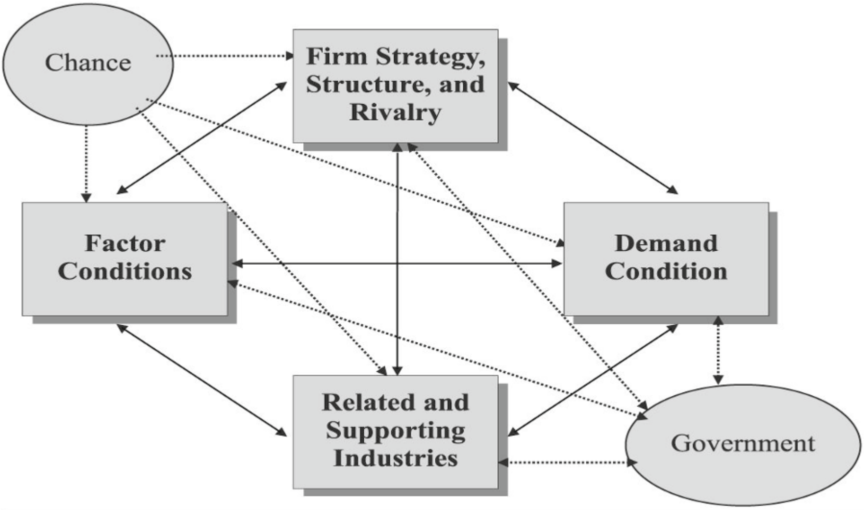

Fig 2-4: Porter's Diamond model
Source: Porter (1990), p. 127.

The extent and nature of demand within the nation is described by *demand conditions*. Porter, differentiating between home and foreign demand, stressed that home demand has more influence on competitive advantage than foreign demand, because the composition of home demand relates more to quality rather than quantity in determining competitive advantage. The more demanding the home buyers are the more pressure is put upon companies to meet and to increase high standards in terms of product quality, special features, and service.

The existence of *related and supporting industries* is a third determinant of comparative advantage. Spatial proximity of upstream or downstream industries fosters technological spillovers and innovation through the exchange of information and ideas. For example, the dissemination of business know-how can spread amongst firms as they share educated human resources and research institutions.

Lastly, *firm strategy, structure, and rivalry* includes the conditions in which firms are created, organized and managed, as well as the environment of domestic rivalry. Porter argues that a strong domestic rivalry increases comparative advantage since it puts pressure to improve and innovate on domestic firms. The successful domestic companies are then better prepared to also withstand international competition.[119]

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[119] Porter (1990), *The Competitive Advantage of Nations*, p. 179.

As shown in Fig 2-4, Porter added chance and government as factors influencing the four main determinants of comparative advantage. Government policies on education and subsidies, for example, affect factor conditions. Government regulation and the setting of product standards influence demand conditions and also related and supporting industries. Porter (1990) defined chance events as "occurrences that have little to do with circumstances in a nation and are often largely outside the power of firms (and often the national government) to influence."[120] Some examples of chance include inventions, oil shocks, major shifts in world financial markets, and wars.

Porter's model has been criticized by many academics and especially economists for not offering a significantly new approach to analyzing the determinants of competitiveness. Porter's framework is rather descriptive and does not allow for any mathematical analysis or modeling of the influence of different factors. Moreover, Porter's framework focuses very narrowly on national markets. With the rise in importance of multinational enterprises (MNE) the possibilities of governments to influence business conditions are changing if not waning. Moreover, government behavior itself is influenced by the effects of globalization and transnationalization. Porter does not address how MNE themselves affect government policy and how MNE can shift some or all of their activities across national borders more easily than national firms.

2.4.2 Infant Industry Argument

The infant industry argument has been traditionally used to justify government intervention in international trade. The basic argument goes back to Alexander Hamilton (1791) and Friedrich List (1841)[121] and states that production costs for new industries will initially be higher than for well-established industries for the same goods in foreign countries. The temporary protection of infant industries will increase national welfare in the long run, because without the protection the infant industry would not be able to develop or survive due to the competition from well-established rival industries in other countries.[122]

Protection of the infant industry in form of an import tariff would raise the domestic price of the product and consequently reduce imports from the rest of the world. This gives the protected industry time to increase their competitiveness through increased experience which results in lower costs of production and prices. Over time the price reduction would be large enough to abolish the import tariff while the former infant industry grew into an industry able to survive the international competition without protection. Ac-

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[120] Porter (1990), *The Competitive Advantage of Nations*, p. 124.

[121] The first English translation of List's work was published in 1856 under the title "*The National System of Political Economy*."

[122] For a detailed discussion of List's work see Shafaeddin (2005), *Friedrich List and the Infant Industry Argument*.

cordingly, a key element of an infant industry strategy is the existence of a positive dynamic production externality. To justify the protectionist measures production experience over time should stimulate learning effects that will improve production efficiency in the future.

While even economists such as John Stuart Mill accepted the argument that early industries needed government support for a restricted period of time[123], neoclassical trade theory still points out two main problems with an infant industry strategy.[124]

First, infant-industry protection like other protectionist measures raises the domestic price of the imported good and results in a transfer income from consumers to producers.[125] As Meade (1955) and others have argued the existence of higher initial production costs compared to the foreign competitors is not a sufficient justification for protectionist measures, which raise the price above world market levels.[126] If the producing firms of the protected industry are able to decrease their production costs after the learning period to earn a sufficient surplus, it should be possible for the firms to bridge the two periods by raising funds in the capital market rather than by receiving an artificial protection through the government. In fact, all new industries will have higher initial costs due to less efficient production processes and sunk costs such as the purchase of machinery and will have to cover the excess costs over returns during the early stages by borrowing from the capital market. Through the infant industry strategy governments take on the risks involved with creating new industries that should be incurred on the private sector.

The second main critique is that protection deflects the economy from its comparative advantage: By making protected activities artificially profitable, trade protection diverts resources to possibly less productive uses.

From a political economy standpoint rather than a trade theory perspective more problems arise with an infant industry strategy. Political capture can hinder the effective implementation of an infant industry strategy and more importantly the timely destruction of the protectionist measure after a restricted period of time. The protection itself may slow down increases in efficiency in production, since the need for the protected indus-

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[123] See Shafaeddin (2005), *Friedrich List and the Infant Industry Argument*, p. 55.

[124] See Messerlin (2006), *Enlarging the Vision for Trade Policy Space: Special and Differentiated Treatment and Infant Industry Issues*, pp. 1398-1401 and Baldwin (1969), *The Case Against Infant-Industry Tariff Protection* for a critique of an infant industry strategy. Krueger/Tuncer (1982), *An Empirical Test of the Infant Industry Argument* developed an empirical test for the validity of the infant industry argument and applied that test on Turkish data. They tested whether input per unit of output declined faster in protected than in unprotected Turkish industries, which could be regarded as an argument for protectionist measures, but found no evidence for such a tendency.

[125] Baldwin (1969), *The Case Against Infant-Industry Tariff Protection*, p. 296.

[126] Meade (1955), *Trade and Welfare*, p. 256.

tries to reduce costs is less urgent as long as prices above world market levels prevail at least when the degree of competition on the domestic market is also relatively low.

Moreover, economists question the ability of governments to pick those industries with the highest future growth potential. In order to be able to do so, governments would have to have reliable and comprehensive information about industries in their economies. Even if governments actually protect those industries which exhibit strong learning effects in their production and which generate learning spillover effects to other industries, the level of protection is also decisive for this strategy to be more or less successful. Here again, due to the incomplete information available to governments the risk of a misallocation of resources is great.

Hansen/Jensen/Madsen (2003) apply the infant industry argument to the Danish wind energy industry. Hansen states that the protectionist policy has to pass two tests in order to be deemed successful: firstly, the Mill's test which states that government aid in the upstart phase has to result in a build up of an internationally competitive industry in the long run, and secondly, the Bastable's test, which claims that a precondition for a successful infant industry strategy is the existence the dynamic economies of scale or learning-by-doing within the industry so that the initial costs could be paid back later.[127]

The infant industry argument was originally only applied to developing countries that try to develop an export industry facing competition from more developed countries.[128] This was the case for example for Germany and the United States before the turn of the 20th century, when they were faced with strong competition from companies in England.[129] This argument was traditionally not applied to infant industries within well developed countries such as Denmark or Germany today.

Moreover, the main justification for infant industry protection does not hold true for renewable energy use today. The main justification is that temporal protection will lead to steep learning curves through experience which drives down prices and thus, after a period of time, allows the former infant industry to compete in international markets. In the case of the Danish wind energy industry this is clearly not the case, since Danish wind energy companies are not faced with strong competition from more developed countries. Denmark has established the first and one of the most competitive wind energy industries worldwide.

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[127] The tests are discussed in Kemp (1960), *The Mill-Bastable Infant-Industry Dogma*, pp. 65-67.

[128] Messerlin (2006), *Enlarging the Vision for Trade Policy Space: Special and Differentiated Treatment and Infant Industry Issues*, pp. 1397-1398.

[129] Frieden (2006), *Global Capitalism: Its Fall and Rise in the Twentieth Century*, p. 63.

2.4.3 First-Mover Advantages

The first-mover advantage concept posits that the first mover into a market may acquire certain advantages over later entrants through the early entrance which results in a dominant position in the market over a longer period of time. The first-mover theory has first been developed in the late 1960s in the management and business literature and was concerned with firms' entry strategies, often using game theory to analyze under which circumstances it is beneficial for a firm to enter a certain market before its competitors.[130] The main questions asked are accordingly, should a firm enter a market as a first-mover, bearing extra costs and risks to benefit from first-mover advantages, or should it wait and enter when the market has developed and it can learn from the first movers' mistakes?

In the 1980s, theoretical and analytical literature within economics and industrial organization economics challenged some of the assumptions of the marketing and strategic management literature and offered new insights into possible explanations for first-mover advantage.[131] These reasons to explain first-mover advantage include cost advantages[132], barriers to entry advantages[133], switching costs and first-mover image[134], economies of scale and learning curve economies[135] and consumer preference formation.[136] Cost advantages occur during the first phase of limited competition and thus increased profitability due to the strategic positioning of the early entrant. When later market entry is difficult and imitation of the product is costly, these cost advantages can exist for a significant period of time. Switching costs arise through transaction costs from switching brands, learning costs and contractual costs. In addition, Schmalensee (1982) shows that imperfect information on the part of consumers leads to a positive evaluation of early producers and thus first-mover advantage as well. If consumers acquired positive experiences with the first product, they will tend to favor this product over later products.

In the late 1980s and early 1990s, however, a growing number of articles questioned the first-mover concept and formulated arguments for first-mover disadvantages or sec-

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[130] See Frawley/Fahy (2005), *Revisiting the First-Mover Advantage Theory: A Resource-Based Perspective*, p. 275, Jensen (2003), *Innovative Leadership: First-Mover Advantages in New Product Adoption* and Sonnegård (1996), *Determination of First Movers in Sequential Bargaining Games: An Experimental Study*.

[131] See e.g. Gilbert/Birnbaum-More (1996), *Innovation Timing Advantages: From Economic Theory to Strategic Application* and Frawley/Fahy (2005), *Revisiting the First-Mover Advantage Theory: A Resource-Based Perspective*.

[132] See Robinson/Fornell (1985), *Sources of Market Pioneering Advantages in Consumer Goods Industries*.

[133] See Bain (1956), *Barriers to New Competition: Their Character and Consequences in Manufacturing Industries*.

[134] See Lieberman/Montgomery (1988), *First-Mover Advantages*.

[135] See Kerin/Varadarajan/Peterson (1992), *First-Mover Advantage: A Synthesis, Conceptual Framework and Research Propositions* and Urban/Carter/Gaskin et al. (1986), *Market Share Rewards to Pioneering Brands: An Empirical Analysis and Strategic Implications*.

ond-mover advantages.[137] Arguments for second-mover advantages include that late-movers can free-ride on the early firm's investment in technology and market development. Accordingly, some of the costs of the early entrant can be avoided. Golder/Tellis (1993) analyze approximately 500 brands in 50 product categories using an historical approach and conclude that moving first into a market creates no advantage. They differentiated between product pioneers (first to develop a product) and market pioneers (first to sell the product). They find that only 53% of market pioneers survived in the market and their average market share was only 10 percent. In contrast, early market movers but not pioneers had a much lower failure rate of 8% and a higher average market share with 28%. Thus, their results suggest that the order of market entry is not necessarily related to long-term market performance. Hoppe (2000) argues that important second-mover advantages exist because of informational spillovers.[138] Rhee (2006) demonstrates that first-mover disadvantages can also be the result of consumer heterogeneity along unobservable characteristics, even in the absence of informational spillovers.[139] The academic debate on the relevance of first- or second-mover advantages is ongoing.

2.4.3.1 First-Mover Advantages and Environmental Innovation

Since the 1990s, the first-mover concept has been transferred to the environmental debate and later to the climate and renewable energy debate as well. This research asks to what extent regulation in the environmental and energy sector can create markets for environmental and renewable energy products that other countries import and therefore generate export opportunities for the pioneering country.[140]

The argument of first-mover advantages in the context of environmental policy and technology has been most prominently formulated by Porter/van Linde (1995). They argue that strict environmental regulations can push local firm’s innovativeness towards increased resource efficiency so that innovations are profitable even if foreign countries do not adopt the regulation.[141] The country may be able to gain a double advantage: first

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[136] Schmalensee (1982), *Product Differentiation Advantages of Pioneering Brands*, p. 349.

[137] See e.g. Cho/Rhee (1993), *Latecomer Strategies: Evidence from the Semiconductor Industry in Japan and Korea* and Shankar/Carpenter/Krishnamurthi (1998), *Late Mover Advantage: How Innovative Late Entrants Outsell Pioneers*. For more recent publications see Hoppe (2000), *Second-Mover Advantage in the Strategic Adoption of New Technology Under Uncertainty* and Rhee (2006), *First-Mover Disadvantages with Idiosyncratic Consumer Tastes Along Unobservable Characteristics*.

[138] Hoppe (2000), *Second-Mover Advantage in the Strategic Adoption of New Technology Under Uncertainty*, p. 332.

[139] Rhee (2006), *First-Mover Disadvantages with Idiosyncratic Consumer Tastes Along Unobservable Characteristics*, p. 99.

[140] See Jaffe/Newell/Stavins (2002), *Environmental Policy and Technological Change* for a detailed overview of the debate.

[141] Environmental standards can have various effects on industries. Some authors argue that the international competitiveness of industries can be negatively affected by high environmental standards, which

through the export earnings due to the first-mover advantage in new technologies and second because of less pollution if the pollutant in question is internationally dispersed. The so-called Porter hypothesis further argues that environmental regulation - regularly - does not reduce the profits of firms.

Other authors question the positive effect of strict regulation on export performance. Dosi/Pavitt/Soete (1990) and Palmer/Oates/Portney (1995) argue that regulation acts most often as an obstacle to innovation and only a deregulated market creates a conducive environment for innovations which lead to competitive advantages.

It is true that standard trade theory predicts that stricter national regulation *can* result in a specialization in environmentally friendly goods and might trigger innovation. A generalization of either negative or positive effects of strict regulation is difficult, though, since neither an empirical correlation between strict environmental standards and increased international competitiveness nor between lax environmental norms and weak competitiveness has been proven.

Many empirical studies come to the surprisingly consistent conclusion that environmental norms do not considerably influence either the competitiveness or the flow of direct investment.[142] The main reason is that factors other than environmental standards have a much higher influence on production costs; factors such as labor costs, level of education, infrastructure or taxation. For certain environmental- and energy-intensive industries, such as the paper, chemical or oil industry, this might be different, though. This does not imply, however, that environmental standards do not effect the development of new products and markets.

2.4.3.2 First-Mover Advantages and Renewable Energy Industries

Recent research expanded the debate from first-mover advantages through environmental regulation and competitive environmental technologies to the energy sector. These studies ask for example: “Why does the EU actively promote renewable energy?”[143] Two possi-

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increase the production costs of goods and services, which in turn could lead to a dislocation of production to countries with lower environmental standards (industry flight), see among others Feketekuty (1993), *The Link Between Trade and Environmental Policy*, p. 186. Environmentalists fear that countries will be pressured to lower strict environmental norms in order to remain competitive, which could result in weak environmental protection globally („race to the bottom“), see Esty (2001), *Bridging the Trade-Environment Divide*, p. 121. There is no empirical proof, however, for either a large-scale industrial flight because of environmental norms or a “race to the bottom”.

[142] See for some of the more comprehensive studies OECD (1997), *Economic Globalisation and the Environment*, p. 11, Jaffe (1995), *Environmental Regulation and the Competitiveness of US Manufacturing: What Does the Evidence Tell Us?*, OECD (1993), *Environmental Policies and Industrial Competitiveness*, p. 7 and Barker/Köhler (1998), *International Competitiveness and Environmental Policies*, Maennig (1998), *Zur internationalen Wettbewerbsfähigkeit deutscher umweltintensiver Güter und deutscher Umweltschutzprodukte*, Niedersächsisches Institut für Wirtschaftsforschung (2000), *Zur Position Deutschlands im Handel mit potenziellen Umweltschutzgütern*.

[143] See Brandt/Svendsen (2006), *Climate Change Negotiations and First-Mover Advantages*.

ble answers could be: out of a sense of moral obligation to tackle climate change through global warming or out of an attempt to capitalize on its first-mover advantage concerning renewable energy systems.

Brandt/Svendsen (2004) and Brandt/Svendsen (2006) analyze first-mover advantages related to technological leadership in renewable energy industries that materializes in export opportunities. Technological leadership can be the result of either specific R&D programs or of policy measures with technological advances as a side effect. Both cases cre-create export opportunities on international markets due to early entrance. The authors identify two different types of first-mover advantages with regard to renewable energy technologies. In the first case (type 1), export opportunities only materialize if the importing country has specific policies for either renewable energy promotion or carbon emission reductions in place. The second type of first-mover advantages (type 2) also exist when the technology is competitive even without such specific policies in the importing country.[144] The authors argue that one reason the European Union (EU) is committed to strengthen the Kyoto Process is that it aims to expand exports of renewable energy technologies. Since renewable energy technologies are still generally more expensive than conventional technologies (type 2 of first-mover advantage do not accrue), carbon emission reduction targets or mandatory levels of renewable use in more countries would increase type 1-advantages.[145]

2.4.3.3 Lead Markets

Closely connected to research on first-mover advantages is the lead market concept. The concept of lead markets draws upon innovation and environmental economics theory in the sense that it combines questions of the effects of environmental regulation with the analysis of how innovations are selected and what are the determinants of their success or failure.[146] Thus, the lead market concept expands research on first-mover advantages by not only discussing the effects of national regulation on competitiveness, but creating a framework to analyze under which conditions “environmental regulations can create lead markets, enabling local firms to export innovations that are induced by local market conditions and national regulations.”[147]

What is a lead market? The European Commission uses the term in its 2006 competitiveness report and defines lead markets as: “the market where an innovation is first

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[144] Brandt/Svendsen (2004), *Switch Point and First-Mover Advantage: The Case of the Wind Turbine Industry*, p. 6.

[145] Brandt/Svendsen (2006), *Climate Change Negotiations and First-Mover Advantages*, p. 1179.

[146] See Jacob/Jänicke/Beise et al. (2005), *Lead Markets for Environmental Innovations*, p. 7.

[147] Beise/Rennings (2003), *Lead Markets of Environmental Innovations: A Framework for Innovation and Environmental Economics*, p. 4.

widely used that later becomes successful internationally regardless of where that innovation was invented."[148] A definition by Beise/Rennings (2003) formulates: "Lead markets are regional or national markets (or market segments), that have first adopted an innovative design which subsequently becomes adopted by most other countries."[149] Both definitions are quite similar and focus on two elements: Lead markets are markets where (1) an innovative design is first developed and marketed which then (2) diffuses worldwide.

The literature on lead markets includes descriptive case studies on certain innovations[150], marketing studies on the international diffusion of innovations[151], analyses of the market-linkage of R&D[152] and studies on the impact of national regulation and market conditions on innovation. The last strand of research is most relevant for the purpose of this study since it asks how government regulation (and other factors) can influence innovation and thereby create export possibilities.

Beise/Rennings (2005) analyze systematically the factors that raise the chances of an internationally successful innovation. The authors identify five relevant factors for lead markets: Price advantages, demand advantages, transfer advantages, export advantages and market structure advantages (see Table 2-1).[153]

Tab 2-1: Factors relevant for lead markets

1. Price advantages	National conditions that result either in relative price decreases of a nationally preferred innovation design compared to designs preferred in other countries, or in the anticipation of international factor price changes
2. Demand advantages	National conditions that result in the anticipation of the benefits of an innovation design emerging at a global level
3. Transfer advantages	National conditions which increase the perceived benefit of a nationally preferred innovation design for users in other countries, or by which national demand conditions are actively transferred abroad
4. Export advantages	National conditions that support the inclusion of foreign demand preferences in nationally preferred innovation designs

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[148] European Commission (2006), *European Competitiveness Report: Competitiveness and Economic Reforms*, p. 111.

[149] Beise/Rennings (2003), *Lead Markets of Environmental Innovations: A Framework for Innovation and Environmental Economics*, p. 5.

[150] See European Commission (2006), *European Competitiveness Report: Competitiveness and Economic Reforms*, p. 114 for a short description of these studies.

[151] These studies aim to find statistical explanations for different average lag times between the introduction of an innovation and its global diffusion, see e.g. Tellis/Stremersch/Yin (2003), *The International Take-Off of New Products*.

[152] See European Commission (2006), *European Competitiveness Report: Competitiveness and Economic Reforms*, p. 115 for an overview of these studies.

[153] Beise/Rennings (2005), *Lead Markets and Regulation: A Framework for Analyzing the International Diffusion of Environmental Innovations*, pp. 8-9.

5. Market structure advantages	National conditions that increase the level of competition between domestic companies and facilitate low market entry barriers for new ones

Source: Beise/Rennings (2005), pp. 8-9

From a case study on fuel efficiency cars and wind energy, Beise/Rennings (2005) conclude that price advantages do not seem to be a dominant driver of the international diffusion of innovation in both case studies. Albeit all factors are to some degree relevant, the authors argue that demand advantages and strict regulation are crucial for the development of lead markets. With respect to the importance of lead markets in renewable energy technologies, several authors have analyzed the importance of a strong domestic demand for export performance. Using wind energy technologies as a case study, Wiser/Lewis (2007), Brandt/Svendsen (2006) and Johnson/Jacobsson (2003) agree that a strong home market base is critical for success on international markets. Accordingly, one of the main assumptions of lead market theory is that countries will then be successful in trading certain technologies internationally, if they also use a relatively high share of these technologies domestically. For example, only if Germany produces a substantial amount of its energy from wind, will it be successful in trading wind energy technologies.

For the analysis of renewable energy promotion measures and market development, the following questions will serve as guidelines: Can lead market strategies be found in the three case countries? What are the costs and benefits of those? Which instruments are in place to create such markets? Did lead markets develop without government intervention?

2.5 Summary and Conclusion

This chapter analyzed possible economic reasons for government intervention in renewable energy markets. Analytically, market intervention in domestic renewable energy markets and government export promotion (or import restriction) of renewable energy technologies have been distinguished.

From the theoretical discussion, I conclude that due to the characteristics of renewable energy technologies government promotion of renewable energy sources is justified as a way of correcting negative externalities, balancing information asymmetries and controlling market power. Besides, almost all energy technologies have received government support in their initial states: “Few energy technologies have reached maturity without substantial public sector investment.”[154] Without government support to stimulate technological change, market forces alone would result in less than optimal diffusion of renew-

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[154] United Nations Environment Programme (2002), *Reforming Energy Subsidies*, p. 20.

able sources. The limited expansion of renewable energy technologies would not be sufficient to achieve dynamic learning effects and benefit from scale economies which ultimately lead to reduced prices and enhanced competitiveness compared to conventional technologies. As long as negative externalities of fossil fuel use are not internalized in its prices there is a strong case for government intervention in energy markets. Thus, first-best measures would affect the producers of negative external costs directly (producers of electricity from fossil fuels) by forcing them to internalize these costs in their prices. Second-best measures provide some form of promotion to those producers that create no or little negative external costs to balance the cost-disadvantage compared to producers of negative externalities. The level of promotion thereby depends on the level of externalities.

Still, even if regulation is necessary because of market failure, the right level of involvement and the economic implications of failing to determine the right level are critical. The benefits of increased renewable energy use as such, e.g. for the environment, the labor market, exports and energy security, are not sufficient to justify government intervention in markets. Such intervention only creates efficient results if the benefits are of a public good character, meaning the benefits would not be achieved by markets alone. From the characteristics of public goods that have been discussed earlier in this chapter (non-excludability and non-rivalry) it is obvious that environmental benefits clearly have both of these characteristics. National security can also generally be regarded as a public good.[155] Employment and export creation present less clear cases. Employment opportunities are generally characterized by non-excludability, nobody can be excluded from seeking a new job, but not everybody will get a new job. Thus, there is rivalry in consumption. The case to classify export opportunities as a public good is even less strong, but then economic stability and security which would be enhanced by trading might be considered public goods. To sum up, renewable electricity is not a purely public good. However, the expansion of renewable power creates a range of benefits which have a public good character. Thus, state intervention to provide more electricity from renewable sources is justified by this entire bundle of public benefits.

However, the case is even less evident for government export promotion of renewable energy technologies with the intention to create comparative advantages for domestic industries on international markets. First of all, the main determinants of comparative advantage are still disputed in the literature. Whereas traditional trade models explain comparative advantage with resource endowments and factor proportions, new trade mod-

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[155] A study by Adelphi Consult/Wuppertal Institut found a positive impact of increased renewable energy use on peace and security, Adelphi Consult & Wuppertal Institut (2007), *Die sicherheitspolitische Bedeutung erneuerbarer Energien*.

els focus on imperfect competition, increasing returns to scale, product differentials, and the timing of innovation. Besides the differing views on the determinants of comparative advantage, also the theoretical arguments for government export promotion such as infant industry protection and first-mover advantages are ambiguous. While the need to protect an infant industry is historically the most often raised argument to justify government intervention in international trade, the argument has generally been applied to developing countries and not to developed countries. Most countries, however, that do promote exports of renewable energy technologies today are in fact industrialized countries such as Germany, Japan, the United States or Denmark.

First-mover advantages and the lead market concept might present more convincing cases for government export promotion of renewable energy technologies. Still, even if first-mover advantages, measured in export performance and export market shares, might be gained through such measures, the risk remains that governments will not promote the most competitive domestic industries and thus are responsible for a misallocation of scarce resources.

3 The Context of Renewable Energy Promotion

To put the promotion of renewables into context, this chapter starts with a discussion of the three key drivers of an increased use of renewable energy technologies, showing why it is justified to argue that renewables will continue to gain in importance in the years and decades to come: (a) rising energy demand, (b) the limits of fossil fuels and (c) climate change. The current slump in global economic activity also led to a reduction in global demand and resulted in lower prices for fossil fuels. However, this does not alter the long-term trend of rising energy demand from developing as well as developed countries. It might still slow the transformation of the energy system, since lower fossil fuel prices also reduce the relative price-competitiveness of renewable energy sources.

The ultimate challenge of any government promotion of renewables is to reduce their generation costs in order to make them cost-competitive with conventional technologies and thereby ensuring that necessary initial promotion does not turn into long-lasting financial support. These costs, however, always have to be evaluated relative to the costs of conventional technologies, which in turn are influenced by the degree to which their externals costs are internalized among other factors. As the previous chapter concluded, government intervention in renewable energy markets is justified because renewables have a cost-disadvantage as long as the external costs of fossil fuel and nuclear energy use are not fully internalized in their prices. Section 3.3 presents (a) the current costs of renewables and (b) discusses attempts to quantify the external costs of electricity production. This serves as a basis for the evaluation of promotion instruments.

Besides discussing the context of renewable energy promotion, the aim of this chapter is also to get a better understanding of the functioning of different instruments to promote renewable energy technologies. Section 3.4 thus focuses on a general discussion of the two most important instruments to promote renewable energy use: feed-in tariffs and renewable portfolio standards.

3.1 Key Drivers of Renewable Energy Use

Modern utilization of renewable energy has steeply increased after the oil price shocks[156] in 1973/74 and 1979/80. Some argue that renewable energy will continue to play only a

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[156] The term energy “crisis”, often used in literature, is misleading, since the term “crisis” refers to a sudden lack of supply. Oil price shock is the more appropriate term since global energy supply through the global energy markets was never threatened. The oil producing OPEC countries had strategically decreased their production level which led to skyrocketing oil prices. This was especially effective because the world economy was booming at the time, oil consumption was rising, and the United States

K. Jordan-Korte, *Government Promotion of Renewable Energy Technologies,* DOI 10.1007/978-3-8349-6587-5_3,

small role in the future energy mix and interest in renewable energy might diminish all together with declining fossil fuel prices. It is true that interest in renewable energy subsided in the 1980s and early 1990s with oil prices at very low levels. It needed a sharp rise in oil prices since the turn of the century to increase the awareness of the necessity of alternative energy sources again. But even with fossil fuel prices significantly lower than there were in the spring of 2008, the interest in renewable energy sources stays strong.

I argue that the situation today is remarkably different from the early 1980s when the oil prices plummeted and alongside investment in renewable energy. Three main drivers are responsible for the future development of renewable energy use: global energy demand, the finiteness of fossil fuels and environmental and climate challenges.

3.1.1 Increased Energy Demand

Energy demand will continue to increase globally, both in the developed as well as the developing world. According to the International Energy Agency (IEA) global primary energy demand is projected to increase significantly over the next 25 years, even if the world economy grows at a moderate rate. The IEA estimates that between 2005 and 2030, world energy demand will increase by 55% in a business-as-usual (BAU) scenario, meaning that no dramatic changes in political measures or technologies used occur.[157]

Over 70% of this increase is expected to come from developing countries; most importantly China and India, the "emerging giants of the world economy"[158], which account for nearly half of the expected increase alone. India and China have already experienced steep increases in their energy consumption since the early 1990. China's energy consumption increased on average by 6 percent per year since 1990 and on average by 10 percent since 2000. In India, the energy consumption increased only slightly slower with 4.8 percent annually on average since 1990. China's energy consumption is expected to triple and India's to double until 2030.[159] TPED of the United States is expected to increase by 25% until 2030 compared to 2005 and Japan's TPED will rise by 19.5%.[160] Germany is expected to be a major exception with TPED actually decreasing by 17% until 2030 from 2000 levels.[161]

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oil production peaked in 1971. See for a more detailed discussion Reiche (2002), *Aufstieg, Bedeutungsverlust und Re-Politisierung Erneuerbarer Energien*, p. 35.

[157] The data is taken from the Reference Case of the World Energy Outlook 2007, International Energy Agency (2007), *World Energy Outlook 2007*, p. 42.

[158] International Energy Agency (2007), *World Energy Outlook 2007*, p. 41.

[159] International Energy Agency (2007), *World Energy Outlook 2007*, pp. 117-119.

[160] International Energy Agency (2007), *World Energy Outlook 2007*, pp. 608 and 612.

[161] Prognos AG (2006), *Auswirkungen höherer Ölpreise auf Energieangebot und -nachfrage. Ölpreisvariante der Energiewirtschaftlichen Referenzprognose 2030*, p. X.

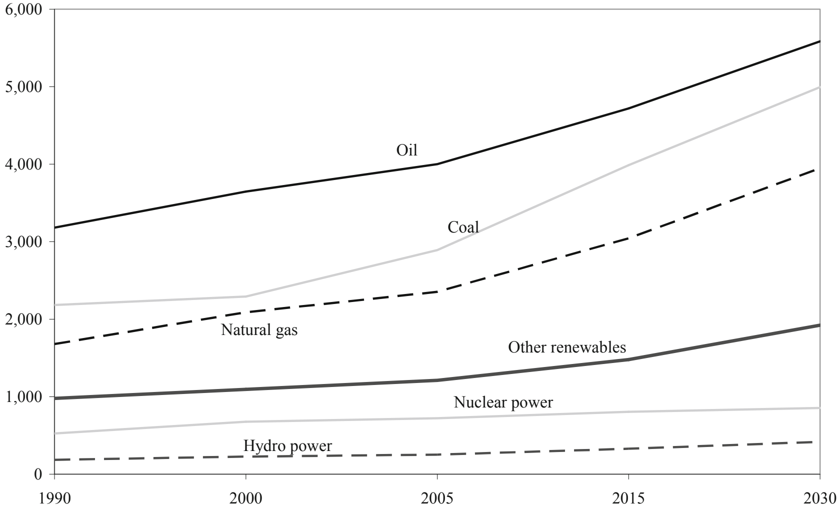

Fig 3-1: World Total Primary Energy Demand, 1990-2030, in Million Tons of Oil Equivalent (Mtoe)
Source: International Energy Agency (2007), World Energy Outlook 2007. Paris, p. 74.

3.1.2 The Limits of Fossil Fuels

Fossil fuels such as oil, natural gas and coal, which today present over 80 percent of global energy consumption, are finite but will continue to dominate the fuel mix for the next decades. The debate about when the world will “run out” of oil is very controversial and has been going on for over thirty years.[162] It is thus very important to differentiate between sound scientific estimates and dramatized reports in the media. Most studies agree on the order with which fossil fuels will cease to be used on a large scale if not on the concrete timing. Global oil reserves will be diminished first, followed by natural gas reserves. Estimates for coal show the greatest recoverable amounts and coal will continue to be used for the next centuries. The rate of consumption of fossil fuels, which is determined by costs, new technologies or new recoveries of fossil fuels, can of course change the amount of remaining years. With enhanced recovery technologies, oil, natural gas and coal fields

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[162] The 1972 report by the Club of Rome warned that the world was running out of natural resources, and started a widespread discussion on the “end of growth”. The study predicted that the world would run out of oil by 2003 and out of gas by 2010, see Meadows (1972), *The Limits to Growth: A Report for the Club of Rome's Project on the Predicament of Mankind*. See for the debate of when global production of oil is goung to peak, Hirsch (2005), *The Inevitable Peaking of World Oil Production*, Williams (2003), *Peak-oil, Global Warming Concerns Opening New Window of Opportunity for Alternative Energy Sources* and Yergin (1993), *The Prize: The Epic Quest for Oil, Money and Power*.

might be more effectively exploited. Moreover, unconventional fossil fuels such as heavy oil, oil sands, and oil shales might increase the remaining fossil reserves considerably. It is clear, however, that the remaining fossil energy reserves are highly concentrated in the so-called strategic ellipse stretching from Russia through the Caspian Sea and Central Asia to the Persian Gulf. 70% of the world's proven oil reserves[163] and almost as much of the natural gas reserves are concentrated in this region.[164] This highly instable region will even increase in importance since many of the massive oil fields in the North Sea as well as in Mexico have reached their peak oil production.[165]

In any case, because of the limits of fossil fuels and increased global energy demand both the demand as well the supply side of energy market will stay strained.

3.1.3 Sustainability and Climate Change

The combustion of fossil fuels, deforestation and agricultural output pose a significant threat to the global climate. Today, there is overwhelming evidence that human activity is largely responsible for the observed increase in worldwide temperature, commonly referred to as global warming. Greenhouse gases[166] are accumulating in the atmosphere of the earth, causing air and ocean temperatures to rise. In its latest report, the Intergovernmental Panel on Climate Change (IPCC) states that since 1974 global CO_2 emissions have increased by 70% and temperatures have increased by about 0.6°C in the last century.[167] Both the concentration of greenhouses gases in the atmosphere and with it human-induced warming are expected to continue through the 21st century with possibly devastating effects. The IPCC predicts a further warming of 0.2°C[168] per decade during the twenty-first century which would result in a great increase of extreme weather events, sea level rise and an extinction of endangered species.[169]

Combustion of fossil fuels is the largest source of CO_2 emissions and accounts for over 80% of all greenhouse gases. According to the IEA, global CO_2 emissions from en-

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[163] Reserves refers to the known deposits that can be exploited profitably with today‘s technology and at today‘s prices.

[164] See British Petroleum (2008), *Statistical Review of World Energy*, Oil Reserves, http://www.bp.com/sectiongenericarticle.do?categoryId=9023769&contentId=7044915 (access date: 07/29/2008).

[165] US Energy Information Administration (2006), *Short-Term Energy Outlook*, p. 2.

[166] The most important greenhouse gases are carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), and tropospheric ozone (O3).

[167] Intergovernmental Panel on Climate Change (2007), *Climate Change 2007: Synthesis Report*, pp. 31 and 36.

[168] This increase is projected for a range of emissions scenarios.

[169] Intergovernmental Panel on Climate Change (2007), *Climate Change 2007: Synthesis Report*, p. 45.

ergy use will increase by 62% between 2002 and 2030[170] in a BAU scenario (see Fig 3-1), with far-reaching effects on all aspects of human life. Given (a) the amount of energy required to sustain the world economy over the next decades, (b) the dominant role fossil fuels are expected to continue to play, and (c) the resulting CO_2 emissions, any solution to reduce greenhouse gas emissions and ultimately stabilize their concentrations require fundamental changes in the way the world produces and uses energy.

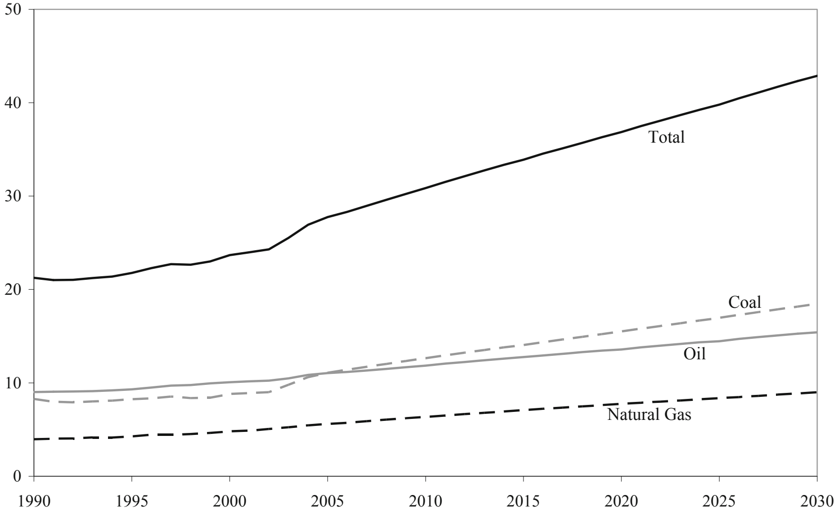

Fig 3-2: World Carbon Dioxide Emissions by Fuel Type, 1990-2030, in billion metric tons
Source: Energy Information Administration, International Energy Outlook 2007. Washington, DC, p. 73.

In the past years, more and more political and economic leaders worldwide seem to share this view. A survey of the world leaders at the World Economic Forum 2007 in Davos displayed a doubling of those who regard climate change concern as a priority for world leaders compared to 2006.[171] The change in perception of climate change was especially strong after the publication of the Stern Review report on the economics of climate change in 2006. The Stern report estimates that if there are no far-reaching attempts to reduce greenhouses gases in the atmosphere, the overall costs of climate change will be equivalent to at least 5% of global GDP each year from now on. In contrast, the costs of

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[170] The IPCC expects an increase of 40 to 110% of CO2 emissions from energy use in the same period with current climate change mitigation policies and related sustainable development practices, see Intergovernmental Panel on Climate Change (2007), *Climate Change 2007: Synthesis Report*, p. 44.

[171] Ernesto Zedillo, Speech at Yale University at the conference on the Stern Report on the Economics of Climate Change, February 15, 2007. See also the website of the World Economic Forum, http://www.weforum.org.

action to avoid the negative impacts of climate change are estimated to be about 1% of global GDP per year.[172]

Nevertheless, for the stated three reasons - increased energy demand, the limits of fossil fuels and climate change - it is safe to argue that renewable energy will increase its importance in the coming decades. Renewable energy sources will not supersede fossil fuels in the near future, but they will play a rapidly growing and increasingly important role in meeting global energy demand in the years to come.

There are large potentials for increased use of all major sources of renewable energy electricity generation in the future. Theoretically, future electricity demand could be met by renewables sources alone by 2050.[173] Theoretically, the radiant energy on only 1.5% of global land surface would theoretically be sufficient to serve total energy needs worldwide.[174] The harvesting of this enormous potential is still far from reality, however, both because of technological as well as economical limitations.

3.2 Three Main Policy Objectives of Renewable Energy Policy

Renewable energy policy is influenced by many different factors and is shaped by different traditions and cultures. However, three main objectives of renewable energy policy can be identified from the three major driving forces of renewable energy use: a) energy security, b) sustainability/environmental protection and c) economic development.

Energy security: Most countries and certainly the three case countries are concerned by their dependence on foreign fossil fuels. They strive to reduce this dependency and to diversify their energy supply.

Sustainability/environmental protection: A second objective of renewable energy policy is to reduce greenhouse gases and other environmental pollution through energy use.

Economic Development: One more objective of renewable energy policy is to enhance economic development, job creation, and to improve export potential and competitiveness.

Thus, renewable energy policy goals are shaped by this so called magical triangle[175] of policy objectives. The triangle of policy objectives helps to build a framework to analyze and to compare renewable energy policy. While all countries aim to achieve these three goals, the emphasis varies among them. The empirical analysis of the three coun-

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[172] Stern (2006), *The Economics of Climate Change: The Stern Review*.

[173] Vries/Vuuren/Hoogwijk (2007), *Renewable Energy Sources: Their Global Potential for the First-Half of the 21st Century at a Global Level: An Integrated Approach*.

[174] Erdmann (1995), *Energieökonomik: Theorie und Anwendungen*, p. 100.

[175] Erdmann/Zweifel (2007), *Energieökonomik: Theorie und Anwendungen*, p. 10.

tries' approaches reveals which objectives are given higher priority in the respective strategies.

Moreover, the policy objectives are not necessarily compatible and therefore countries will have to decide which goal should be pursued with more force and vigor. While gains in energy efficiency help to both lessen the environmental impact of energy use and to increase energy security because of reduced energy needs, strict climate change targets are useful in mitigating the effects of climate change but might hinder economic development due to higher production costs of the domestic industry. It is also an open question if the policies a country chooses to pursue these objectives vary according to the different emphasis given to them.

3.3 Generation Costs of Renewable Energy and External Costs of Electricity Generation

The cost of generating electricity from renewable sources has been and to some degree still is one of the major obstacles to renewable energy growth.[176]

However, today several renewable energy technologies are – under favorable conditions - already cost-competitive with conventional energy sources. These are most notably wind power and hydro power, which - under optimal conditions – cost between 3-10 US cents/kWh and 2-10 US cents/kWh respectively (see Table 3-1). This implies that electricity from hydro and wind is roughly comparable in cost to electricity from coal, natural gas, and nuclear energy, and exhibits lower cost than electricity from oil. Other renewable energy sources are still far away from being cost-competitive. The cost of solar photovoltaic generation currently remains significantly higher than the cost of electricity generation from any other renewable sources.

Nevertheless, the costs for all renewable energy sources have been reduced impressively over the past decades and the costs of most of the newer technologies are expected to continue to fall. Costs for solar and wind power generation have been cut by half in the past 10–15 years.[177] For the long term and under favorable conditions, the lowest cost to produce renewable electricity might be 1–2 US cents a kilowatt-hour for geothermal, 3 US cents a kilowatt-hour for wind and hydro, 4 US cents a kilowatt-hour for solar thermal and biomass, and 5-6 US cents a kilowatt-hour for photovoltaic.[178] In contrast to fossil fuel

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[176] See Jensen (2004), *Promoting Renewable Energy Technologies*, p. 74. In 2002, Taylor still argued that costs are "the main disadvantage of renewable energy", Taylor/Doren (2002), *Evaluating the Case for Renewable Energy. Is Government Support Warranted?*, p. 6.

[177] REN21 (2005), *Renewables 2005. Global Status Report*, p. 5.

[178] United Nations Development Programme (2000), *World Energy Assessment. Energy and the Challenge of Sustainability*, p. 220. See also Krewitt/Schlomann (2006), *Externe Kosten der Stromerzeugung aus Erneuerbaren Energien im Vergleich zur Stromerzeugung aus fossilen Energieträgern* and Wen-

technologies, the generation costs of renewable technologies are very site-specific, which makes a comparison difficult. The numbers presented here are all average prices. Nevertheless, the trend of reduced generation costs becomes clear in Table 3-1. In the short term, however, generation costs for some renewable technologies could also increase: especially the construction of new wind power plants is currently slowed down, because there are bottlenecks in the delivery of certain parts of wind turbines due to high global demand, which result in rising prices.

Tab 3-1: Electricity generation costs (US cents/kWh)

	Current Cost	Projected costs beyond 2020
Biomass	5-15	4-10
Wind Power		
Onshore	3-5	2-3
Offshore	6-10	2-5
Solar		
Photovoltaic	20-40	5-6
Thermal Power	12-18	4-10
Hydroelectric Power		
Large Scale	2-8	2-8
Small Scale	4-10	3-10
Geothermal Energy		
Electricity	2-10	1-8
Marine Power		
Tidal	8-15	8-15
Wave Energy	8-20	5-7
Natural Gas	3.7-6	n.a
Coal	2.5-5	n.a
Nuclear	2.1-3.1	n.a
Oil	8.1	n.a

Source: Own compilation. The data for natural gas, coal, nuclear and oil are taken from International Energy Agency (2005), *Projected Costs of Generating Electricity*, pp. 12, 13 and 72. The data for renewables are taken from REN21 (2007), *Renewables 2007. Global Status Report*, p.14 and REN21 (2007), Costs of Renewable Energy Compared with Fossil Fuels and Nuclear Power.

3.3.1 Factors Relevant for Decrease in Generation Costs

Which factors have been most important in the reduction of renewable energy generation costs? As Sandén (2005) and others argue, mostly two factors led to the reduction in generation costs: (a) steep experience curves and (b) economies of scale.

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zel/Staiß/Nitsch et al. (2006), *Stromerzeugung aus Erneuerbaren Energien: Ausbau und Kostenentwicklung bis 2020* for two more recent articles on the costs of renewables.

Experience curves, which depict an inverse relationship between cost and the cumulative production of a technology, have been used frequently to explain declining renewable energy generation costs.[179] Increased experience or learning leads to more efficient production processes, e.g. through technology improvements. Economies of scale present the other essential factor resulting in declining generation costs per renewable energy unit produced. With increasing production through increased market penetration, costs per unit have been reduced.

Isoard/Soria (2001) model the contributions of the effects of learning curves and economies of scale in the capital cost reduction pattern of renewables. They analyze manufacturers' annual cost and installed capacity data for solar photovoltaic and wind power, two technologies for which capital costs represent on average 90 percent of the cost of electricity produced. For PV and wind, they find that learning effects are a more important driving force for generating cost reduction than economies of scale, which are also important nonetheless.

Sandén (2005) confirms these findings. Sandén models the amount of PV systems needed to produce a target price, meaning to become economically competitive with conventional electricity. He assumes a progress ratio of 0.80, which means that costs for PV electricity decrease by 20% for each doubling of cumulative production, which has been empirically confirmed.[180] The author finds that due to learning effects a cumulative production of 382 gigawatt (GW) is needed to reach the target cost. This also implies, though, that if the annual growth rate of PV production is only 15% it would take 40 years to reach competitiveness under the stated assumptions.

Apart form the specific reasons for the reduction of generation costs of renewables, these costs must always be seen relative to the costs of conventional fuels. How lucrative renewable energy will be, largely depends on the development of world prices for fossil fuels. PV could become economically competitive significantly earlier, if fossil fuel prices continue to rise, due for example to regional or global prices on carbon dioxide emissions. More importantly, the comparative cost structure of renewable energy also largely de-

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[179] Recent publications using experience curves to analyze the cost reduction and costs potential of renewable energy include International Energy Agency (2000), *Experience Curves for Energy Technology Policy*, Junginger/Turkenburg/Faaij (2003), *Global Experience Curves for Wind Farms*, Neij (1997), *Use of Experience Curves to Analyse the Prospects for Diffusion and Adoption of Renewable Energy Technology*, Kamp (2004), *Notions on Learning Applied to Wind Turbine Development in the Netherlands and Denmark* and Kobos/Erickson/Drennen (2006), *Technological Learning and Renewable Energy Costs: Implications for US Renewable Energy Policy*. See also Arrow (1962), *The Economic Implications of Learning by Doing* and Dasgupta/Stiglitz (1988), *Learning-By-Doing, Market Structure and Industrial and Trade Policies* for a general discussion on learning by doing.

[180] See Parente/Goldemberg/Zilles (2002), *Comments on Experience Curves for PV Modules*, quoted after Sandén (2005), *The Economic and Institutional Rationale of PV Subsidies*, p. 140.

pends on the degree to which the negative externalities resulting from fossil fuels use will be better reflected in their prices in the future.

3.3.2 Quantifying External Costs of Electricity Production

In the past years, several attempts have been made to get a better understanding of external costs in electricity production.[181] The German Fraunhofer Institute for Systems and Innovation Research together with the Institute of Technical Thermodynamics in Stuttgart developed a model to evaluate external costs of electricity production from different energy sources.[182] This study quantified environmental external costs from climate change and health costs from air pollution, but excluded all other possible external costs such as national and economic security costs in their analysis.

The study is based on a benchmark of € 70 per ton CO_2, which is far above the price level for a ton of CO_2 at the European Energy Exchange (EEX).[183] Accordingly, the interpretation of the study's finding has to take these high carbon prices into account, which naturally increase the external costs for electricity production from fossil fuels.

Still, Fig 3-3 clearly shows that the external costs of renewable energy sources in electricity production are considerably lower than those from conventional plants.[184] The numbers presented here are based on a life cycle approach which includes all steps from the build up of the power plant to its dismantling.[185] The external costs of renewable electricity production are all below 1 € cent per kWh (with the exception of current photovoltaic technology). Electricity from coal produces the highest external costs with 5.7 to 7.9 € cent per kWh and modern natural gas plants still create 2.9 € cent per kWh of external costs.

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[181] Those studies that exist mostly refer to the European electricity market. There is no recent comprehensive assessment of external costs of electricity use for the US market, see Menz (2005), *Green Electricity Policies in the United States: Case Study*), p. 2408. Since external costs can be very site-specific the externalities for the European and US electricity market could be different.

[182] Krewitt/Schlomann (2006), *Externe Kosten der Stromerzeugung aus Erneuerbaren Energien im Vergleich zur Stromerzeugung aus fossilen Energieträgern*.

[183] Since the beginning of the first trading period of the European Emission Trading System (EETS) in 2005, the price per ton CO2 varied greatly, but plummeted in 2006 after it became known that too many emission rights had been handed out. The second trading period started in 2008 and allocated emission rights were reduced to ensure higher price levels. In August 2008 one ton CO2 was traded for approximately 20 €. See for more market data the website of the European Energy Exchange at www.exx.com.

[184] The burning of biomass is rated as CO2-neutral because the amount emitted by combustion of the biomass is balanced by the amount of CO2 sequestered by production of biomass. However, large hydro power plants can lead to the flooding of large areas and the resulting decay of plants in the flooded areas produce greenhouse gases.

[185] Owen (2004), *Environmental Externalities, Market Distortions and the Economics of Renewable Energy Technologies*, p. 131.

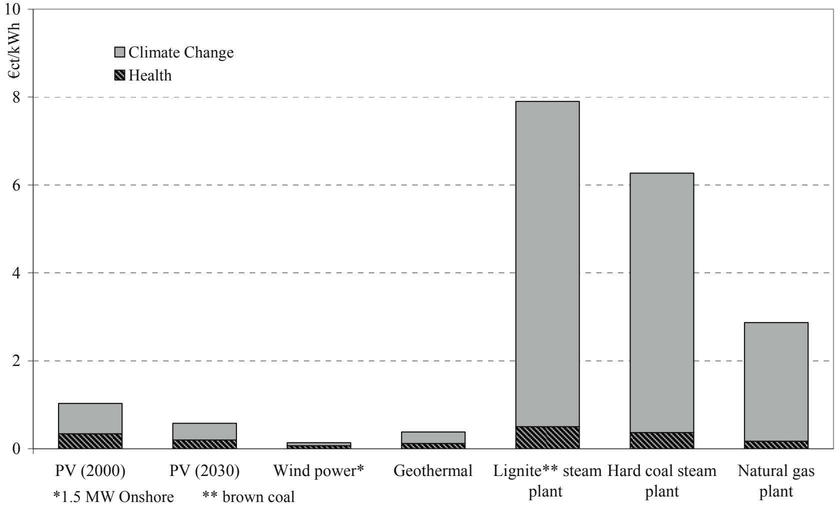

Fig 3-3: External costs of electricity production (€ct/kWh)
Source: Krewitt/Schlomann (2006), Externe Kosten der Stromerzeugung aus Erneuerbaren Energien im Vergleich zur Stromerzeugung aus fossilen Energieträgern, p. 2.

The European Commission finances another project to get a deeper understanding of external costs created by the electricity and the transport sector. The “ExternE project” considers three main categories in their analysis of external costs; (1) effects on human health, (2) on agriculture and buildings and (3) damages caused by global climate change. Major findings of the study include that the effects are very site-specific and differ across European countries. In general, the level of uncertainty for effects of global warming is much higher than for the other two categories. In the estimates of the ExternE project CO_2 emissions are valued in the range of € 18-40 per ton of C02 and thus much lower than in the Fraunhofer Institute project. Estimates of external costs of electricity production for Germany range from 3-6 € cent per kWh for modern coal power plants, to 1-2 € cent per kWh for natural gas plants, 0.6 ct/kWh for PV plants and 0.05 ct/kWh for wind power plants (see Table 3-2). The estimated external costs numbers for PV and wind power plants are roughly equal to those in the Fraunhofer Institute project, the numbers for natural gas and coal plants are slightly lower. This is not surprising given that the ExternE project assumes significantly lower carbon dioxide prices.

Tab 3-2: External cost estimates for electricity production in Germany for existing technologies (in € cent per kWh)

Technology	PV	Wind	Biomass	Coal and Lignite	Gas	Oil
€ cent per kWh	0.6	0.05	3	3-6	1-2	5-8

Source: European Commission (2003), External Costs: Research Results on Socio-Environmental Damages Due to Electricity and Transport, p. 13.

Since inefficient market outcomes due to external costs of fossil fuel production are one of the mains reason to justify government intervention in energy markets and the promotion of renewable energy, quantifying external costs of energy use is an important prerequisite for any policy measures aiming at creating efficient energy markets where the total costs of all technologies used to produce energy are reflected in their prices. The two studies presented show that prices for fossil fuels do not reflect their total costs yet and it remains to be seen if the policy measures used to promote renewables in Germany, Japan and the United States address this problem.

3.4 Renewable Energy Policy Instruments

Many industrialized countries started intensive research programs in the early 1970s to develop renewable energy sources. In the first phase of the development of renewable energy technologies, R&D was the first and almost sole mechanism to promote renewables. The next group of policy measures included investment incentives, tax measures and incentive tariffs. Since the late 1980s, an increasing number of countries started to implement obligatory measures such as quota systems, tender systems and feed-in tariffs to promote renewable energy technologies. Today, at least 60 countries worldwide implemented some form of renewable energy promotion and most of these (approx. 55) countries also use obligatory measures to promote renewables. By 2007, at least 37 countries and 9 states or provinces had implemented feed-in tariffs (price policies) and at least 18 countries and 26 states or provinces had enacted renewable portfolio standards (quota policies).[186]

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[186] REN21 (2007), *Renewables 2007. Global Status Report*, p. 9. See also the Global Renewable Energy Policies and Measures database of the International Energy Agency at http://www.iea.org /textbase/pm/grindex.aspx (access date: 08/05/2008). The database contains information for more than 100 countries and categorizes renewable energy policy instruments according to 9 main categories.

Since the late 1990s, the theoretical discussion of instruments to promote renewable energy use and to increase market penetration has accelerated.[187] The debate draws from the on-going but older debate of environmental policy instruments.[188] It centers on the analysis of price and quantity regulation as the two prototypes of governmental promotion.[189] For the purpose of this study, instruments are understood in a very wide sense referring to all measures which are effective in removing barriers to the deployment of renewables in the electricity sector. Renewable energy policies instruments can be grouped into three main categories:[190]

- Financial incentives (tax exemption, below market interest rates)
- Mandatory instruments (price-based, quantity-based, tendering system)
- Accompanying measures (voluntary agreements, information and educational measures, R&D measures)

The two most wide-spread mandatory promotion instruments are feed-in tariffs and renewable portfolio standards. These are therefore described in more detail in the following

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[187] See among many Mez/Piening (2000), *Ansätze und Erfahrungen mit Mengensteuerungssystemen in der Energie- und Umweltpolitik in den USA, den Niederlanden, Dänemark und Großbritannien*, Ackermann/Andersson/Söder (2001), *Overview of Government and Market Driven Programs for the Promotion of Renewable Power Generation*, Berry/Jaccard (2001), *The Renewable Portfolio Standard: Design Considerations and an Implementation Survey*, Espey (2001), *Renewables Portfolio Standard: A Means for Trade with Electricity from Renewable Energy Sources?*, Bräuer (2002), *Ordnungs-politischer Vergleich von Instrumenten zur Förderung Erneuerbarer Energien im Deutschen Stromsektor*, Finon/Menanteau/Lamy (2003), *Prices Versus Quantities: Choosing Policies for Promoting the Development of Renewable Energy*, Finon/Menanteau (2003), *The Static and Dynamic Efficiency of Instruments of Promotion of Renewables*, Langniss (2003), *Governance Structures for Promoting Renewable Energy Sources*, Nielsen/Jeppesen (2003), *Tradable Green Certificates in Selected European Countries. Overview and Assessment*, Neuhoff (2005), *Large-Scale Deployment of Renewables for Electricity Generation*, Agnolucci (2006), *Use of Economic Instruments in the German Renewable Electricity Policy*, Agnolucci (2008), *Factors Influencing the Likelihood of Regulatory Changes in Renewable Electricity Policies*.

[188] See Weitzman (1974), *Prices vs. Quantities* for the classical debate of price-based and quantity-based environmental policy instruments. For more publications that analyze environmental policy instruments see Frey/Oberholzer-Gee (1996), *Zum Konflikt zwischen intrinsischer Motivation und umweltpolitischer Instrumentenwahl*, Häder (1997), *Umweltpolitische Instrumente und neue Institutionenökonomik*, Lange (2001), *Umweltpolitische Entscheidungen unter Unsicherheit und bei Restriktionen in der Instrumentenwahl. Eine umweltökonomische Analyse*, Field/Field (2002), *Environmental Economics. An Introduction*, Mez/Piening (2000), *Ansätze und Erfahrungen mit Mengensteuerungssystemen in der Energie- und Umweltpolitik in den USA, den Niederlanden, Dänemark und Großbritannien* and European Environment Agency (2006), *Using the Market for Cost-Effective Environmental Policy: Market-Based Instruments in Europe*.

[189] A very insightful discussion of quantity versus price regulation in renewable energy policy offer Finon/Menanteau (2003), *The Static and Dynamic Efficiency of Instruments of Promotion of Renewables*.

[190] Some authors categorize renewable energy instruments based on the direction of support, such as policies aimed at the demand-side, the supply-side, generation or capacity building, see International Energy Agency (2004), *Renewable Energy: Market and Policy Trends in IEA Countries*, p. 85, Sellers (2005), *Renewable Energy Markets: Past and Future Trends*, p. 4 and Haas/Huber/Langniss et al. (2004), *How to Promote Renewable Energy Systems Successfully and Effectively*, p. 834.

section.[191] Both these instruments are geared towards the supply side (producers) of renewable power. Feed-in tariffs are price-driven instruments, which implies that the price is set (by the government) and the quantity is decided by the market, whereas quota system are capacity-driven measures since the quantity is set and the price is decided by the market. Most studies analyzing renewable energy instruments focus on two questions; either which measures serve better to increase the market deployment of renewables or how much competition is induced by different promotional measures. This analysis intends to also highlight a third question by asking how the two different promotion types affect the development of renewable energy generation costs.[192] The development of generation costs can be used as an indicator for the level of innovation that is induced by the different promotion types.[193] The impact of promotion schemes on generation costs and innovation is of critical importance since only cost-competitiveness of renewable energy sources ensures that government promotion will be limited in its duration.

3.4.1 Price-Based Systems

Feed-in tariffs are the main form of price regulation. They are characterized by a legally set minimum price and the obligation of grid operators or utilities to purchase renewable power at this price for a specified period of time. The government authorities determine the price per kWh that the utilities have to pay for renewable power generation fed into the local grid system. The utilities are obliged to purchase all renewable power produced from renewable energy power plants at the given price. The utilities accordingly can neither decide on the price nor on the quantity of renewable power that they have to purchase. Thus, with feed-in tariffs the price is set ex-ante and the amount of renewable energy power produced is decided by the market.

As the feed-in tariff is higher than the average electricity price on the market, the instrument has the same effect as a subsidy for renewable electricity producers even if the subsidy is not paid for by the government but by grid operators and utilities. Ultimately,

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[191] Tender or bidding systems have also been a widely discussed instrument, see Langniss (2003), *Governance Structures for Promoting Renewable Energy Sources*, p. 56. Tender systems had been used mostly in the UK, but lost in importance with the phasing-out of the UK tender system in 1998. Under the tender system, a central agent puts certain quantities of renewable energy electricity out to tender from time to time. Renewable electricity producers compete in individual bidding rounds to cover a previously determined quantity contingent. The winning bidders then receive a fixed-term purchase guarantee for the electricity they generate.

[192] Finon/Menanteau/Lamy (2003), *Prices Versus Quantities: Choosing Policies for Promoting the Development of Renewable Energy*, p. 800 and Langniss (2003), *Governance Structures for Promoting Renewable Energy Sources*, pp. 64-71 highlight the difference between static efficiency which aims to minimise overall cost expenditures and dynamic efficiency which refers to permanent incentives to cost reductions through technological progress.

[193] See Haas/Meyer/Held et al. (2008), *Promoting Electricity from Renewable Energy Sources - Lessons Learned from the EU, United States, and Japan*, p. 464 who also use the development of renewable energy generation costs as an indicator for innovation.

all electricity consumers pay for the subsidy since grid operators and utilities will pass on the additional costs. In a system with feed-in tariffs, the amount q of renewable energy power produced will generally be determined by the point where the marginal cost of producing renewable energy power equals the politically fixed feed-in tariff p (Fig 3-4). The grey shaded area shows the producers' rent.

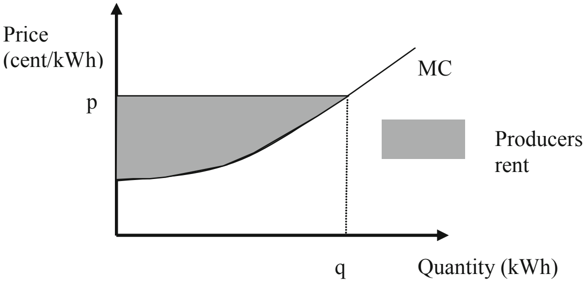

Fig 3-4: Price-based system
Source: After Finon/Menanteau/Lamy (2003), Prices Versus Quantities: Choosing Policies for Promoting the Development of Renewable Energy, p. 802.

Feed-in tariffs thus give an incentive to increase renewable power production as long as the marginal costs are lower or equal to the fixed feed-in tariff. Moreover, since all renewable power produced will have to be bought by the utilities, renewable energy generators face little risk and are provided with great long-term planning security. This secures the income of producers for the time the tariff is guaranteed and consequently reduces entrepreneurial risk.[194]For the deployment of renewable energy these factors result in fast market uptake.

However, feed-in tariffs are often criticized for not providing sufficient incentives for reduced generation costs. These studies claim that while feed-in tariffs are relatively successful in market deployment, they fail to create a dynamic reduction of generation costs.[195] The lack of efficiency is generally subscribed to two factors:

a) *Information asymmetry*: the tariffs are set by a regulatory authority. The authority, however, generally lacks sufficient information in terms of the production costs and their development for different technologies. Therefore it is unlikely that tariffs are actually set at efficient prices. Other authors also emphasize that it is politically difficult to lower tar-

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[194] Compare Ackermann/Andersson/Söder (2001), *Overview of Government and Market Driven Programs for the Promotion of Renewable Power Generation*, p. 199 and Reiche/Bechberger (2004), *Policy Differences in the Promotion of Renewable Energies in the EU Member States*, p. 843.

[195] European Commission (1999), *Electricity from Renewable Energy Sources and the Internal Electricity Market*, p. 18.

iffs once they are set as existing producers have strong incentives to keep their level of support.[196]

b) Lack of competition: with feed-in tariffs renewable energy generators do not compete for prices, since all renewable energy produced can be sold to the market.[197] Some authors claim that this decreases price competition both between renewable energy generators and between non-renewable and renewable electricity generators. The incentives for innovation, it is argued, is thus lower than with RPS where the minimal amount of renewable energy that has to be fed into be grid is politically determined but prices are set by the market.

However, it can be assumed that renewable energy producers aim to maximize profits. Then there certainly is an incentive in price-based systems to reduce marginal costs in order to increase the rent. As Fig 3-5 shows the producers rent will increase according to their ability to decrease marginal costs, e.g. through technological innovations. If marginal costs can be reduced from MC_1 to MC_2 then producers can generate an additional rent illustrated by the dark grey shaded area. Fig 3-5 also shows that the reduction of production cost in price-based systems leads ceteris paribus to a larger quantity at equilibrium at a given price.

Furthermore, Butler/Neuhoff (2008) show that the high degree of competition among renewable energy manufactures results in a sustainable decrease of generation costs even though there is no direct price competition between renewable energy generators.[198] Lastly, fast market deployment that typically occurs in price-based systems also affects the development of generation costs. An increase in market deployment generally leads to reduced generation costs due to experience curves and economies of scale (compare section 3.3.1). Thus, even though there is no direct price competition, the intention of renewable energy power producers to maximize profits and the rapid market deployment with resulting learning effects and economies of scale leads to a reduction of renewable energy generation costs and creates incentives for innovation.

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[196] Espey (2001), *Renewables Portfolio Standard: A Means for Trade with Electricity from Renewable Energy Sources?*, p. 557.

[197] Finon/Menanteau/Lamy (2003), *Prices Versus Quantities: Choosing Policies for Promoting the Development of Renewable Energy*, p. 807.

[198] The findings are based on a study of the wind energy industry in Germany and the UK, see Butler/Neuhoff (2008), *Comparison of Feed-in Tariff, Quota and Auction Mechanisms to Support Wind Power Development*.

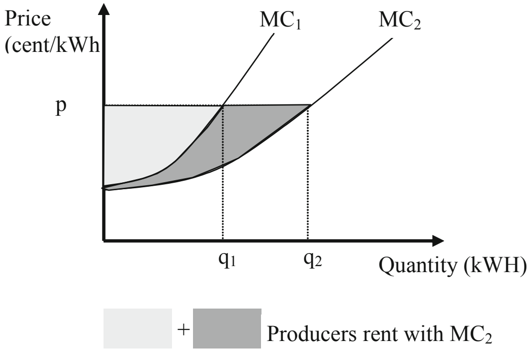

Fig 3-5: Price-based system, reduction of marginal costs
Source: Further developed from Finon/Menanteau/Lamy (2003), Prices Versus Quantities: Choosing Policies for Promoting the Development of Renewable Energy, p. 802.

3.4.2 Quantity-Based Systems and Tradable Certificates

Quota systems are the second most important type of instruments used to promote renewable energy. Renewable portfolio standards (RPS) are the most common form of a quota system.

In a quota system, the utilities are obliged to sell a fixed quota of electricity produced from renewable energies over a specified time period to the market. The electric utilities have the option of producing the fixed amount of electricity themselves or buying it from a renewable energy generator. Most often, renewable portfolio standards also allow utilities to purchase certificates from other generators with renewable energy capacity.[199] Such tradable renewable certificates are issued by renewable electricity generators either by selling kWh to the electricity grid at the market price, or by selling certificates to other utilities.[200] If utilities opt to fulfill their obliged quota by buying part or all the renewable energy from other suppliers, they have the freedom to purchase the renewable energy (or certificates) for the cheapest price on offer on the market. Thus, with quantity regulation the quantity of renewable energy that has to be generated is politically fixed whereas the price of renewable energy power produced is decided by the market.

The generation costs for renewable power are very site-specific depending on geographical conditions, the sophistication of technologies used and of course different forms

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[199] For on overview of renewable portfolio standards see Espey (2001), *Renewables Portfolio Standard: A Means for Trade with Electricity from Renewable Energy Sources?* and Berry/Jaccard (2001), *The Renewable Portfolio Standard: Design Considerations and an Implementation Survey*.

[200] See Bertoldi/Huld (2006), *Tradable Certificates for Renewable Electricity and Energy Savings* for a discussion of tradable certificates in EU member countries.

of renewable energy. Therefore, producers of renewable energy have different marginal cost curves. The trading of renewable energy (green) certificates balances the different marginal cost curves by enabling producers with lower marginal costs to produce more than their quota and selling the surplus via certificates on the market. Producers with higher marginal costs produce less than obliged and buy the additional capacity through green certificates. Accordingly, in a quantity-based system that is linked to tradable certificates two markets are created: one market where the physical renewable power is traded and a second market where only the attribute of renewable power is traded in the form of green certificates.

The inclusion of tradable certificates enables quotas to be reached in an efficient way. Without tradable certificates different marginal cost curves could only be balanced by assigning different obligations to different producers. It is highly unlikely, however, that the government entity responsible for the assignment would have the necessary information to set the appropriate obligation level to equalize marginal costs among more and less competitive producers of renewable energy power. Thus, under information on the price of renewable energy power at equilibrium, only the flexibility created by trading green certificates creates efficient outcomes by balancing different marginal cost curves. If one obliged party can produce renewable energy at relatively low generation costs because of favorable conditions, this producers is encouraged to produce beyond his quota and sell the surplus to other obliged parties.

How does a quantity-based system affect market deployment and the development of generation costs? Under a renewable portfolio standard, there is no incentive to produce more than the politically fixed amount in quantity-based systems. This limits dynamic market deployment. Moreover, RPS often result in a concentration of few areas that are used for renewable energy generation. Only the most profitable sites with the most cost-efficient technology will be used, because generators compete for prices. This further hinders rapid market deployment. Finally, the least-cost criterion results in market barriers for small generators that have higher generation costs than large renewable power plants.

With regard to the reduction of generation costs, quantity-based systems such as renewable portfolio standards create price competition among renewable energy producers, since the price is determined by the market while the quantity is fixed. Thus, only those producers with competitive prices are able to sell their output.

How large is the incentive in this system, however, to reduce prices, e.g. through technological innovation? If renewable energy generators reduce their marginal costs and pass on this reduction in their prices, the quantity that these producers can sell on the market increases but at a lower price. This means that the surplus for these producers from reduced generation costs is limited. By contrast, if renewable energy producers reduce generation costs under a feed-in tariff, they can still realize the same (fixed) price. Thus, reduced marginal production costs increase the producers' rent since the entire surplus goes to the generator.

3.5 Summary

The risks posed by climate change, dwindling fossil fuel reserves and increasing energy demand are reinforcing the need for a greater share of renewables in the world's energy mix. The cost structure of renewable energy generation continues to ease a path towards a higher share of renewables in electricity production. Learning and scale effects will make renewable electricity increasingly competitive with conventional fuels. So far, renewable energy sources are still dependent on governmental support. The study of instruments to promote renewables is thus of central importance. Two different forms of regulation have mainly developed: quantity- and price-based models.

The theoretical discussion of these two archetypes of renewable energy promotion revealed that with regard to the

Capacity to induce additional generation: feed-in tariffs are more effective in triggering new renewable energy capacity since producers are able to sell all quantity produced and planning security is high. Renewable portfolio standards are less effective since there is less planning security and no incentives to produces above the obliged quota.

Capacity to reduce generation costs: feed-in tariffs give incentives to reduce generation costs (surplus of lower costs goes to producers), but do not create direct competition between generators. Under RPS the surplus of reduced generation costs is limited, but RPS induce direct price competition between generators.[201]

However, the effect of different instruments generally depends on their specific design. The analysis so far does not allow judgment on which instrument creates more incentives to reduce costs and introduce more innovative production processes. Thus, as Dinica (2006) argues, the comparison of instruments on a theoretical level is not sufficient, since the policy design is crucial to the effectiveness and efficiency of the instruments.[202] The analysis of specific renewable energy promotion measures is needed in light of these theoretical findings in the next chapter.

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[201] Espey argues that the most important advantages of Renewable portfolio standards are a high degree of competition among generators or developers of renewable energy technology and more freedom of choice concerning the options for meeting the requirements, see Espey (2001), *Renewables Portfolio Standard: A Means for Trade with Electricity from Renewable Energy Sources?*.

[202] Dinica (2006), *Support Systems for the Diffusion of Renewable Energy Technologies*, p. 461.

4 National Markets and Promotion Policies for Renewable Energy Sources

This chapter presents and analyzes government promotion of renewable energy technologies in Germany, Japan and the United States in the electricity sector. A whole range of instruments has been introduced to expand the use of renewable energy technologies in the past decades. Today however, two distinctively different designs prevail as the dominant instruments used: price-based systems and quantity-based systems. These instruments and their mechanisms have been illustrated in the previous chapter.

The aim of this chapter is to get a better understanding of specific instruments used in Germany, the United States and Japan aimed at increasing renewable energy generation domestically.

In order to evaluate the renewable energy promotion policies this chapter:

- discusses and analyzes renewable energy promotion policies in Germany, the United States and Japan,
- traces the development on national renewable energy markets carefully in order to determine which of the case countries have been more or less successful in stirring renewable energy development domestically and
- analyzes the capacity to induce technological innovation by looking at the development of generation costs.

This analysis provides useful insights as to how successful the policies are in the respective fields. It is impossible, however, to attribute the policy outcome to one single policy or factor or to isolate the effects of one policy instrument since they affect one another. A renewable energy strategy as a whole is responsible for policy effects. Thus, while it will not be possible to "prove" the success or the superiority of any instrument, the analysis provides strong arguments for an evaluation.

4.1 Renewable Energy Policy Instruments in Germany

The federal German government is responsible for the drafting, financing and implementing the main policy tools for the promotion of renewable energies in Germany. In addition to federal programs for renewable energy promotion, most of the Länder (states) and also some local governments have independent support schemes for renewable energies.[203] Renewable energy policy in Germany is also influenced by the European level, especially in terms of renewable energy targets, but energy policy generally remains the jurisdiction

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[203] Agnolucci (2006), *Use of Economic Instruments in the German Renewable Electricity Policy*, p. 3538.

K. Jordan-Korte, *Government Promotion of Renewable Energy Technologies,* DOI 10.1007/978-3-8349-6587-5_4,

of the EU member countries. On the federal level in Germany, the jurisdiction over energy policy is divided between the Ministry of Economics and Technology (BMWi) and the Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). While the BMWi is responsible for energy policy in general, the BMU is in charge of renewable energy sources and any environmental regulations that affect the energy sector. The responsibility for renewables was only assigned in 2002 to the BMU from the BMWi.[204]

This section focuses on policies at the federal level since the federal German government has been the main driver for the deployment of renewable energy technologies. Again, only policies relevant for the electricity sector are examined.[205] Renewable energy policy measures were first introduced after the first oil price hike 1973/74. For the first two decades renewables were promoted through some limited spending on Research and Development (R&D). The first main market creation measure was introduced in 1991 with the federal Electricity Feed-In Law (EFL).[206]

Today, the German government[207] applies different policy instruments for the promotion of renewable energy technologies in the electricity sector.[208]

Main elements of this policy are:

- The Renewable Energy Sources Act of 2000, its 2004 revision and its 2008 amendment,
- Preferential loans through the Credit Institute for Reconstruction (KfW) and
- further financial incentives.

All these measures (except the 2008 amendment of the EEG) have been introduced under the former red-green coalition, which represented the majority in the German Bundestag from 1998 until 2005. The Renewable Energy Sources Act and its predecessor the Feed-In Law of 1991, have been the major drivers behind growth in renewable energy for electricity generation.

4.1.1 Renewable Electricity Targets

Most countries express their goals in renewable energy promotion through targets. Targets can be set as qualitative or quantitative specifications. Qualitative targets for example

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[204] Lauber/Mez (2004), *Three Decades of Renewable Electricity Policies in Germany*, p. 611.

[205] For the renewable heat and transport sector, other policies are relevant such as the market incentive program for the heat sector.

[206] Lauber/Mez (2004), *Three Decades of Renewable Electricity Policies in Germany*, p. 599.

[207] When referring to the German government, this means the federal German government.

[208] See International Energy Agency (2004), *Renewable Energy: Market and Policy Trends in IEA Countries*, pp. 289-319 for a detailed overview on renewable energy policy instruments in Germany. Agnolucci (2006), *Use of Economic Instruments in the German Renewable Electricity Policy* discusses the EEG from an institutional perspective, presenting the institutional conflicts in the crafting of the EEG and the amendment to the EEG in 2004.

state that renewables are intended to increase energy security by slowing oil imports or turning an economy carbon-free. Quantitative measures sometimes require a certain quantity but most often a certain percentage of renewable in total energy or electricity supply.

The German government has committed itself under the EU Directive for Electricity Produced from Renewable Energy Sources 2001 to increase the share of renewable energy in electricity supply to 12.5% by 2010. This goal was reached three years early in 2007. The 2008 amendment of the Renewable Energy Sources Act (EEG) therefore sets a more ambitious objective: to increase the share of renewable energy in electricity supply to 25-30% until 2020.[209] The long-term aim of the German government is to provide 50% of total primary energy supply (TPES)[210] with renewable sources by 2050.[211] By 2020, Germany intends to have an installed capacity of 28 GW from on-shore wind, 10 GW from off-shore wind, 6.1 GW from biomass, 5.1 GW from hydro, 15 GW from photovoltaic and 280 MW from geothermal energy.[212]

Renewable energy policy has to be seen in the context of climate change policy as well, since the expansion of renewables is a cornerstone in the attempt to fight climate change. Within the framework of the Kyoto Protocol and the European climate change policy, Germany committed itself to reduce greenhouse gas (GHG) emissions by 21% compared to 1990 until 2012. Until 2004, Germany has reduced greenhouse gas emissions by 17.2% compared to 1990.[213] The German government further committed itself to reduce CO_2 emissions by 40% until 2020 compared to 1990.[214]

The development of renewable energy in Germany is further influenced by the decision to phase-out nuclear energy until 2020.[215] Even though there has been considerable debate about postponing this phase-out, the government so far still agrees that the last nuclear power plant will be taken from the grid by 2020. This increases the need to develop adequate additional electricity capacity.

4.1.2 Renewable Energy Sources Act (EEG)

The central policy to promote the deployment of electricity from renewable energy has been a feed-in tariff fixing a minimum price for electricity from renewable energy

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[209] Renewable Energy Sources Act (EEG), §1.

[210] Primary energy supply refers to all indigenous energy production plus net energy imports.

[211] German Federal Ministry for the Environment (2006), *Erneuerbare Energien in Zahlen - nationale und internationale Entwicklung*.

[212] German Federal Ministry for the Environment (2008), *Was bringt uns das neue Erneuerbare-Energien-Gesetz (EEG)?*.

[213] United Nations (2006), *GHG DATA 2006 – Highlights from Greenhouse Gas (GHG) Emissions Data for 1990-2004 for Annex I Parties*.

[214] Gabriel (2007), *Klimaagenda 2020: Klimapolitik der Bundesregierung nach den Beschlüssen des Europäischen Rates*.

[215] International Energy Agency (2006), *World Energy Outlook*, p. 13.

sources.[216] The Renewable Energy Sources Act (EEG) came into force on April 1, 2000 as the successor of the 1991 Electricity Feed-In Law (EFL) and regulates the compensation for electricity generated from renewable energy sources. Grid operators are obliged to connect renewable energy installations to their grids and to feed in electricity produced from renewable energy sources. The electric utilities have to buy the renewable power at a premium rate during a specified period of time. The tariffs, in general, are guaranteed for 20 years from the year of commissioning. The EEG was amended in 2004 and in 2008.[217]

Paragraph 1 of the EEG states:

> "The purpose of this act is to facilitate a sustainable development of energy supply, particularly for the sake of protecting our climate, nature and the environment, to reduce the costs of energy supply to the national economy, also by incorporating long-term external effects, to protect nature and the environment, to contribute to avoiding conflicts over fossil fuels and to promote the further development of technologies for the generation of electricity from renewable energy sources."[218]

The overall aim of the EEG already allows the determination of some tendency as to the prioritization of aims according to the magic triangle of energy policy aims explained in section 3.2. First, Paragraph 1 starts with the explicit mentioning of sustainable development and the protection of the climate, nature and the environment. It then proceeds to emphasize the reduction of energy supply costs, followed by the promotion of technological development. The paragraph holds no explicit reference to energy security supply, merely the reference "to avoid conflicts over fossil fuels". This is an indicator that the EEG primarily emphasizes two aims amongst the three objectives of the magic energy triangle: sustainability and economic development. Energy security is not equally emphasized.

Historically, the former EFL was successful in initiating a significant surge in wind energy development, but failed to spur the development of other renewable energy technologies. This was because the EFL required utilities to pay a minimum price for the renewable power produced which was not differentiated by renewable energy technology, but which depended on the development of domestic electricity prices. The higher generation costs for solar PV, landfill gas and biomass compared to the production costs of wind and hydro power hindered an uptake of the former technologies.[219] Moreover, the EFL re-

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[216] The theoretical concept behind a feed-in tariff is described in section 3.4.1.

[217] Details of the 2004 amendment are discussed in Reiche/Bechberger (2004), *Renewable Energy Policy in Germany: Pioneering and Exemplary Regulations*.

[218] See the non-binding translation of the EEG at http://www.bmu.de/files/pdfs/allgemein/ application/pdf/eeg_en.pdf (access date: 10/22/2008).

[219] The EFL determined the reimbursement rates for the renewable energy technologies eligle to be 80-90% of the average price for conventional electricity received by the utilities.

quired the utilities of one supply area to buy all the renewable power generated in their supply area. The EEG changed this ruling and determined that renewable electricity must be evenly distributed among all suppliers based on their total electricity sales. This ensured that utilities with greater renewable power generation in their supply area were not overly affected by the law.

The renewable energy sources, which are eligible for the compensation under the current EEG, are hydropower, wind, solar, biomass and geothermal energy as well as landfill, pit and sewage gas. Since the amendment of 2004, large scale hydro (capacity of more than 5 MW) also qualifies for the feed-in tariff. To create a level playing field among electricity producers the EEG grants feed-in tariffs that take into account the specific generation costs of each individual renewable energy technology and the external costs of conventional power generation. The tariff also depends on the installation size and the year of commissioning. The remuneration paid for each technology is being reduced annually by a certain factor (see Table 4-1). This mechanism was included to avoid one of the problems typically inherent in feed-in tariffs: a lack of incentives for further cost reductions. Table 4-1 shows the remuneration and degression rates and compares the 2004 and 2008 amendments. The remuneration rates apply for plants commissioned in 2004 or 2009 respectively. For plants that are commissioned later, the tariff paid is decreased by the stated annual degression rate to account for technological and market learning. Every two years the Ministry for the Environment has to submit a report on the diffusion and on the generation costs of renewable electricity. On the basis of this report, adjustments to the tariffs, the degression rates and the time span for the tariffs are being discussed among the relevant stakeholders.

Major changes of the 2004 amendment include the eligibility of hydro power plants up to 150 MW, increased rates for offshore wind and solar photovoltaic, and significant new incentives for biomass (especially small plants). Economic incentives granted to onshore wind have been reduced as the feed-in rates have been decreased and the annual reduction rate was raised to 2%. The amendment 2004 also introduced a restriction concerning wind power in that utilities are only obliged to buy power from wind power plants when these produce at least 60% of a reference amount. This is supposed to prevent the building of inefficient wind power plants, for example in areas where the conditions are suboptimal.

Tab 4-1: Remuneration and degression rates for renewable power in cents/KWh

Installation capacity	New installations commissioned 2009	New installations commissioned 2004	annual degression 2009 (2004)
Biomass			
150 kW - 500 kW	9.18-11.67	9.9-11.5	1% (1.5%)
500 kW - 20 MW	7.79-8.25	8.4-8.9	
Landfill/ Sewage/ Mine			
500 kW - 5 MW	6.16-9.0	6.65-7.67	1.5% (1.5%)
5 MW - 20 MW	4.16	6.65	
Geothermal energy			
5 MW - 10 MW	16.0	14-15	1% (1%)
from 10 MW	10.5	7.16-8.95	
Photovoltaic			
plants up to 30 kW	31.94	57.4	10%, 9% as from 2011
plants from 30kW	31.94	54-54.6	(5%)
on roof up to 100kW	40.91-43.01	-	8% as from 2011
on roof from 100kW	33.0-39.58	-	10% as from 2011
Hydro Power			
500 kW - % MW	7.65-12.67	6.65-9.67	1% (1%)
5 MW - 50 MW	4.34-6.32	4.56-6.65	
50 MW - 150 MW	3.5	3.7	
Wind Power			
on shore	5.02-9.2	5.5-8.7	1% (2%)
off shore	3.5-13.0	6.19-9.10	5% (2%) as from 2015

Source: Renewable Energy Sources Act (EEG), amendments 2004 and 2008

The 2008 amendment resulted in a significant reduction of feed-in rates for solar PV. After the increase of the feed-in tariffs for solar PV four years earlier, the high remuneration rates were faced with criticism. It was argued that the tariffs would result in great costs for the German taxpayer and a technology was being supported which was not yet efficient enough. The reduction of solar renumeration rates can partly be explained by this criticism. More importantly, however, the rates were adjusted because of the dynamic learning curves in solar PV which had resulted in much lower generation costs in the past years. Solar PV generation costs are expected to further decrease significantly. Therefore, the 2008 amendment also raised the annual reduction rate for plants commissioned later than 2009 from 5% to 10%. Still, as Table 4-1 shows, the remuneration for PV will stay considerably higher than for any other renewable energy technology. The 2008 amendment also introduced for the first time a remuneration of solar on roofs or buildings.

The feed-in rates for small hydro power have been increased while those for large hydro power have been decreased. The annual reduction rate for on shore wind power plants has been slightly decreased since the potential for on shore wind is largely exploited and additional reductions in generation costs will be less dynamic. Therefore, the tariff will be decreased every year by one percent for new installations, as opposed to two percent previously. The remuneration rates for offshore wind power plants have strongly increased to create additional dynamic. Because optimal sites for additional wind farms in Germany are becoming increasingly scarce, the German government intends to shift wind energy power towards offshore wind parks. By 2030, the German government hopes to increase offshore installed capacity to 20000-25000 MW; a very ambitious goal given the fact that so far installed offshore capacity is negligible. If the German Government realized its goals, offshore wind energy could meet 15% of Germany's electricity demand in 2030.[220]

The amendment of the EEG in 2008 introduced further flexibility mechanisms, most importantly the adjustment of an annual reduction rates for solar PV. If total PV production falls below (degression will be lowered) or is higher (degression will be increased) than a certain amount.

4.1.3 Preferential Loans

The large-scale provision of "soft" loans with interest rates below market rates and favorable payment conditions for renewable energy technology installations have been essential in promotion the deployment of renewable energy sources.[221] Access to capital is very important for the deployment of renewable energies, since capital costs are often high, especially upfront. Especially smaller power producers suffer from a lack of access to inexpensive capital.[222] Therefore, most policies that were introduced in addition to the EEG focus on giving access to capital, normally through loan programs.

The most important preferential loan program is administered through the German Credit Institute for Reconstruction (KfW), which is under the control of the state and the regions. Credit terms range from ten to twenty years and interest rates are 1 to 2% below market rates.[223] Prior to 2003, also the Deutsche Ausgleichsbank, which merged in 2003 with the KfW, was a significant source of funds for renewable energy. From 1990 to 2005 loan programs by the KfW and the Deutsche Ausgleichsbank granted more than € 10.7 billion in reduced interest loans for renewable energy installations.[224] About 88% of these loans were granted for wind power projects. Since 2005, the share of grants for wind energy projects is declining, while solar and geothermal installations are receiving more loans. In 2005, one quarter of preferential loans already went to solar projects.[225] In 2008,

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[220] German Federal Ministry for the Environment (2007), *Offshore Wind Power Development in Germany*.

[221] Staiß (2001), *Jahrbuch erneuerbare Energien 2001*, I-144.

[222] Staiß (2001), *Jahrbuch erneuerbare Energien 2001*, I-144.

[223] Staiß (2007), *Jahrbuch erneuerbare Energien 2007*, I-220.

[224] Lauber/Mez (2004), *Three Decades of Renewable Electricity Policies in Germany*, p. 604.

[225] Staiß (2007), *Jahrbuch erneuerbare Energien 2007*, I-219.

the KfW provided more than € 350 million funding for renewable energy installations. From 2009, around € 500 million will be available per year.[226]

4.1.4 Further Financial Incentives

Historically, many small programs had been introduced that have already ended such as the solar PV roof programs and other market incentives programs. Solar photovoltaic currently remains and always has been the most expensive renewable energy technology. Solar photovoltaic generation thus was very limited in the 1980s and 1990s. The German government provided a first stimulus with the 1000 roof program which granted funding for the installation of solar panels on roofs from 1991 to 1995. However, PV generation only increased to any significant level with the 100,000 roof program which lasted from 1999 to 2003 and provided reduced loans with low interest rates for PV roof installations. These loans were equivalent to a subsidy of 23% of the investment.[227] The instrument was relatively successful and by 2003 more than 350 MW of solar PV capacity was installed through the program. To compensate for the end of the 100,000 Roof Program in 2003, the compensation rates for PV were significantly increased in the 2004 amendment of the EEG.

A further financial stimulus for renewable energy development was induced by the ecological tax reform of 1999. The aim of the ecological tax reform is to increase the costs of energy consumption that produce negative externalities and thus make energy source without these externalities more competitive. Accordingly, the eco tax intends to internalize the costs of fossil fuel use through increased taxes. The eco tax has been increased annually from 2000 until 2003 and thus provides incentives for energy savings and the use of renewable energy. The revenue is used to lower the retirement pension contributions from employees as well as employers, leading to a relative decrease of labor costs compared to energy costs. A smaller part of the revenue was also used for renewable energy promotion, especially the 100,000 roof program. Since the end of the 100,000 roof program, the eco tax still indirectly affects renewable energy use through the taxes on conventional energy sources.[228]

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[226] Markt und Mittelstand (2008), *KfW fördert Erneuerbare Energien*.

[227] International Energy Agency (2004), *Renewable Energy: Market and Policy Trends in IEA Countries*, p. 298.

[228] German Institute for Economic Research (DIW) et al. (2008), *Economic Analysis and Evaluation of the Effects of the Renewable Energy Act*, p. 19.

Tab 4-2: Major federal renewable energy policies in Germany

Name of Policy or Program	Years effective	Description	Type of Policy
Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz, EEG)	2000-present	Replaced the EFL, focuses on the goal to produce 25 to 30 percent of electricity from renewable energy sources by 2020. The act requires electric utilities to purchase renewable energy at politically determined feed-in rates. Revisions of the 2004 and 2006 and 2008 amendment.	Guaranteed price; feed-in tariff
Preferential loans by the Kreditanstalt für Wiederaufbau (KfW)	1990-present	Gives loans with below market interest rates to promote installation of renewable energy technologies.	Financial incentive
Ecological Tax Reform	1999-present	Tax on energy consumption so that prices reflect the total economic cost of energy use and externalities are internalized in energy prices. The revenue is used to reduce the cost of labor and – to a lesser degree – for programs to promote renewable energy sources.	Financial incentive
Electricity Feed-In Law (EFL) (Strom-Einspeisungs-Gesetz)	1991-2000	Required utility companies to purchase a percentage of their electricity from renewable energy sources. Renewable electricity rates were calculated based on the previous year's electricity rates.	Guaranteed price; feed-in tariff
100,000 roof programm	1999-2003	Aimed to install additional 300 MW of PV by 2003. The program provided soft loans with low interest rates for PV installation.	Financial incentive

Source: US International Trade Commission (2005), Renewable Energy Services: An Examination of U.S. and Foreign Markets, p. F-9 and own compilation.

Germany so far experienced several main problems with its policy approach: The greatest challenge of German renewable energy policy and its main instrument, the feed-in tariff, is setting the guaranteed tariff at efficient levels. If levels are too high compared to generation costs than output will be artificially high, whereas if levels are too low than renewable energy output will be lower than at optimum.

It has repeatedly been argued that the German EEG does not introduce sufficient competition to induce cost reductions. Under the EEG, renewable energy generators are not exposed to competition, since all renewable power produced has to be purchased by the electricity utilities. It has been shown theoretically that the assumption of too few incentives to reduce generation costs cannot be generalized. Section 4.7 looks at the respective development of generation costs to allow for a judgment on the development of these costs in light of the chosen policy instruments. However, as Sensfuß (2007) has argued one problem of the German feed-in tariff is that renewable energy generators are ill-prepared for the time after the feed-in tariffs are guaranteed.[229]

4.2 Renewable Energy Policy Instruments in the United States

In the United States governments at the federal and the state level have promoted renewable energy technologies using a variety of policy instruments. Since the US states are the principal regulatory actors in the electricity sector, the most important measures in renewable energy policy have been enacted at the state level. Federal policies used to promote renewable energy include primarily financial incentives and R&D programs. At the state level, the instruments most widely used are financial incentives but also mandatory regulations such as net metering and renewable portfolio standards (RPS).[230] In general, the states have jurisdiction over the retail rates for electricity and distribution service, while at the federal level the Federal Energy Regulatory Commission (FERC) is responsible for transmission and wholesale electric rates in interstate commerce, hydroelectric licensing and mergers of investor-owned electric utilities. Electricity regulation is thus divided between the federal and the state levels.[231]

FERC also oversaw the deregulation of the electricity sector in the US in the 1990s. From 1996 on, the FERC issued orders to grant access to utility transmission lines for all power producers.[232] Deregulation was based on two laws: the Public Utility Regulatory Policies Act of 1978 and the Energy Policy Act of 1992.[233] The access to transmission lines for all power producers increased competition and strengthened the position of independent power producers, which could now supply consumers.[234] This development was also pivotal for new power producers which produced electricity from renewable energy sources.

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[229] Sensfuß/Ragwitz/Kratzat et al. (2007), *Fortentwicklung des Erneuerbaren Energien Gesetzes (EEG) zur Marktdurchdringung Erneuerbarer Energien im deutschen und europäischen Strommarkt*, p. 5.

[230] See Berry (2002), *The Market for Tradable Renewable Energy Credits*, Darmstadter (2002), *Whistling in the Wind? Toward a Realistic Pursuit of Renewable Energy*, US Energy Information Administration (2005), *Policies to Promote Non-Hydro Renewable Energy in the United States and Selected Countries*, Kydes (2007), *Impacts of a Renewable Portfolio Generation Standard on US Energy Markets*, Langniss/Ryan Wiser (2003), *The Renewables Portfolio Standard in Texas: An Early Assessment*, Menz (2005), *Green Electricity Policies in the United States: Case Study*, US Energy Information Administration (2005), *State Renewable Energy Requirements and Goals: Status Through 2003*, US Department of the Interior (2005), *Renewable Resources for America's Future* for more information on renewable energy policy in the US.

[231] Kohl/Müller (2007), *U.S. and German Approaches to the Energy Challenge*, p. 10.

[232] Klass (2003), *A Critical Assessment of Renewable Energy Usage in the USA*, p. 361.

[233] Kohl/Müller (2007), *U.S. and German Approaches to the Energy Challenge*, p. 10.

[234] The electricity crisis in California at the turn of the century, however, renewed the debate on risks and benefits of deregulation. As a result, the process of deregulation in the electricity sector is stalled in many states, see Kohl/Müller (2007), *U.S. and German Approaches to the Energy Challenge*, p. 10.

At the federal level, the control over energy policy is in the hands of the Department of Energy, which is responsible for all energy sources as well as energy R&D and energy research through its national laboratories. A further actor is the Environmental Protection Agency (EPA), which implements measures to minimize the environmental impacts of energy use, e.g. by setting fuel emission standards to reduce air pollution or by promoting energy efficiency.

4.2.1 Renewable Electricity Target

The US federal government so far has neither committed itself to producing a certain share of electricity from renewables nor to reducing greenhouse gases. It is the last industrialized countries that did not implement the Kyoto Protocol. Nevertheless, recent political developments and increased pressure by a variety of different groups (consumers, environmental organizations but also business organizations) deem it likely that under US President Barack Obama a mandatory limitation of greenhouse gases will be put in place.

4.2.2 Renewable Energy Policy Instruments at the Federal Level

Federal promotion of renewable energy sources had its beginning in the 1970s and 1980s as a reaction to the oil price hikes of the 1970s and was motivated by energy security concerns. National energy security has been an important driver of US energy policy for decades.[235] Since President Richard Nixon has first called for his “project independence” in 1973, almost all US presidents have repeated this goal.[236] In 2006, former US President Bush even spoke of the United States’ “addiction” to oil; a term that so far had only been used by critics of the US energy policy and its high reliance on fossil fuels.[237] In official publications on renewable energy, energy security is most often named as the most important driver of federal renewable energy programs.[238] The other two objectives of (renewable) energy policy, economic development and the protection of the climate and the environment, rate slightly lower than energy security concerns in US (renewable) energy policy.

Even though there has been some debate on national renewable portfolio standards requiring the US to produce a certain share of electricity from renewable sources, no such legislation has been implemented.

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[235] Compare Jordan (2005), *Changes and Continuities in U.S. Energy Policy*, Toman/Gruensprecht Howard (2002), *US Energy Security. Problems and Policies*, Brown/Sovacool/Hirsch (2006), *Assessing U.S. Energy Policy*, Randall (2005), *United States Foreign Oil Policy Since World War I: For Profits and Security*, Adelman (2004), *The Real Oil Problem*.

[236] President Nixon proclaimed his »Project Independence« in 1973 and unrealistically demanded that the US would meet all his energy needs by domestic energy sources by 1980.

[237] US White House (2006), *State of the Union Adress*.

[238] See Sissine (2005), *Renewable Energy: Tax Credit, Budget, and Electricitx Production Issues*, summary (p. 2).

4.2.2.1 Public Utility Regulatory Policies Act

The first policy instrument to have a major impact on the development of renewable electricity was the Public Utility Regulatory Policies Act (PURPA) of 1978. PURPA required utilities to purchase power from independent power producers at the utility's "avoided cost" of producing the power itself. The definition of "avoided cost" and the implementation of the law differed from state to state, but most states interpreted "avoided costs" as the marginal costs of existing facilities.[239] In the early years of implementation, the prices paid for the renewable power were thus pegged to high convention fuel prices of that time, which stimulated new renewables development. After an initially rapid expansion, the number of new contracts decreased as the cost for conventional fossil fuels, which formed the basis for avoided costs, turned out to be much lower than previously forecasted. Therefore, the tariff paid to independent power producers of renewable electricity was too low to spur additional development.[240] Still, the United States was thus the first country to enact a regulatory tool for renewable energy promotion with this purchase obligation.

The 1978 Energy Tax Act (ETA) created a program of tax credits for consumers purchasing alternative energy equipment. This included a 30-percent investment tax credit for residential consumers for solar and wind energy equipment and a 10-percent investment tax credit for business consumers for the installation of solar, wind, geothermal, and ocean thermal technologies. These tax credits were originally set to expire in 1982, but were repeatedly extended.

Such financial incentives were the only policy instruments aimed at renewable energy use in the late 1980s and the 1990s.

4.2.2.2 Financial Incentives

The federal US government has so far heavily relied on financial incentives to promote renewable energy use in the power sector. Today, three instruments are most relevant: The Production Tax Credit (PTC) for privately or investor-owned facilities, the Renewable Energy Production Incentive (REPI) for publicly-owned facilities and the Business Investment Tax Credit (ITC), which gives tax credits to solar power facilities.

The only major law promoting renewable energy in the 1990s was the Energy Policy Act of 1992. The Energy Policy Act established a production tax credit (PTC) in the form of a per kilowatt-hour (kWh) federal tax credit for electricity generated by qualified energy resources. The tax credit amount is 1.5 cents per kilowatt-hour (1993 dollars and indexed for inflation) for most technologies. For some, such as landfill gas, municipal solid

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[239] Klass (2003), *A Critical Assessment of Renewable Energy Usage in the USA*, p. 364.

[240] International Energy Agency (2004), *Renewable Energy: Market and Policy Trends in IEA Countries*, p. 648.

waste and large hydro power, the tax credit is half that. Tax-paying privately and investor-owned plants are eligible for the PTC. The incentive expired in 1999, but has since been renewed repeatedly, typically for three or more years.[241] The Energy Policy Act of 2005 devoted US$ 2.7 billion in tax reduction to extend the renewable PTC through December 31, 2007.[242] The Tax Relief and Health Care Act of 2006 extended the credit through December 31, 2008. In October 2008, the PTC was again renewed under the Energy Improvement and Extension Act.[243] This legislation expanded the list of qualifying resources. Now, the generation of ocean and tidal energy also falls under the PTC. The inflation adjusted tax credit currently amounts to 2 US cents per kWh for wind, closed-loop biomass[244] and geothermal energy. The PTC amounts to 1 US cent per kWh for all other eligible sources.

Public, non-taxpaying power facilities cannot apply for the PTC. However, the 1992 Energy Policy Act created a new Renewable Energy Production Incentive (REPI) payment, which is available to publicly-owned utilities. The REPI is managed by the US Department of Energy. The REPI applies to solar, wind, biomass and geothermal energy, tidal, wave and ocean energy and fuel cells using renewable fuels. Qualifying facilities are eligible for annual incentive payments of 1.5 cents per kilowatt-hour (1993 dollars and indexed for inflation) for the first ten year period of their operation.[245] However, these payments are subject to annual appropriations by US Congress which decreases investors planning reliability.[246] From 2003 until 2006, for example, the REPI had not been authorized. Its impact of renewable power generation has therefore been limited.

Privately or investor-owned solar power facilities cannot apply for the PTC, but they receive a Business Investment Tax Credit (ITC).[247] The ITC was first created by the Energy Policy Act of 1992 and allowed commercial facilities to take a tax credit of up to 10% of their investments for purchase and installation of solar energy stations. The Energy Policy Act of 2005 increased the existing credits for solar energy, fuels cells and micro turbines. The credit for solar energy now amounts to 30% of expenditures, with no

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[241] Sissine (2005), *Renewable Energy: Tax Credit, Budget, and Electricitx Production Issues*, summary (p. 2).

[242] The complete text of the Energy Policy Act 2005 can be viewed at http://frwebgate.access. gpo.gov/cgi-bin/getdoc.cgi?dbname=109_cong_bills&docid=f:h6enr.txt.pdf (access date: 08/25/06).

[243] US Congress, H.R. 1424.

[244] Closed-loop biomass refers to any organic substance from a plant which is planted solely for the purpose of being used to produce energy.

[245] See the website of the U.S. Department of Energy, Renewable Energy Production Incentive, http://apps1.eere.energy.gov/repi/ (access date: 10/31/2008).

[246] Bird/Bolinger/Wiser et al. (2005), *Policies and Market Factors Driving Wind Power Development in the United States*, p. 1399.

[247] International Energy Agency (2004), *Renewable Energy: Market and Policy Trends in IEA Countries*, p. 647-648.

maximum credit limit stated. The ITC has been extended until 2016 under the Energy Improvement and Extension Act of 2008.

From the three incentives, the PTC was the most successful in stirring renewable power generation when in place. Still, the uncertainty of the continued availability of the PTC proved to be a great problem for new investments and a steady market development. Investors often postponed investment until it was definite that the incentives would be reauthorized.[248]

4.2.2.3 Developments since 2007

In the more recent past, there have been debates in the US Congress on implementing a federal RPS, requiring utilities to provide a certain share of electricity from renewable energy sources. The most prominent proposal has been introduced by Senator Jeff Bingaman, a Democrat from New Mexico. The Bingaman-initiative mandated a share of 15% of electricity from renewable energy by 2020.[249] The proposal triggered an intense debate, but was eventually voted down. The opponents of a national RPS mostly argued that electricity prices would be increased by such an approach.[250] This claim was countered by RPS proponents by citing a study of the Energy Information Administration (EIA). This study examined the possible impacts of a national 15% RPS as proposed in the Bingaman-bill. In terms of electricity prices, the study found that a 15% RPS would likely raise retail prices by less than 1% over the 2005 to 2030 period.[251] Also, coal and natural gas prices would be slightly decreased because of reduced demand for fossil fuels.

In December 2007, the Energy Independence and Security Act was signed into law. The law is especially relevant for renewable fuels used in the transportation sector[252], but also contains some measures supporting renewable electricity, such as a 50% matching grant for the construction of small renewable energy projects (up to 15MW). Although the impact of the law on the renewable energy industry will be limited, the debates surrounding the enactment showed that members of US Congress are increasingly interested in renewable energy sources.

Thus the chances are high for a more stringent role of the federal US government in renewable energy policy in the coming years. US President Barack Obama has emphasized that energy policy will be one of the major issues to tackle in the next years. Obama

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[248] International Energy Agency (2004), *Renewable Energy: Market and Policy Trends in IEA Countries*, p. 647.

[249] US Congress, S. 1537.

[250] Sissine (2007), *Renewable Energy Portfolio Standard (RPS): Background and Debate Over a National Requirement*, p. 8.

[251] US Energy Information Administration (2007), *Impacts of a 15-Percent Renewable Portfolio Standard*, p. iv.

[252] The law mandates that fuel producers use at least 36 billion gallons of biofuel in 2022.

has repeatedly stated that he intends to promote the use of renewable energy sources and has called for a national renewable portfolio standard of 25% by 2025. The passage of such legislation would have large stimulatory effects for the renewable energy sector.

4.2.3 State Level

Regulatory responsibility for the electricity industry in the United States rests with both state public utility commissions and the FERC. The FERC implemented the intention of US Congress for greater competition, with the stated objective to “remove impediments to competition in wholesale trade and to bring more efficient, lower cost power to the Nation’s electricity customers.”[253] As part of the Energy Policy Act of 1992, US Congress had voted to promote greater competition in the power market.[254] In 2003, 23 states and the District of Columbia had passed legislation to either require or encourage open and equal access to utilities’ transmission lines for all electricity producers. Following the California electricity crisis in 2001[255], however, by 2007, several states either passed legislation suspending the restructuring process (California), delaying the process (Montana, Oklahoma) or even repealing the restructuring process (Nevada, New Mexico and Arizona).[256]

In this newly deregulated electricity sector, the US states took on prominent roles in the promotion of renewable energy. The early 2000s, thus, saw a second wave of renewable energy deployment in US states. The first wave had started thirty years earlier in response to the oil price hikes of the 1970s. In the 1970s and 1980s, renewable energy, mostly wind energy, boomed in some US states, most notably in California, where state incentives had been introduced to supplement the federal tax credit. With falling oil prices in the 1980s, however, this early renewable energy activity subsided.

Today, the most important state policy instruments are renewable portfolio standards, net metering programs and the use of a distribution charge to create public benefits funds (PBF) to supports renewable energy. Voluntary renewable energy purchases by electricity customers through “green pricing” and green power marketing programs have also been decisive. Recently, many state programs have been motivated by greenhouse gas reduction targets that individual states have ratified. California, as the traditional frontrunner in US energy and environmental policy, passed the Global Warming Solutions Act of 2006

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[253] US Energy Information Administration (2003), *Electricity Power Industry Restructuring Fact Sheet*, p. 1. See for a critical review of electricity sector restructuring in the United States Joskow (2002), *Electricity Sector Restructuring and Competition: A Transactions-Cost Perspective*.

[254] See Klass (2003), *A Critical Assessment of Renewable Energy Usage in the USA*, p. 361.

[255] See Joskow (2001), *California's Electricity Crisis* for a review of the 2001 electricity crisis in California.

[256] US Department of Energy (2007), *Restructuring Status of Electric Markets*.

in 2006, which set targets to reduce global warming emissions to 1990 levels by 2020 (25% reduction compared to 2006 emissions).[257]

4.2.3.1 Renewable Portfolio Standards (RPS)

Currently, 35 US states implemented Renewable Portfolio Standards (RPS). There has been a lot of state activity in recent years. In 2003 only 10 US states had RPS in place. In almost all states with RPS, the minimum purchase requirement of renewable power for retail supplier of electricity is combined with a credit trading program to increase the flexibility of the scheme. The years 2007 and 2008 saw a major RPS policy expansion, with six and seven new states respectively enacting RPS policies.

RPS differ greatly across different states but the procurement quotas for utilities typically run for 10-15 years.[258] In the past years, several states have increased their quotas and accelerated compliance schedules. New Jersey, for example, increased its RPS to 22.5% in 2021. New York State implemented an RPS in 2004 with a target of 24% by 2013. Wisconsin had reached its initial target of 2.2% by 2012 several years earlier and thus the state increased the target to 10% by 2015.

The RPS was initially especially successful in Texas. Texas implemented an RPS in 2000 that required the installation of 2000 MW of new renewable capacity by 2009 and 5880 MW by 2015. Already in 2002, more than half of the 2009 target was in place; wind power generation capacity between 2002 and 2001 had skyrocketed from 181 MW in 2000 to 1096 in 2001.[259] A combination of factors put Texas substantially ahead of schedule, with the most important factor being favorable transmission access rules, good wind resources, and the availability of long-term 10-25 year power purchase contacts from utilities.[260] Nearly all of the added capacity in Texas has been wind power and in 2006 Texas had more wind energy capacity installed than California. This was much to the frustration of California, which until the late 1990s hosted almost 70% of nationwide installed wind energy capacity. There is a debate in California to introduce feed-in tariffs to spur wind energy development and to counter Texas success.[261] Today, with increased RPS in many states, renewable energy installations are becoming more widely distributed across US states.

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[257] See the full text of the law at http://www.leginfo.ca.gov/pub/05-06/bill/asm/ab_0001-0050/ab_32_bill_20060927_chaptered.pdf (access dare: 10/15/2007).

[258] Database of State Incentives for Renewables and Efficiency (DSIRE), http://www.dsireusa.org/

[259] U.S. Department of Energy, Wind and Hydro Power Program, http://www.eere.energy.gov/windandhydro/windpoweringamerica/wind_installed_capacity.asp (access date: 10/15/2007).

[260] Martinot/Wiser/Hamrin (2004), *Renewable Energy Policies and Markets in the United States*, p. 6.

[261] Interview with Heather Raitt, Energy Commission California, Renewable Energy Program, Mar 22, 2007. In 2008, six US states have introduced feed-in tariff bills, but none has been implemented yet, see

In order to avoid a concentration on only those renewable energy technologies that have the highest economic competitiveness, such as wind power and hydropower units, many renewable portfolio standards differentiate tariffs between various technologies. Table 4-3 shows that several states such as Colorado, Nevada and New Jersey require a certain share of electricity from solar PV (see Table 4-3). The targets thereby range from 5% from solar in Nevada to 0.3% from solar in New Hampshire. Other states such as California and New York State do not have any technology specific requirements.

The most important difference among the states RPS lies in the definition of qualifying renewables. Wind energy, solar electric, landfill gas and biomass are eligible in all states with RPS programs, but the rules vary for other technologies (see Appendix Table A-1). Only small hydroelectric is accepted in several states, but other states do not distinguish between small and large hydro. In Massachusetts hydroelectric is only eligible from new sites or from existing hydroelectric facilities after significant efficiency improvements. Some states accept tidal and ocean energy whereas others do not include these forms of renewable energy. Municipal solid waste is excluded in several states since it is often relatively dirty and therefore does not fulfill certain environmental requirements.

Rickerson/Bennhold/Bradbury (2008), *Feed-in Tariifs and Renewable Energy in the USA - a Policy Update*.

Tab 4-3: Renewable Portfolio Standards in US states

State	In Effect since	Requirements	Technology Minimum
Ohio	2009	12,5% by 2024	0,5% from solar by 2024
Missouri	2008	11% by 2020	NS
New Hampshire	2008	23,8% by 2025	0,3% PV
North Carolina	2008	IOU: 12.5% of 2020 retail sales; MU: 10% of 2017 retail sales	0.2% solar electricity and thermal energy by 2018
South Dakota	2008	10% by 2015	NS
Utah	2008	20% of retail sales by 2025	NS
Vermont	2008	20% of retail sales by 2017	No
Virginia	2008	12% of 2007 total sales by 2022	No
Illinois	2007	25% by 2025	75% from wind power
Michigan	2007	7% by 2016 (MU only)	NS
Minnesota	2007	Xcel Energy*: 30% by 2020, Other utilities: 25% by 2025	For Xcel Energy: 25% from wind power by 2020
New Mexico	2007	IOU: 20% by 2020; MU: 10% by 2020	NS
North Dakota	2007	10% by 2015	No
Oregon	2007	25%, 10% and 5% by 2025 for large, small and smallest utilities	No
Arizona	2006	15% by 2025	No
Montana	2006	15% by 2015	No
New Jersey	2006	22.5% by 2021	2.21% from solar
Washington	2006	15% by 2020	No
Delaware	2005	20% by 2019	2% from PV by 2019
District of Colum	2005	11% by 2022	0,386% from PV by 2022
Pennsylvania	2005	18% by 2021	0,5% from PV by 2020
Colorado	2004	IOU: 20% by 2020; MU: 10% by 2020	4% of RPS total from solar
Hawai	2004	20% by 2020	No
Maryland	2004	20% in 2022	2% from PV in 2022
New York	2004	24% by 2013	No
Rhode Island	2004	16% by 2020	No
California	2003	20% by 2010	No
Massachusetts	2002	4% in new RE by 2009, an additional 1% of sales thereafter	NS
Nevada	2002	20% by 2015	5% from solar
Wisconsin	2001	10% by 2015, RPS varies by utility	No
Maine	2000	10% new resources by 2017	No
Florida	1999	7,5% by 2015 (MU only)	NS
Texas	1999	5,880 MW by 2015	at least 500 MW from renewables other than wind
Connecticut	1998	10% by 2010, 27% by 2020	7% from solar, wind, landfill gas, ocean tical or wave energy by 2010
Iowa	1983	105 MW	NS

* Xcel = biggest electric utility in M.; IOU: Investor owned utility; MU: municipal utility

Source: Database of State Incentives for Renewables and Efficiency (DSIRE).

US states so far experienced several main problems with the RPS:

- Limited deployment of renewable sources: The RPS in several states is relatively unambitious, e.g. in Arizona with 15% of total electricity from renewables by 2025 or in Missouri with 11% by 2020. Low standards and few incentives to increase the renewables share above the obligated quota limit the diffusion of renewable energy sources.
- Narrow application of RPS: Some states such as Colorado or Florida only apply the RPS to some electric utilities while exempting the majority of utilities and thereby reducing the impact of the RPS significantly.[262]
- Uncertainty in design of RPS: In several states, the RPS has to be reviewed every five years. Electric utilities and independent power producer therefore cannot be certain that the RPS will be continued or if its level will be changed, which reduces planning security.[263]
- Insufficient enforcement of the RPS: Some states do not state clearly how a failure to comply with the RPS will be punished which lessens the incentive for electric utilities to adhere to the RPS.

4.2.3.2 Public Benefit Funds

Public benefit funds (PBF) are in place in 17 states and the District of Columbia. In these states a charge on electricity bills is collected from customers to support a variety of programs, such as support for energy efficiency, clean energy research, low-income households and renewable energy projects (Appendix Table A-2).[264] Some states include a provision that the surcharge cannot be passed on to customers but has to be generated by the electric utilities themselves. The revenues from the surcharge typically range from US$ 0.001 to 0.003 per kWh. The annual aggregated revenue of PBF is close to US$ 500 million and by 2017 close to US$ 4.03 billion will be spend on renewable energy projects through PBF.[265]

California was the first state to create a PBF in 1996 to collect funds for renewable energy technologies. The original funds have been extended in 2002 for ten more years to collect so called supplemental energy payments to finance renewable energy and energy efficiency programs and energy R&D. The main part of the renewable energy fund is used

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[262] Langniss (2003), *Governance Structures for Promoting Renewable Energy Sources*, p. 93.

[263] Langniss (2003), *Governance Structures for Promoting Renewable Energy Sources*, p. 93.

[264] Database of State Incentives for Renewables and Efficiency (DSIRE), http://www.dsireusa.org/

[265] Union of Concerned Scientists (2004), State Public Benefit Funding for Energy Efficiency, Renewables, and R&D, quoted after Byrne/Hughes/Rickerson et al. (2007), *American Policy Conflict in the Greenhouse: Divergent Trends in Federal, Regional, State, and Local Green Energy and Climate Change Policy*, p. 4564.

to offset the higher costs of renewable electricity generation. Other states use the funds for specific renewable energy projects or to give financial help to low-income families.

Many investors, however, are very critical of these funds, because they remain under government scrutiny and could be used for other projects if political will changes.[266] Moreover, they often prove to be administratively complex.[267] Proponents of PBF argue that the funds should be dispersed through an auction system, since this would promote competition among renewable energy technology groups. In fact, states apply very different methods of spending the money in the funds, ranging from direct investment grants to tender systems and auctions.[268] While in some states the financial endowment of the PBF is too small to generate a significant impact on renewable energy development (e.g. only US$ 2 million annually in Pennsylvania, the state with the sixth largest population), the PBF in New York is comparably well endowed and will collect US$ 1.87 billion from 1998 to 2011.

4.2.3.3 Net Metering

A further instrument to spur renewable energy development is net metering. Net metering is available in all states and the District of Columbia except for Alabama, Alaska, Kansas, Mississippi, South Dakota and Tennessee.[269] Net metering experienced a rapid expansion in the past years. In 1998, only 22 states had net metering laws. Net metering allows consumers who have their own electricity generating units (mostly PV or small wind generators) to both feed electricity into the grid system and to receive power from the grid through a bi-directional meter. With net metering the customer can feed electricity into the grid in times when the generation exceeds the need for electricity. The electricity installed meter will thereby turn backwards, effectively banking electricity. Conversely, in times when more electricity is needed than generated, the customer receives electricity from the grid. Consequently, the customer does not have to purchase electricity at the retail price when power is taken from the grid but is using his own excess generation. There are a great variety of net metering laws in US states, but in most states residential, commercial, and industrial customers are eligible for net metering. In several states industrial customers are excluded from net metering.

The wave of deregulation in many US states in the 1990s also included laws or regulation to implement retail access, giving customers the opportunity to purchase green elec-

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[266] California Energy Commission (2006), *2006 Integrated Energy Policy Report*, p. 16.

[267] Interview with Heather Raitt, Energy Commission California, Renewable Energy Program, Mar 22, 2007.

[268] Bolinger/Wiser/Milford et al. (2001), *Clean Energy Funds: An Overview of State Support for Renewable Energy*, p. 18.

[269] Database of State Incentives for Renewables and Efficiency (DSIRE), http://www.dsireusa.org/

tricity products.[270] At the end of 2005, about 600 utilities or 20% of all utilities in the US offered a "green power" option. Green pricing sales amounted to more than 740 MW of new renewable energy capacity and over 450,000 customers purchased green power.[271] Growth in green pricing is expected to persist in the US as the average price premium charged for green power through green pricing programs continues to decline.[272]

Tab 4-4: Major federal renewable energy policies in the United States

	Name of Policy or Program	Years effective	Description	Type of Policy
Federal Level	Energy Tax Act of 1978	1978-present	The law originally provided a 10-percent tax credit to companies that invested in geothermal, solar, wind, and ocean thermal technologies. The law was subsequently amended in 1986, 1992 and 2005 (see below)	Tax credits
	Public Utility Regulatory Policies Act (PURPA)	1978-present	PURPA was designed to decrease the United States' dependency on oil imports by requiring electric power utilities to purchase power from small producers using renewable energy sources. Utilities were required to purchase such power at fixed costs.	Incentive tariffs
	Energy Policy Act	1992, 2005	These acts provide tax credits for investment in the production of electricity from eligle renewable sources. Production tax credits are granted on a per kilowatt-hour basis. These credits are available for private and commercial installations (PTC) and for publicly-owned facilities (REPI). The Business Investment Tax Credit (ITC) is especially relevant for solar installations.	Tax credits, production incentives
State Level	Renewable Portfolio	various	requirement that utilities supply a certain amount of power from renewable sources in a certain time period.	Incentives, subsidies
	Public Benefit Funds	various	PBF collect funding through a charge on electricity sold in the state to finance various energy programs, including renewable energy projects.	Public Investment
	Net metering	various	Net metering allows to bank electricity in the grid in time of excess capacity.	Financial incentive

Source: US International Trade Commission (2005), *Renewable Energy Services: An Examination of U.S. and Foreign Markets*, p. F-17 and own compilation.

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[270] View for the analysis of green pricing in the US Bird/Brown (2005), *Trends in Utility Green Pricing Programs* and the website of the Energy Efficiency and Renewable Energy branch of the U.S. Department of Energy, http://www.eere.energy.gov/.

[271] Bird/Brown (2005), *Trends in Utility Green Pricing Programs*, p. 1.

[272] Several empirical studies about the individual willingness to pay for green electricity show that people pay higher prices for green electricity products because they wish to feel better with green electricity and not because they are primarily interested in the objective environmental impact of their decision, see Menges (2003), *Supporting Renewable Energy on Liberalised Markets: Green Electricity Between Additionality and Consumer Sovereignty*, p. 594.

4.3 Renewable Energy Policy Instruments in Japan

The initial impetus for renewable energy development in Japan came from the oil price hikes of the 1970s. As a response, Japan initiated efforts to diversify its energy sources and to increase energy supply security. [273] One element of this strategy was to increase energy efficiency; another step was the promotion of nuclear energy.[274] A further part of Japan's efforts to reduce energy dependence was the development of renewable sources of energy, which are labeled “new energy sources” in Japan.

In the energy sector, the most important single actor is the powerful Ministry of Economy, Trade and Industry (METI)[275], especially its Agency for Natural Resources and Energy (ANRE) and its New Energy Industrial Technology Development Organization (NEDO). In general, the Japanese federal state has played a central role in coordinating industrial development, more so than in the US or Germany.[276] In Japan, the federal level also has more influence on energy and renewable energy policy than the local level. This finding is in line with the general distribution of competences in policy-making in Japan, but diverts from findings in environmental policy-making. The environmental policy literature on Japan identifies local governments to be essential actors both in terms of agenda-setting and implementation of environmental regulation.[277]

In contrast, renewable energy policy-making is much more centralized and mostly pursued through METI and NEDO. This difference can be explained by several factors. First, the environmental degradation that came with Japan’s rapid industrialization after World War II made Japan one of the most polluted countries worldwide by the late 1960s. The effects of this pollution could be felt directly at the local level. As a result, local environmental groups fought for more environmental protection and the local level gained more importance in environmental policy than in energy policy.[278] Second, renewable energy policy-making in Japan takes place in a close network of business, bureaucracy and

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[273] See Calder (2001), *Japan's Energy Angst and the Caspian Great Game* for an overview on Japan’s foreign energy dependence.

[274] In 2001, the Advisory Committee for Natural Resources and Energy of METI released a revised Long-Term Energy Supply and Demand Outlook emphasizing efficient use of energy and the development of nuclear power plants as effective means of reducing carbon dioxide emissions. See also Schreurs (2002), *Environmental Politics in Japan, Germany and the United States*, p. 61.

[275] The Ministry of Economy, Trade and Industry (METI) was called Ministry of International Trade and Industry (MITI) until 2001, see http://www.meti.go.jp/english/aboutmeti/index.html (access date: 10/03/2007).

[276] Samuels (1990), *The Business of the Japanese State: Energy Markets in Comparative and Historical Perspective*, p. 21. There is a debate, however, in the literature on the level of centralization in Japan compared to other countries. Reed agrees that Japan is generally more centralized than the US, but finds the levels of centralization in Germany and Japan to be comparable, Reed (1986), *Japanese Prefectures and Policymaking*, p. 163.

[277] Schreurs (2002), *Environmental Politics in Japan, Germany and the United States*, p. 72.

[278] Broadbent (1999), *Environmental Politics in Japan: Networks of Power and Protest*, pp. 130-133.

government. All three players are situated in Tokyo and try to influence the policy-making process from there.[279] The concentration of political and economic power in Tokyo makes it easier for leaders to build a strong network through frequent contacts.

It has been argued in the literature that Japan does not see the promotion of renewable energy as a priority in its energy strategy and devotes too little resources to it.[280] This assessment can be supported by looking at Japan's "New National Energy Strategy 2006". In this strategy, METI announces three objectives in its energy policy:

- to increase energy security
- to promote sustainable development
- to assist Asian countries in their development.[281]

While from this listing energy security and sustainable development (e.g. reduced greenhouse gas emission) seem to be of similar importance, the details of the strategy show that energy security and reduced dependence from foreign fossil fuels are the primary objectives. Nuclear energy development is supposed to further increase energy security. Thus, Japan's current energy policy focuses on securing supplies of fossil fuels[282] and increasing the use of nuclear energy.[283] The emphasis on renewable use is comparably lower, even though a higher share of renewable energy use would also serve to reach the most important policy objective: energy security.

Until the late 1990s, Japan mostly relied on R&D to encourage the use of renewables under the Sunshine Project. The Sunshine Project was launched in 1973 by the Ministry of International Trade and Industry (MITI) and funded a range of different renewable sources but mostly focused on solar photovoltaic and geothermal energy.[284]

The most important measures to promote renewable energy sources in Japan are the Sunshine Project, voluntary purchase agreements and the 2003 Basic Law which established a national Renewable Portfolio Standard.

4.3.1 Renewable Electricity Targets

Japan set a target for the utilization of electricity from renewable sources of 16 TWh by 2014. Japan relies primarily on absolute targets (see Table 4-5), but also announced a rela-

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[279] Interview with Professor Frances Rosenbluth, Department of Political Science, Yale University, April 19, 2007.

[280] Elder/Bhattacharya/Romero (2007), *The Puzzle of Japanese Renewable Energy Policy: Why Japan is Lagging and How It Can Catch Up*, p. 1.

[281] Ministry of Economy (2006), *New National Energy Strategy*, p. 1.

[282] Compare Koike/Mogi/Albedaiwi (2008), *Overseas Oil-Development Policy of Resource-Poor Countries: A Case Study from Japan*.

[283] Elder/Bhattacharya/Romero (2007), *The Puzzle of Japanese Renewable Energy Policy: Why Japan is Lagging and How It Can Catch Up*, p. 1.

[284] Watanabe (1995), *Identification of the Role of Renewable Energy: A View from Japan's Challenge*, p. 242.

tive target with a renewables share in electricity supply of 1.35% by 2010. This goal seems to be relatively unambitious, but since two main renewable energy sources (geothermal and hydro electric energy) are excluded, Japan has to increase the share of wind, solar and waste power generation significantly in order to reach its target. The 2010 target is further specified by individual technology, aiming for 4820 MW PV production (from 330 MW in 2000), 3000 MW wind energy production (from 144 MW in 2000) and 4170 MW waste power generation (from 1030 MW in 2000).[285] The aims, however, are not legally binding and serve more as a general guideline.[286]

Tab 4-5: Annual renewable electricity utilization targets, in TWh

2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
7.32	7.66	8.00	8.34	8.67	9.27	10.33	12.20	13.15	14.10	15.05	16.00

Source: Agency for Natural Resources and Energy (2003), Outline of the RPS System in Japan, http://www.rps.go.jp/RPS/new-contents/top/toplink-english.html (access date: 03/15/2008).

A further target relevant for renewable energy production stems from the Kyoto Protocol. In 1997, Japan was the host to the Third Conference of the Parties to the United Nations Framework Convention on Climate Change during which the Kyoto Protocol was negotiated. Japan ratified the Protocol in 2002 and has agreed to reduce 6 percent of its CO_2 emissions by 2012 compared to the base year 1990.[287]

In May 2007, Japan announced the "Cool Earth 50" initiative. This initiative sets the long-term goal of a 50% reduction of the world's total greenhouse gas emissions by 2050. In order to reach its share, Japan emphasizes the development of innovative technology.[288] However, Japan is currently struggling to even meet its Kyoto targets. Its greenhouse gas emissions so far are considerably above 1990 levels.

4.3.2 Sunshine Project

Japan's support of renewable energy began in 1973 with the Sunshine Project, an R&D program to develop renewable energy sources such as solar and geothermal energy but also coal gasification and hydrogen.[289] The solar energy efforts were first focused on solar

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[285] Website of the Global Renewable Energy and Policy Measures Database, Japan, New Energy Target, http://www.iea.org/textbase/pm/?mode=re&id=90&action=detail (access date: 09/15/2008).

[286] Email contact with Takashi Kawabata, New and Renewable Division, METI, November 10, 2008.

[287] Website of the United Nations Framework Convention on Climate Change, http://unfccc.int/kyoto_protocol/background/items/3145.php (access date: 05/16/2006).

[288] The most important of 21 selected technologies include: biofuels for transport, photovoltaic power generation, hydrogen and high-performance power storage systems, see Ministry of Economy (2008), *Cool Earth-Innovative Energy Technology Program*.

[289] See for Japan's sunshine project Kurokawa/Ikki (2001), *The Japanese Experiences with National PV System Programmes*, Kurokawa (1996), *Overview of System Technology in Japan*, Watanabe (1995),

thermal technologies, but after 1980, spending on photovoltaic was increased.[290] In 1993, the Sunshine Project was reorganized and the New Sunshine Program was created which integrated the old project and the moonlight project (R&D to increase energy saving).[291]

The success of the program with regard to the promotion of PV was substantial and is shown in more detail in the next chapter. Besides the (New) Sunshine project, there were two other factors responsible for the development of PV generation capacity. First, the 70,000 Solar Roofs program was implemented in 1994 to increase the use of PV in the residential sector. This program provided subsidies to support the installation of PV technology but was terminated in 2005.[292] Secondly, the government introduced net metering, so electricity from PV could be fed into the grid and taken from the grid at retail prices. Net metering provides a form of guaranteed-pricing since customers can “store” excess capacity for later use and only pay retail prices for their net use of electricity over the complete billing cycle.[293]

4.3.3 Voluntary Purchase Agreements

In the early 1990s, Japan started to experiment with the first market deployment strategies to promote renewable energy use. The instrument applied was voluntary agreements between the public and private sectors, which was initiated in 1992.[294] This instrument was implemented through an appeal by the government to electric utilities to purchase electricity generated with renewable sources. Consequently, electric utilities made “voluntary” purchase agreements with renewable energy generators and sold this electricity to households at retail prices. The agreements are normally valid for a ten-year period. According

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Identification of the Role of Renewable Energy: A View from Japan's Challenge, Shum/Watanabe (2007), *Photovoltaic Deployment Strategy in Japan and the USA* and US Energy Information Administration (2005), *Policies to Promote Non-Hydro Renewable Energy in the United States and Selected Countries*, pp. 23-24.

[290] Watanabe (1995), *Identification of the Role of Renewable Energy: A View from Japan's Challenge*, p. 265.

[291] See Watanabe (1995), *Identification of the Role of Renewable Energy: A View from Japan's Challenge*, p. 238, Honda (1998), *NEDO’s Solar Energy Program* and Kurokawa/Ikki (2001), *The Japanese Experiences with National PV System Programmes* for an overview of measures to promote photovoltaic deployment in Japan. More recently Shum/Watanabe (2007), *Photovoltaic Deployment Strategy in Japan and the USA* compared the efforts of the United States and Japan to increase solar energy.

[292] Haas/Meyer/Held et al. (2008), *Promoting Electricity from Renewable Energy Sources - Lessons Learned from the EU, United States, and Japan*, p. 452.

[293] Agency for Natural Resources and Energy (2007), *Present State and Goals of New Energy Implementation*.

[294] International Energy Agency (2004), *Renewable Energy: Market and Policy Trends in IEA Countries*, p. 416.

to the IEA, these voluntary purchase agreements made a significant contribution to market deployment for wind and solar energy in the 1990s.[295]

The success of such an arrangement can only be understood in the context of the Japanese political economy and Japan's regulatory tradition. Takamichi Mito, professor at Kyushu University argues:

> "Compared to other major economies, however, Japan has a key advantage in that historical and cultural factors lend themselves to fostering a close networking of people and institutions between government and industry. The government, therefore, can influence the market using this extensive and frequent contact nearly as much as supply and demand forces without resorting to strict direct regulation."[296]

In the political system in Japan, the deep connections between industry, bureaucracy and politics have historically influenced and dominated much domestic policymaking.[297] This network establishes a system of information exchange, campaign contributions and ruling in different areas. It is characterized by mutual dependency and built on internal consensus. This general understanding of Japanese politics helps to explain the use of voluntary agreements in renewable energy policy-making. Voluntary agreements are also a commonly used instrument in the environmental sector. Imura/Schreurs (2005) show that Japanese environmental management style is distinct from Europe or the US in that there is less emphasis on litigation, more emphasis on administrative guidance and considerable use of voluntary mechanisms for policy implementation.[298] This tradition of voluntary agreements and deep connections between the private and the public sector is also continued in renewable energy policy. However, this does not mean that the relations between government and business are always harmonious. Japanese industry will not simply agree to any voluntary agreement imposed on them by the government. Through their many connections with politicians and bureaucrats, industry will evaluate how serious a voluntary agreement is to be taken and thus how feasible it is to fight for changes.[299] Generally, policies very often emerge as a compromise, taking into account the viewpoints of all sides.[300] With regard to the purchase agreement between electric utilities and renewable

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[295] International Energy Agency (2004), *Renewable Energy: Market and Policy Trends in IEA Countries*, p. 416.

[296] Mito (2000), *Japan's Energy Strategy, Russian Economic Security, and Opportunities for Russian Energy Development: Major Issues and Policy Recommendations*, p. 5.

[297] This network between industry, bureauracy and politicians is often referred to as the "iron triangle".

[298] Imura/Schreurs (2005), *Environmental Policy in Japan*, p. 6.

[299] Interview with Professor Frances Rosenbluth, Department of Political Science, Yale University, April 19, 2007.

[300] Mito (2000), *Japan's Energy Strategy, Russian Economic Security, and Opportunities for Russian Energy Development: Major Issues and Policy Recommendations*, p. 7.

energy generators, the Japanese government was successful in convincing the utilities of the necessity of the agreement.

4.3.4 Renewable Portfolio Standard

A milestone in Japanese renewable energy policy was the passage of the "Law Concerning Special Measures for the Utilization of New Energy" (New Energy Law), which was enacted in 1997 and amended in 2002.[301] After the voluntary purchase agreements discussed above spurred the deployment of renewable sources in the electricity sector, the New Energy Law created a more direct form of regulation. The New Energy Law promotes the deployment of solar, wind, geothermal and small hydro (up to 1 MW capacity) power. The amendment of 2002 included biomass in the promotion scheme and introduced a very modest Renewable Portfolio Standard.[302] Under this RPS, electricity retailers are obliged to supply 12.2 TWh or 1.35% of electricity from renewable energy sources by 2010.[303] The METI establishes annual targets of renewable power utilization up to 2014 (see Table 4-5). Electricity retailers can meet their obligations under the RPS in three ways: (1) by generating renewable electricity, (2) by buying renewable electricity, or (3) by buying renewable energy or new energy certificates.

The renewable energy certificates are recorded in units of 1 MW for all electricity generated by an accredited facility. Electric retailers must fulfill their obligation by June 1 of each year. If they produced more renewable energy than their required amount, they can sell the surplus via the certificates. Otherwise they must buy additional certificates from renewable energy generators to meet their obligations. If retailers fail to meet their obligation and also do not comply with an order by the METI a penalty not exceeding ¥ 1 million may be applied.[304]

The required amount varies according to the size of the electric retailers. The calculation of the required amount from each retailer is very complex and includes the electricity supply volume of the retailer, the national usage target rate and an adjustment rate taking into account voltage variation related to the installation of new energy generation facilities. The RPS leaves some flexibility in the choice of the renewable energy technology to

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[301] Agency for Natural Resources and Energy (2007), *Outline of Current New Energy Policy*. See also International Energy Agency (2004), *Renewable Energy: Market and Policy Trends in IEA Countries*, p. 416.

[302] Agency for Natural Resources and Energy (2007), *Outline of Current New Energy Policy*. See also Nishio/Asano (2006), *Supply Amount and Marginal Price of Renewable Electricity Under the Renewables Portfolio Standard in Japan*, p. 2373.

[303] Agency for Natural Resources and Energy (2003), *Outline of the RPS System in Japan*.

[304] Agency for Natural Resources and Energy (2003), *Outline of the RPS System in Japan*.

meet the obligation.[305] The intended result is a further reduction of generation costs by enhancing competition among renewable energy sources.[306]

However, large-scale hydro as well as geothermal power plants cannot be certified as renewable energy power plants. Moreover, the renewable power generated from eligible sources must be sold to the grid in order to be certified as renewable electricity.[307] In order to set an upper limit for the costs through the obligations under the RPS the maximum price of renewable energy certificates is set at 11 JPY/kWh.[308] This is supposed to limit the costs for electric utilities, which have to buy additional renewable energy certificates.

Tab 4-6: Major federal renewable energy policies in Japan

Name of Policy or Program	**Years effective**	**Description**	**Type of Policy**
(New) Sunshine Program	1974-2000	This program promoted R&D for renewable energy sources, in 1993 the program was reorganized and integrated with the Moonlight Program (R&D to promote energy efficiency). The official funding ended in 2000, but a continuation of R&D funding from fiscal year (FY) 2001 through FY 2005 was approved by the Japanese parliament (DIET).	R&D
Voluntary purchase agreements	1992-present	Voluntary purchase agreements between the states and electric utilities to buy renewable power from renewable electricity generator.	Voluntary
The Law Concerning Promotion of the Use of New Energy	1997-present	Law to encourage the deployment of renewable energy sources, amended in 2002 to include biomass as an eligible renewable energy source and to establish a RPS (1.35% of total power supply by renewables, excluding large hydro and geothermal by 2010).	Obligations, RPS, tradable certificates

Source: US International Trade Commission **(2005),** ***Renewable Energy Services: An Examination of U.S. and Foreign Markets,*** **p. F-15 and own compilation.**

The design of the Japanese RPS has three main flaws:

- The upper price limit for renewable energy certificates limits free competition.
- The RPS sets targets which are revised every four years.[309] However, due to the long period until investments in renewable energy plants become profitable this time frame provides insufficient planning security for renewable energy investors.

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[305] International Energy Agency (2004), *Renewable Energy: Market and Policy Trends in IEA Countries*, p. 416.

[306] See Ministry of Economy (2006), *New National Energy Strategy*, p. 21.

[307] Nishio/Asano (2006), *Supply Amount and Marginal Price of Renewable Electricity Under the Renewables Portfolio Standard in Japan*, p. 2373.

[308] Nishio/Asano (2006), *Supply Amount and Marginal Price of Renewable Electricity Under the Renewables Portfolio Standard in Japan*, p. 2374.

[309] Ohira (2006), *Measures to Promote Renewable Energy and the Technical Challenges Involved*, p. 102.

- The penalty for non-compliance with the RPS is not mandatory. It is left to the discretion of the government entity if a penalty will be applied.

4.4 Government Renewable Energy R&D in Germany, Japan and the United States

Spending for research and development is typically necessary in the early stages of development of new technologies. Accordingly, renewable energy R&D was one of the first instruments in all three countries to spur the initial development of renewable energy use. Nevertheless, renewable energy R&D is still essential to foster technological improvements of those renewable energy technologies which are less mature such as solar PV, geothermal energy[310] and wave and tidal energy.

In the following section, the different levels of renewable energy R&D in Germany, Japan and the United States are compared by looking at different indicators: a) historical development of renewable energy R&D, b) the share in total energy R&D and c) the distribution of renewable energy R&D by different renewable energy technologies.

This helps to understand the setting of priorities in the three countries and the current state of governmental R&D support for renewables.

4.4.1 Historical Development of Renewable Energy R&D

From 1974 to 2007, the United States government invested US$ 137 billion in the energy sector, more than any other country in the world. However, in 2007, the US spent with US$ 3.6 billion considerably less on energy R&D than in the late 1970s and early 1980s (see Fig 4-1). US energy R&D peaked in 1979 at US$ 8.8 billion and declined significantly after 1980. After 1997, which was the year that saw the lowest level of funding at US$ 2.4 billion, energy R&D increased again to levels above US$ 3 billion.

From 1974 until 1992, spending on nuclear fission and fusion represented the greatest spending category with on average 50% of total funding in this time period (34% for the total period). Since 1994, however, R&D on energy efficiency has been the single largest spending category, which is surprising given the relatively energy inefficient US economy (on average 18% of total energy R&D from 1994 to 2007). Fossil fuels have received on average 12.5% of annual energy R&D since 1994, nuclear fission/fusion 13.8%, renewable energy 9.6%, power and storage technologies 5% and all other technologies and research 39%.

Since the early 1990s, Japan has had the largest energy R&D budget among IEA countries. Only in 2007, the United States overtook Japan again and spent slightly more

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[310] In Japan, the technological development of geothermal energy is already so advanced that it is considered a mature technology.

on energy R&D. From 1974 to 2007, Japan spent more than US$ 99 billion on energy R&D. In the 1970s and early 1980s Japanese energy R&D was considerably lower than in the United States, but has overtaken US energy R&D in 1992. Japanese energy R&D peaked in 2002 at US$ 4.1 billion and currently stands at US$ 3.4 billion. The expenditures on Japanese energy R&D have been fairly constant in the past three years, whereas the spending has been rising in both Germany and the United States since 2004.

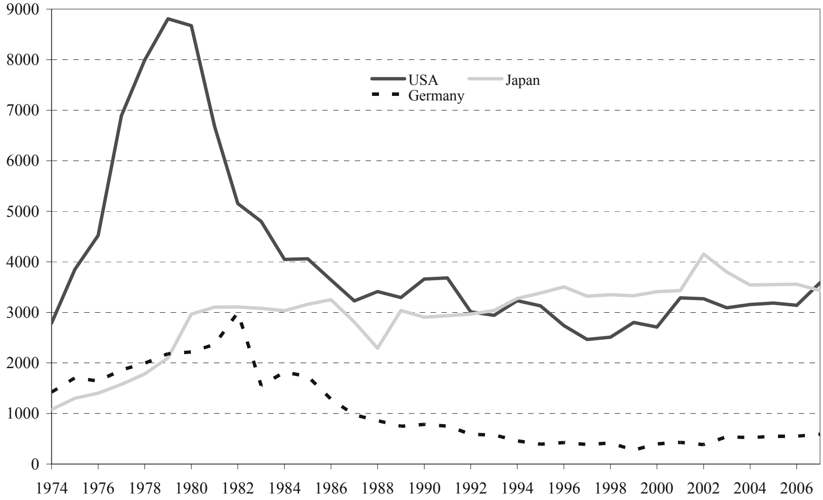

Fig 4-1: Government Energy R&D in Germany, Japan and the United States, 1974-2007, Million US Dollars (2007 prices and exchange rates)
Source: IEA, Government Energy Technology R&D Budgets and Indicators, http://www.iea.org/textbase/stats/rd.asp (access date: 05/21/2009)

The category with the greatest spending of Japanese energy R&D since 1974 has been nuclear fission/fusion (73% of total energy R&D in this time period), followed by spending on fossil fuels (9.0%), energy efficiency (6.5%) and renewable energy (4.3%). The distribution in 2007 is only slightly different from the overall distribution, with nuclear fission/fusion still being the single largest spending category (65%), followed by energy efficiency (12.4%), fossil fuels (8.8%), hydrogen and fuel cells (5.3%) and renewable energy (5.1%).

Germany allocated significantly less funding for energy R&D than its two competitors. Since 1974, Germany's energy R&D expenditures have only been a third of Japanese expenditures and a quarter of US energy R&D. Germany's energy R&D peaked at US$ 2.9 billion in 1982 and currently stands at US$ 588 million. 60% of total German energy since 1974 was allocated to nuclear fission/fusion, followed by funding for renewable energy as the second largest spending category (16.6%). With 9.9% of total energy R&D, fossil fuels are the third largest funding category.

German government renewable energy R&D peaked in the early 1980s and declined notably in the 1980s (see Fig 4-2). Compared to overall government energy R&D, however, the budget for renewables shows a much slower decline during the 1980s and even increased again in the early 1990s in contrast to overall German energy R&D trends. During the rest of the 1990s until 2002, the budget for renewable energy R&D stayed relatively constant at around US$ 100 million per year. In 2007, the German government invested US$ 128 million in renewable energy R&D.

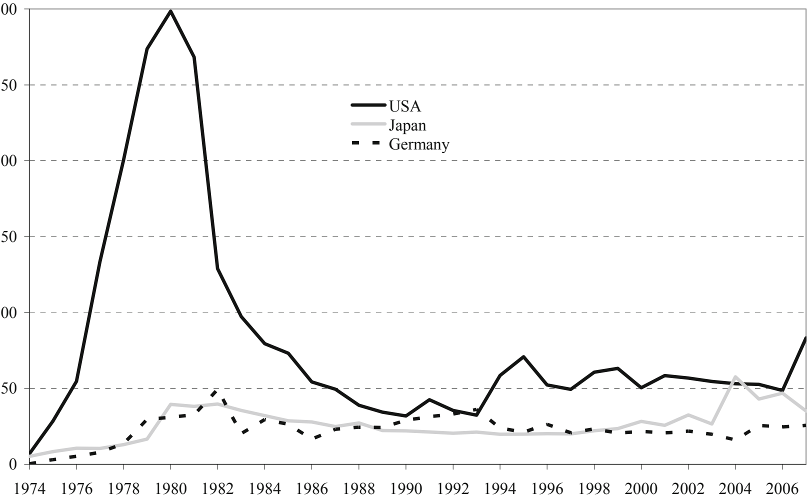

Fig 4-2: Renewable Energy R&D in Germany, Japan and the United States, 1974-2007, Million US Dollars (2007 prices and exchange rates)
Source: IEA, Government Energy Technology R&D Budgets and Indicators, http://www.iea.org/textbase/stats/rd.asp (access date: 05/21/2009)

From 2006 to 2007, US spending on renewable energy R&D saw a jump from US$ 243 million to US$ 416. The United States currently spent considerably more on renewable energy R&D than Japan (US$ 175 million) and Germany, the countries with the second and third largest funding for renewable energy R&D.

The aggregated funding for renewable energy since 1974 is also highest for the United States with US$ 14 billion. Japan invested US$ 4.4 billion on renewable technologies in this period and Germany US$ 3.8 billion. The US spending is however very unevenly dispersed. The effect of the oil price shocks of the 1970s and the following political responses can clearly be seen in the data. In just six years (1977-1982) – in the midst and the immediate aftermath of the oil price shocks of the 1970s – almost 50% of the total investment since 1974 in renewable sources was spent. After 1982 and with significantly declining fossil fuel prices the interest in renewable energy sources and thus renewable energy R&D declined and remained low compared to previous levels but saw another increase in the mid-1990s.

Japan's renewable energy R&D expenditures have been more constant but still saw two sharp increases. One hike was after the 1980 Law Concerning the Promotion of Development and Introduction of Oil Alternative Energy, which more than doubled the funding for renewable energy R&D from US$ 83 million in 1979 to US$ 197 million in 1980. The second hike was in 2004 when renewable energy R&D increased to US$ 288 million from US$ 133 million one year before. Since 2004, however, Japan's renewable energy R&D has been declining.

4.4.2 Share of Renewable Energy R&D in Total Energy R&D

The share of renewable energy R&D in total energy R&D has fluctuated greatly in Germany and the United States. In Japan the share has been more constant, albeit at a relatively low level. Japan's spending on renewables has represented only a small fraction of total energy R&D (see Fig 4-3). From 1974 to 2007, R&D spending for renewable energy technologies was on average 4.3% of total energy R&D funding. Since a share of 8% in 2004, Japan has reduced its spending considerably and thus the renewable energy share decreased to 5.1% in 2007.

For the United States, the share of renewable energy R&D in total energy R&D was remarkably high in the 1970s and stayed high well into the mid-1980s. This helps to explain why the United States was technologically more advanced than its two competitors in renewable energy technologies at that time. In 1981, the United States spent about 20% of its energy R&D on renewable sources. From the early 1980s on, the United States decreased their overall energy R&D and with that the investments in renewable energy R&D. From the mid-1990s on, however, the US government again allocated more funding on renewable energy R&D with a share of around 8-12% in total energy R&D. The average share since 1974 stands at 9% and is thus significantly higher than in Japan (4.3%). In 2007, the renewable share was 11.6%.

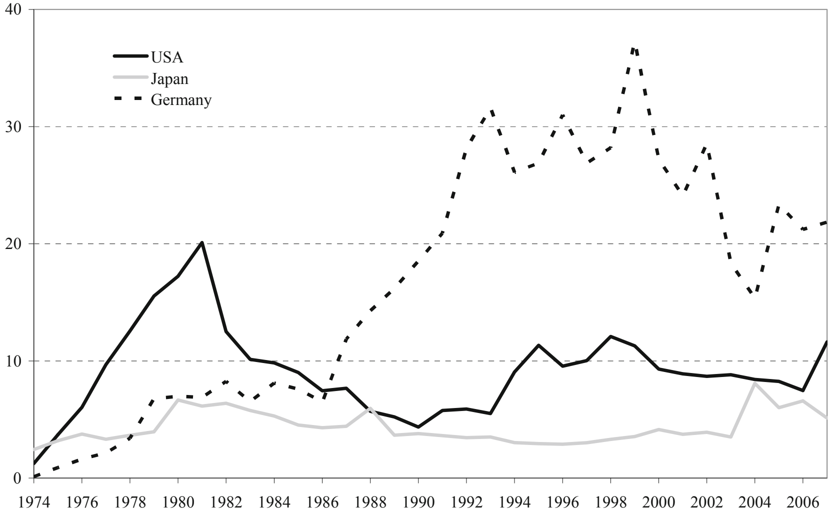

Fig 4-3: Share of renewable energy R&D in total energy R&D, in %, 1974-2007
Source: IEA, Government Energy Technology R&D Budgets and Indicators, http://www.iea.org/textbase/stats/rd.asp (access date: 10/09/2008)

Germany's renewable energy R&D share has been significantly higher than either that of the United States or Japan in the past twenty years. As Fig 4-3 shows there has been a remarkable increase in the share since the late 1980s, when Germany started a serious campaign to promote the use of renewables through R&D. Since 1986, the German government invested on average 23% of its energy R&D on renewable sources. The share peaked in 1999 with 27%, and since then has been declining, but is still significantly higher than in Japan or the United States. It can be argued that Germany puts more priority than the other two countries on promoting renewable energy sources through governmental energy R&D.

However, the high shares of renewable R&D in total energy R&D for Germany are somewhat misleading since they disguise the lower absolute levels of German energy R&D investment. Fig 4-4 shows renewable energy R&D in gross domestic product (GDP) and this figure visualizes that Germany clearly is not such an outlier as suggested by Fig 4-3. It becomes obvious that in terms of renewable energy R&D relative to GDP, the three countries actually display a rather similar development since the mid-1990s and no country is clearly ahead of the other two.

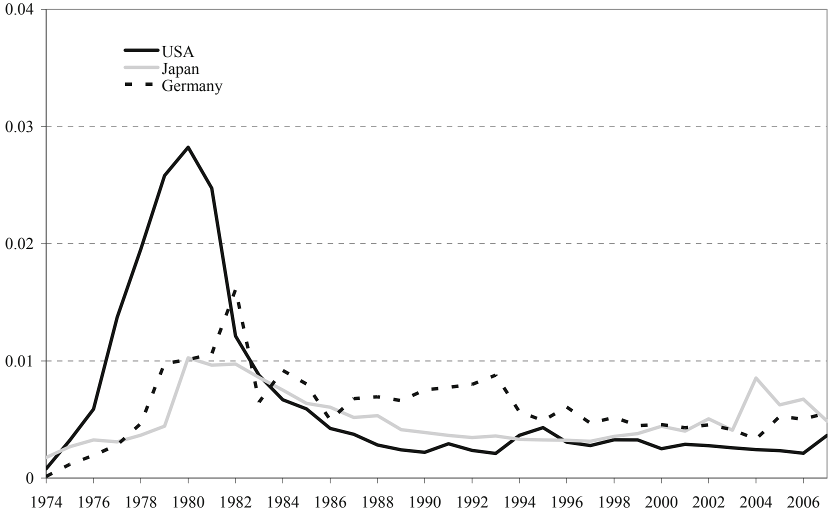

Fig 4-4: Share of renewable energy R&D in GDP, in %, 1974-2007
Source: IEA, Government Energy Technology R&D Budgets and Indicators,); data for GDP: OECD, OECD.Stat, National Accounts.

4.4.3 The Distribution by Renewable Energy Technology

The spending on different renewable energy technologies has been very diverse among the three countries and has also changed over time. In 2007, spending on photovoltaic was highest both for Germany and Japan among all renewable energy sources (49% and 86% respectively of total renewable energy R&D, see Table 4-7). The aggregated renewable energy R&D from 1974 to 2007 was also highest for solar PV for the two countries; with Japan spending 49% of total renewable energy R&D on photovoltaic and Germany 48% (see Table 4-8). The high levels of investment on photovoltaic are not very surprising, however. Solar photovoltaic represents the renewable energy technology with highest generation costs and thus needs more market support but also exhibits great technological improvement potential which is supposed to be unleashed by R&D spending. Moreover, solar photovoltaic is also considered the technology with the greatest future potential in producing renewable power. For Japan, the high levels of spending also reflect the political emphasis on solar energy production since the early 1980s.

For Germany, the breakdown of renewable energy R&D by technology in 2007 clearly represents the current order of priority in renewable energy promotion. Funding of solar photovoltaic is followed by R&D for wind energy (23%), biomass[311] (16%), and geothermal energy (12%). Hydropower does not and did not receive any significant amounts of funding since 1974 neither in Germany nor in the other two countries. The main reason is that hydropower is already so advanced and has generation costs with are comparable to conventional power technologies that funding through R&D is not necessary.

Tab 4-7: Distribution of renewable energy R&D by technology, in %, 2007

	Germany	Japan	United States
Solar Photovoltaics	48.9	86.6	30.8
Solar thermal/heating & cooling	12.8	0.0	6.9
Wind energy	22.7	1.6	11.7
Ocean energy	0.0	0.0	0.0
Biomass	15.9	11.9	47.1
Geothermal	12.1	0.0	1.2
Hydropower	0.3	0.0	0.0

Source: IEA, Government Energy Technology R&D Budgets and Indicators, http://www.iea.org/textbase/stats/rd.asp (access date: 05/21/2009)

The United States government allocated most renewable energy spending on biomass (47%) in 2007. Unfortunately, the data do not differentiate between biomass used in the transport sector and biomass used in the electricity sector. However, it can be expected that the greater share is used for biomass in the transport sector, since US renewable energy policy sets great priority here. One of the greatest aims of US energy (and renewable energy) policy is to reduce the dependence on foreign oil and oil is mostly used in the transport sector. Therefore, the US government promotes biofuels in order to develop alternatives for oil used in the transport sector. R&D spending on biomass is followed by spending in solar PV (31%), wind energy (12%) and solar thermal (7%).

Looking at the whole time period since 1974, the US government allocated 26% of total renewable energy R&D on solar heating and cooling/thermal, 20.5% on solar photovoltaic, 19% on geothermal energy, 16% on biomass and 11% on wind energy.

The emphasis on solar photovoltaic in the market deployment instruments of the Japanese government elaborated above can clearly also be seen in the structure of renewable energy R&D spending. Solar photovoltaic accounted for 86.6% of total renewable energy spending in 2007. The second largest renewable energy spending was on biomass (12%), followed by wind energy (1.6%).

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[311] The data for biomass includes R&D for transport fuels as well as applications for heat and electricity from biomass.

Tab 4-8: Distribution of renewable energy R&D by technology, in %, 1974-2007

	Germany	Japan	United States
Solar Photovoltaics	47.9	48.9	20.5
Solar thermal/heating & cooling	20.6	6.9	25.8
Wind energy	19.6	3.3	11.0
Ocean energy	0.2	1.5	3.6
Biomass	5.0	11.0	16.2
Geothermal	6.6	26.9	18.6
Hydropower	0.0	0.2	0.4

Source: IEA, Government Energy Technology R&D Budgets and Indicators, http://www.iea.org/textbase/stats/rd.asp (access date: 05/21/2009)

Over time, the distribution of renewable energy R&D has changed considerably. Until the mid-1990s Japanese R&D for geothermal energy has historically received large shares of funding of up to 60% in the 1970s. As a result, geothermal energy in Japan is today much more technologically advanced than in most other countries.[312] However, funding for geothermal energy was virtually terminated in 2003. Because of the high levels of spending prior to 2003, aggregated R&D for geothermal energy since 1974 is still the second highest category and accounts for 27% of total renewable energy R&D from 1974 to 2007. In this time period, Japan allocated 49% of total renewable energy R&D on solar PV, 11% on biomass, 7% on solar heating and cooling/thermal, 3.3% on wind energy, 1.5% on ocean energy and 0.2% on hydropower.

From this discussion of (renewable) energy R&D in Germany, Japan and the United States since 1974, the following conclusions can be drawn:

- In absolute terms, the United States currently allocates the highest amount of funding for renewable energy R&D. At the same time, the United States is far from its highest levels of funding in the 1980s and since 2001 renewable energy R&D is declining. Germany invests least in renewable energy R&D of the three countries, but since 2004 funding has been slowly increasing.
- The share of renewable energy R&D in total energy R&D is currently highest in Germany. This reflects the high priority of renewable energy within Germany's energy policy. However, the high share of renewable energy R&D in Germany can also be explained by much lower total energy R&D levels compared to Japan and the United States. So it is pertinent to argue that within Germany's energy policy renewable energy has a high priority but energy R&D levels generally are low. The high shares of German renewable energy R&D in total R&D is further put into perspective

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[312] Iceland is an exception.

by the comparison of renewable energy R&D levels in GDP. All three countries exhibit comparable shares.

- The distribution of renewable energy R&D by technology gives some hints on the political prioritization of renewable energy policy goals. In the United States, for example, funding for biomass is highest, reflecting the US emphasis on reducing the dependence on foreign oil and finding alternatives for oil used in transportation. This supports the assumption that for the US, energy security stands out among the three main aims of renewable energy policy. In Germany the focus is on wind energy and solar PV, thereby promoting two renewable sources with great future potential and two technologies which currently feature higher generation costs than conventional sources. It is more difficult to relate this focus to any of the three policy objectives, but the possible intention to buy down generation costs through R&D spending could hint at the aim to increase long-term economic development of these renewable energy sources. In Japan, the focus shifted from solar PV and geothermal to solar PV and biomass, reflecting the notion that Japan today also emphasizes the need to grow independent of foreign oil imports and to promote energy security.
- It is surprising that ocean energy receives very little R&D in all three countries, even though the geographical potential is high, especially in Japan and the United States.[313] Energy R&D for ocean energy is essential to further the technological potential and should thus be greatly increased.

4.5 Summary on Renewable Energy Policies in Germany, Japan and the United States

The empirical survey of national renewable energy promotion policies in Germany, Japan and the United States found important differences in the approaches.

In Germany the push to promote renewables was also first initiated by security of supply concerns after the oil price hikes in 1973/74 and 1979/80. During the 1990s, however, environmental considerations, including climate change, have gained great importance in the German debate and shaped renewable energy promotion policies. Since the 1990s, it also becomes obvious that in official government statements the emphasis on economic opportunities connected to a higher share of renewable energy is much stronger than in the other two countries. Today, Germany has implemented the most substantial policies to increase renewable energy use of the three countries. While Germany also uses financial incentives and loans programs to promote renewable energy use, the most im-

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[313] Japan’s coastline is 29,751 km, the United States has a coastline of 19,924 km and Germany only of 2,389 km, see CIA, The World Factbook, https://www.cia.gov/library/publications/the-world-factbook/fields/2060.html (access date: 10/13/2008).

portant instrument is a feed-in tariff and relatively ambitious, long-term targets for renewable energy use. The EEG includes different flexibility mechanisms such as an annual degression rate and different remuneration rates reflecting the different generation costs and cost improvement potentials of renewable energy sources. The EEG provides long-term planning security for renewable energy generators since the sale of any renewable power generated at the fixed price is guaranteed under the EEG. However, investor's decisions might be distorted through the EEG since there is little incentive to invest in other, potentially more efficient technologies that are not covered by the EEG. Furthermore, the legislator needs a great amount of information to set the remuneration at efficient levels, again including the risk of technological misallocation.[314]

The main driver for renewable energy policy in the United States has been energy security. In the wake of the oil price hikes in the 1970s, the US federal government supported the use of renewable energy sources intensively, mostly but not solely through R&D. Contrary to conventional wisdom, the United States was the first country to also implement a regulatory tool to promote renewable energy market development under the PURPA 1978. This instrument lost importance, however, because the guaranteed prices for renewable electricity were too low to spur additional development. In the recent past and with increasing and reoccurring concerns of energy security, renewable energy promotion has again gained a more prominent position in US energy policy. This increased interest, however, has so far not translated in substantial policies at the federal level. The instruments applied at the federal level today are still purely market-driven, such as tax credits and other financial incentives. The US federal government has neither implemented regulatory instruments to promote renewable energy use, nor has it agreed to mandatory GHG emission reductions. The federal level under former President George W. Bush was still more concerned with energy supply concerns than with climate change. A speech by the Vice Secretary at the Department of Energy, Karen Harbert, exemplifies that. When sharing her thoughts at the 2007 Wharton Energy Conference about energy challenges of the US, she hardly mentioned climate change, but instead focused on a –in her eyes- new trend, which she labeled "ecoism" with which she was referring to countries that are unwilling to open up their natural resources to foreign investment. The new US administration under President Barack Obama will put more emphasis on mitigating climate change and on supporting the development of renewable energy sources. US states have already been more active in renewable energy promotion in the past years. Many US states have committed themselves to greenhouse gas emission reductions. While

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[314] For an argument along the same lines see Böhringer/Koschel/Moslener (2005), *Emissionshandel, Ökosteuer und Förderung Erneuerbarer Energien: Ökonomische Überlegungen zum Zusammenwirken dreier Instrumente in der Praxis*, p. 43.

the emphasis of state programs to promote renewable energy use has been on financial incentives, many US states have also implemented a regulatory tool: renewable portfolio standards.

Initially, Japan's interest in renewable energy was driven by energy security concerns, but in the 1990s environmental and climate change concerns put additional pressure on Japan to increase its efforts to promote renewable energy. Japan has mostly relied on financial incentives and voluntary purchase agreements to stir market deployment. In 2002, however, Japan has implemented a regulatory tool with the introduction of a renewable portfolio standard. This RPS is, however, very modest. The target will be debated every four years and the RPS does not include long-term goals for a renewable energy share in the electricity mix. This reflects a typical notion of the "Japanese" form of regulation: first, regulation is modest to initiate first changes in industry behavior and to prevent strong industry opposition. Once changes have been achieved to a certain extent, then more stringent regulations are adopted. Japan further relies primarily on absolute renewable targets and not relative targets. Absolute targets are generally less helpful to initiate a comprehensive change in energy use, because the targets could also be reached if the use of other (conventional) forms of energy grows alongside. If the aim is, however, to achieve a sustainable restructuring of the energy sector with an increasing share of renewables in the electricity mix then absolute targets are insufficient. Still, such targets can stir an initial development followed by more stringent and relative targets later on.

Tab 4-9: Main characteristics of renewable energy policy in Germany, the United States and Japan

	Germany	**United States**	**Japan**
Promotion instrument	Feed-in tariff, financial incentives	No national mandatory regulation, financial incentives; state level: RPS	RPS, financial incentive
Targets	Renewable energy share of 20-25% in total electricity supply by 2025	No federal targets	16 TWh renewable power by 2014; no long-term goals
Planning security	Tariffs guaranteed for 25-30 years	Financial incentives only granted for 2-3 years	RPS will be debated every four years
Differentiation by Technology	Tariffs vary by technology	Financial incentives vary by technology	No specification by technology in the RPS
Incentives for technological innovation	Degression of tariffs	-	Price competition

On the whole, while Germany and Japan use some market mechanisms (mostly through financial incentives and loan programs), both implemented regulatory instruments to promote renewable energy use. The federal US government relies heavily on financial incentives and so far has not enacted mandatory promotion policies.

4.6 National Markets for Renewable Electricity

This chapter traces the development of renewable power generation in Germany, Japan and the United States since the early 1990s. How have different renewable energy sources evolved over time? Which have grown more dynamically, which have experienced only slow growth in the respective country?

In global electric power generation capacity, the share of new renewable energy[315] stood at 4.8% or 207 GW worldwide in 2006 (excluding large hydropower).[316] Small hydropower (73 GW) and wind power (74 GW) account for two-thirds of this capacity, biomass power provided 45 GW and geothermal power 10 GW of electricity capacity. If large hydro power is included, renewables accounted for 18% of world power generation in 2005 and were the third largest contributor to global electricity production, after coal (40.3%) and natural gas (19.7%) but ahead of nuclear (15.2%) and oil (6.6%).[317] The fastest growing energy technology worldwide is grid-connected solar photovoltaic (PV), which grew in capacity by 50% annually in 2006 and 2007.[318]

The theoretical analysis of renewable energy support instruments in chapter 3 postulated that feed-in tariffs are more effectives but possibly less efficient in terms of incentives to reduce generation costs since there is no direct price competition among renewable energy producers. Quota systems on the other hand are expected to be less effective but possibly more efficient. The empirical review of renewable energy markets and renewable energy generation costs in Germany, the United States and Japan provide the necessary data to review these assumptions.

4.6.1 Renewable Power Market Development in Germany

Germany uses around 3% of all primary energy consumed worldwide, while providing roughly 6% of global GPD and having 1.23% of the world's population.

Total primary energy consumption in Germany decreased from 359 Mtoe[319] in 1980 to 343 Mtoe in 2000. Since 2000, TPES is experiencing a slight increase and stood at 348 Mtoe in 2006. In 2007, however, energy consumption was reduced by 4% compared to

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[315] See definition in chapter 1.

[316] REN21 (2007), *Renewables 2007. Global Status Report*, p. 38. The most important and most commonly used energy statistics in general are the Statistical Review on World Energy by BP, the World Energy Outlook published by the International Energy Agency, the International Energy Outlook prepared by the US Energy Information Administration and the Renewable Global Status report published by Ren21. Ren21 is a global policy network which was established in 2005 as decided in the Political Declaration of the International Conference for Renewable Energies that took place in Bonn in 2004. The network is governed by a steering committee, which consists of approx. 30 individuals from governments, international governmental organizations, non-governmental organizations, finance and regional and local governments.

[317] International Energy Agency (2007), *Renewables Information 2007*, p. 5.

[318] REN21 (2007), *Renewables 2007. Global Status Report*, p. 6.

one year earlier.[320] Indigenous energy resources in Germany include hard coal, brown coal (lignite), very limited natural gas reservoirs, and renewable energy sources, but Germany is a net energy importer. In 2006, Germany imported 98.9% of its oil consumption, 83.6% of natural gas consumption and 66% of its coal consumption.[321]

Total electricity generation stood at 637 TWh in 2007. Germany's power sector is still highly dependent on fossil-based resources. Of the total generation in 2007, 49% comes from coal, 12% from natural gas and 1.5% from oil. Nuclear power contributes 22.1% and renewables (including hydropower) 15.2%. Of the renewables, 4.3% comes from hydro power, 6.2% from wind, 4.1% from biomass and 0.5% from solar PV. This means that among renewable sources, wind power is the most important source, providing 41% of total renewable power generation. Until 2004, hydro power had been the most important renewable energy sources and is still the second most important today with 28.5% of total renewable power generation. 27% of renewable power is generated from biomass and 3.6% from solar PV.

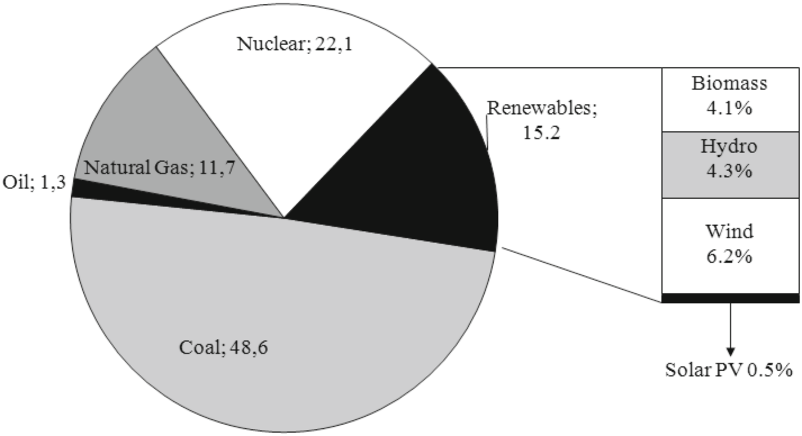

Fig 4-5: Germany – Electricity Generation by Fuel, 2007, in %
Source: International Energy Agency, Gross Electricity Production (GWh), OECDSource.

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[319] Mtoe refers to million tons of oil equivalent and is a common unit of energy.

[320] All data presented in this section and in the sections on Japan and the United States are taken from OECD/IEA energy databases (OECDSource) if not stated differently and checked with national statistics on consistency.

[321] German Federal Ministry of Economics and Technology (2008), *Energiedaten: Nationale und Internationale Entwicklung*.

Since 2000, electricity generation increased by 10%, at an average annual rate of 1.7%. Renewables are the fastest growing energy source in electricity generation and grew by 14.8% annually since 2000. The share of renewables in electricity generation tripled from 1990 to 2007; from 21 TWh or 3.9% of total electricity production to 97 TWh or 15.2% (see Table 4-10).

Tab 4-10: Germany – Electricity production by fuel, in TWh

	1990	1995	2000	2005	2007 Estimated	in % of total 2007*	in % of total RE 2007	Increase 2000-2007 p.y.
Total	**550**	**537**	**577**	**621**	**637**	**100**	**-**	**1.7**
Coal	322	296	304	309	309	48.6	-	0.9
Oil	10	9	5	11	10	1.5	-	8.3
Natural Gas	40	43	52	69	75	11.7	-	4.1
Nuclear	152	153	170	163	141	22.1	-	-2.2
Renewables	**21**	**30**	**40**	**69**	**97**	15.2	**100.0**	**14.8**
Biomass	2	2	4	14	26	4.1	27.0	29.4
Hydro	20	26	26	27	28	4.3	28.5	2.4
Solar PV	0.0	0.0	0.1	1.3	3.5	0.5	3.6	82.6
Wind	0.1	1.7	9.4	27.2	40	6.2	40.9	29.4

* numbers do not add up to 100 due to rounding

Power generation in Germany is forecasted to decrease by 5.3% from 2010 until 2030.[322] All renewable energy sources (except large hydro) as well as natural gas will gain in importance while nuclear, coal and oil will provide a smaller share of power production.[323] Recently, there have been questions about the remaining coal reserves in Germany. The IEA in its International Energy Outlook 2006 states that according to a recent assessment of world coal reserves, the coal reserves in Germany have to be significantly adjusted downwards from 73 billion tons of recoverable coal reserves to 7 billion tons.[324] This would imply that coal would further loose in importance in Germany's power sector.

Fig 4-6 shows how the three main renewable energy sources (excluding hydro) have increased since 1990. After the introduction of the EFL in 1991, growth has been relatively modest. With the introduction of the EEG in 2000, growth has accelerated. Wind energy and biomass generation grew equally strong with a growth rate of 29.4% annually since 2000. Solar PV grew by a remarkable 82.6% on average per year between 2000 and 2007, but started from a very low base.

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[322] International Energy Agency (2007), *Energy Policies of IEA Countries. Germany 2007 Review* p. 120.

[323] International Energy Agency (2007), *Energy Policies of IEA Countries. Germany 2007 Review*, p. 120. These estimates are supported by Prognos AG (2005), *Die Entwicklung der Energiemärkte bis zum Jahr 2030*, p. 5.

[324] US Energy Information Administration (2006), *International Energy Outlook 2006*, p. 52.

While some authors argue that only wind energy has profited from the EEG[325], Fig 4-6 clearly shows that biomass and solar PV have gained alongside. In fact, the effects of German policy instruments on solar PV have been especially striking (Fig 4-7).

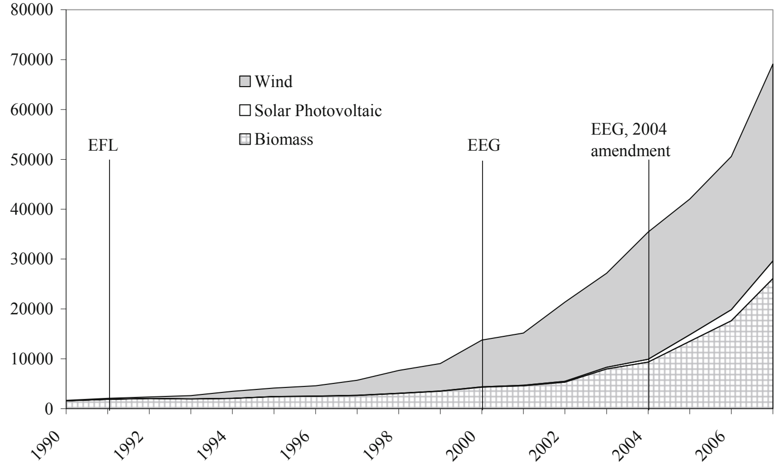

Fig 4-6: Germany – Renewable Electricity Production, 1990-2007, in GWh
Source: International Energy Agency, Renewables Information - Gross Electricity and Heat Generation from Renewable Sources, OECDSource.

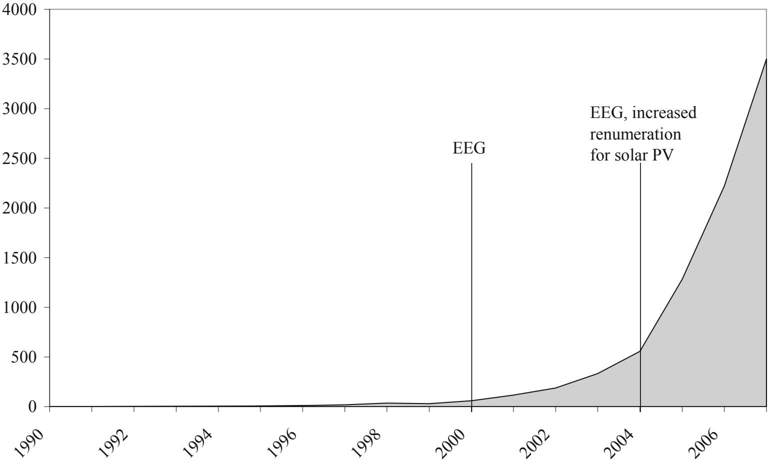

Fig 4-7: Germany – Solar PV Production, 1990-2007, in GWh
Source: International Energy Agency, Renewables Information - Gross Electricity and Heat Generation from Renewable Sources, OECDSource.

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[325] Sijm (2002), *The Performance of Feed-in Tariffs to Promote Renewable Electricity in European Countries*, p. 13.

4.6.2 Renewable Power Market Development in the United States

The United States uses around 20% of all primary energy consumed worldwide, while providing roughly 25% of global GPD and having 5% of the world's population.

In the United States, total primary energy consumption increased from 1927 Mtoe in 1990 to 2320 Mtoe in 2006, an increase of 20%. Whereas Germany and Japan have traditionally been net energy importers for large shares of their energy consumption, this situation is new for the United States, especially with regard to oil (see Fig 4-8). Until 1992, the United States produced more crude oil than it imported. Today, however, the United States has to import 60% of crude oil consumption and 31% of its TPES. Nevertheless, the country has great energy reserves. The US ranks eleventh in world oil reserves, and sixth in natural gas reserves. The United States has the world's largest coal reserves, which relates to about 150-200 years supply left in its reserves.[326]

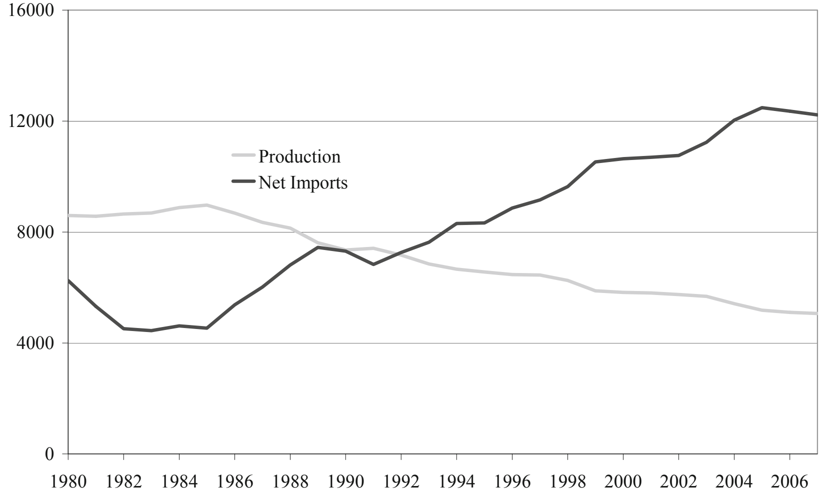

Fig 4-8: United States – Crude Oil Production and Crude Oil Net Imports, 1990-2007, in Thousand Barrels per Day

Source: Energy Information Administration, United States Energy Data.

In 2007, the United States generated 4388 TWh of electricity. Coal is the principal fuel used for electricity generation and has accounted for around 50 percent of US electricity production since 1980. Natural gas is the second most important source and contributed 21% of electricity production in 2007. About 19 percent of United States electricity was generated from nuclear power, oil accounted for only 1.9% of electricity

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[326] British Petroleum (2008), *Statistical Review of World Energy*:

produced. Thus oil is of relatively little importance in electricity generation. Oil is, however, the dominant fuel only in the transport sector, which relies with 96% on oil products. Since the discussion on foreign fuel dependence – especially in the US – concentrates largely on oil, it is important to keep the distinction between the electricity sector and the transport sector in mind.

In 2007, renewables contributed 8.5% of electricity generation. Of the renewables, 6.1% came from hydroelectric facilities, 1.3% from biomass, 0.7% from wind and 0.4% from geothermal (See Fig 4-9). This shows that the US renewable power sector is still heavily dominated by hydroelectric power. Hydro power supplies 71% of all renewable power. 15.6% of renewable power generation comes from biomass, 8.6% from wind and 4.5% from geothermal.

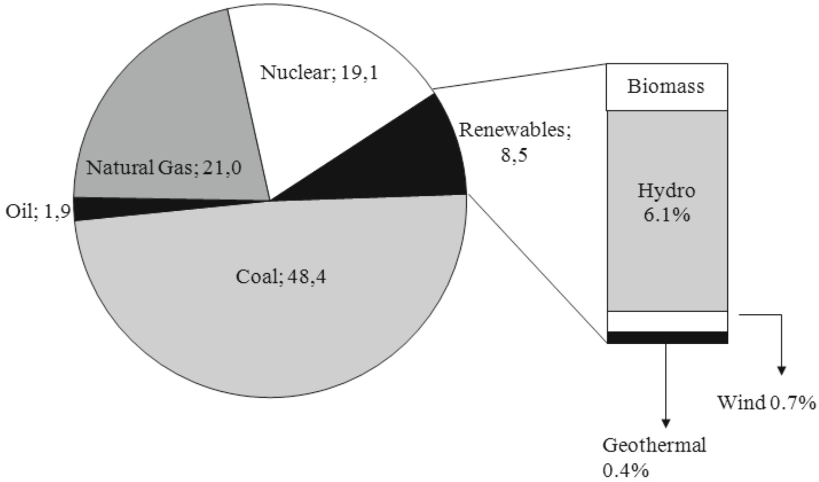

Fig 4-9**:** United States – Electricity Generation by Fuel, 2007, in %
Source: International Energy Agency, Gross Electricity Production (GWh), OECDSource.

Between 2000 and 2007, electricity production in the US increased by 9% at an annual average growth rate of 1.6% (see Table 4-11). Among the energy sources, renewables did not exhibit strong growth since 2000 and only increased annually by 0.9% on average. In relative terms, however, renewable electricity generation even lost in importance. In 1990, the share of renewables in electricity generation stood at 12% and thus 3.5 percentage points higher. This relative decrease can be explained predominantly by a sharp increase in the use of natural gas, which increased by 6% annually since 2000.

Moreover, from 1998 through 2001 severe droughts led to a major decline in hydro power generation. Hydro power generation decreased by 0.2% annually since 2000.

Still, several sources among renewables showed above average growth. The two most dynamic energy sources by far are wind (27.7% p.y. on average since 2000) and solar PV (43.4% p.y. on average). Both started from a very low base, however, and the growth rates are still far below those in Germany and many other industrialized countries.

Tab 4-11: United States – Electricity production by fuel, in TWh

	1990	1995	2000	2005	2007 Estimated	in % of total 2007*	in % of total RE 2007	Increase 2000-2007 p.y.
Total	**3203**	**3558**	**4026**	**4294**	**4388**	**100**	**-**	**1.6**
Coal	1700	1833	2129	2160	2124	48.4	-	0.7
Oil	131	87	118	142	82	1.9	-	-3.8
Natural Gas	382	529	634	783	922	21.0	-	6.0
Nuclear	612	714	798	811	837	19.1	-	1.0
Renewables	**385**	**408**	**357**	**391**	**375**	**8.5**	**100.0**	**0.9**
Biomass	76	51	56	58	59	1.3	15.6	1.6
Hydro	289	338	280	298	267	6.1	71.1	-0.2
Geothermal	16	15	15	17	17	0.4	4.5	1.0
Solar PV	0	0	0	0	0	0.0	0.0	43.4
Wind	3	3	6	18	32	0.7	8.6	27.7

* numbers do not add up to 100 due to rounding

Demand for electric power is projected to increase slightly over the next decade in the reference scenario of the IEA's World Energy Outlook 2007.[327] Until 2015 electricity is expected to grow by 1.2% per year and by 0.9% until 2030. Natural gas will not continue to gain in importance and its share will decrease to 13% in 2030. The shares of coal, nuclear power and hydro power will remain constant until 2030. The areas with strongest growth potential are wind energy and solar PV, according to the IEA.

The interpretation of these projections is always very difficult, however, since there are great uncertainties in the scenarios which stand behind the estimates. The development of the US electricity sector will be heavily influenced by political decisions. If the US does not implement binding reduction goals for carbon emissions and does not set a price on the emission of these pollutants, then the use of coal in electricity generation, the cheapest and most abundant fuel in the US, could be vastly expanded. If the political will favors nuclear power then this technique could gain in importance. Also, the IEA estimates for the development of renewable power could be much too conservative.

Fig 4-10 shows the importance of political measures on wind energy generation, particularly the impact of federal policies. The development of wind generation in the United

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[327] International Energy Agency (2007), *World Energy Outlook 2007*, p. 608.

States has been very uneven. Some authors speak of "boom-bust-cycles"[328] of the wind energy industry. Wind energy installations have peaked in years when the federal production tax credit (PTC, see chapter 4.2.2.b) was scheduled to expire (e.g., 1999, 2001, 2003 and 2005).

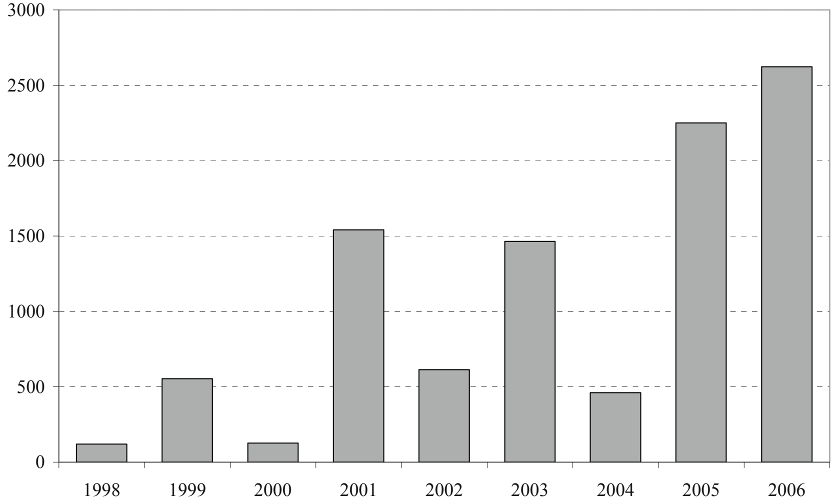

Fig 4-10: United States – Additional Wind Generation Capacity, in MW, 1998-2006
Source: International Energy Agency, Gross Electricity Production (GWh), OECDSource.

The impact of the state's RPS is more difficult to measures, but it is striking that the five US states (except Idaho) with most renewable power generation all have a relatively ambitious RPS in place. Together, Washington (RPS of 15% by 2020), California (RPS of 20% by 2010), Oregon (25% by 20205), New York (24% by 2013) and Idaho (no RPS) account for more than 60% of all renewable power produced in the United States. Their share in US GDP is only 32%.

4.6.3 Renewable Power Market Development in Japan

Japan uses around 4.5% of all primary energy consumed worldwide, while providing roughly 8% of global GPD and having 1.92% of the world's population.

Total primary energy consumption in Japan has stayed comparably constant in the past ten years and stands at 527 Mtoe in 2006. Japan's domestic energy resources are very limited. In fact, Japan's dependency on foreign imports is highest among all major indus-

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[328] Bird/Bolinger/Wiser et al. (2005), *Policies and Market Factors Driving Wind Power Development in the United States*, p. 1398.

trialized countries. Accordingly, Japan has to import almost 99% of its fossil fuels needs and a total of 82.7% of its TPES.

Japan has considerable geographical barriers to the uptake of renewable energy compared to the United States and also Germany. As an island country with many mountains, access to hydro, geothermal and wind energy sites is difficult. The regions with good access for these technologies tend to be already developed for residential or agricultural use.

Total electric generation stands at 1154 TWh in 2007. Japan is largely dependent on fossil fuels for electricity generation. Of total electricity generation, 67.5% was generated from fossil fuels, 23% from nuclear power, 7.4% from hydropower and 2% from non-hydro renewables (see Fig 4-11).

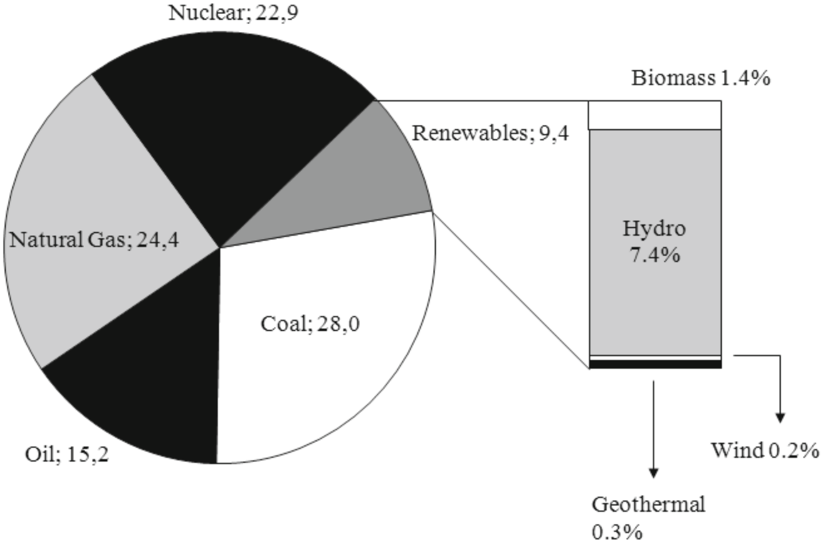

Fig 4-11: Japan – Electricity Generation by Fuel, 2007, in %
Source: International Energy Agency, Gross Electricity Production (GWh), OECD Source.

Among non-hydro renewable sources, biomass is the most important source, providing 15.5% of total renewable power generation. 2.8% and 2.6% come from geothermal and wind power respectively. Since 2000, electricity generation increased by 4.5%, at an average annual rate of 0.9%. Growth in renewable energy generation has not been very dynamic: renewable power generation increased by only 1.1% annually.

Compared to 1990, renewable energy generation has not increased, resulting in a much lower share in total electricity production (13% in 1990, compared to 9.4% in 2007). In 1990, the structure of the Japanese renewable power market did not display a fundamentally different structure. Renewable power generation was and still is dominated by hydro power. Biomass was then and still is the second most important renewable energy sources, followed by geothermal. The use of wind power and solar PV mark the only difference between 1990 and today.

Accordingly, Japan still relies heavily on only one source for its RE power generation (hydro), whereas Germany has three main pillars of RE power generation: wind energy, hydro, and biomass. Nevertheless, among the renewable sources, wind power and solar PV grew most dynamically, albeit starting from very low bases. Electricity generation from geothermal showed strong growth in the mid-1990s, but since 1998 has remained constant at about 3000 GWh per year.

Tab 4-12: Japan – Electricity Production by Fuel, in TWh

	1990	1995	2000	2006	2007 Estimated	in % of total 2007*	in % of total RE 2007	Increase 2000-2006 p.y.
Total	**838**	**962**	**1053**	**1100**	**1154**	**100**	**-**	**0.9**
Coal	116	166	234	299	323	28.0	-	5.0
Oil	251	213	147	121	175	15.2	-	-3.3
Natural Gas	166	193	244	254	281	24.4	-	1.1
Nuclear	202	291	322	303	264	22.9	-	-0.1
Renewables	**109**	**108**	**116**	**119**	**108**	9.4	**100.0**	**1.1**
Biomass	12	14	16	19	17	1.4	15.5	5.1
Hydro	96	91	97	96	86	7.4	79.1	0.4
Geothermal	2	3	3	3	3	0.3	2.8	-1.6
Solar PV	0	0	0	0	0	0	0.0	36
Wind	0	0	0	2	3	0.2	2.6	82

* numbers do not add up to 100 due to rounding

It is, however, very difficult to capture solar photovoltaic generation output because of its widespread off-grid use, especially in Japan. Therefore, the very low solar PV generation masks the success of the Japanese PV industry. Looking at installed capacity is a better indicator for solar PV use in Japan. In terms of capacity, the share of solar PV in total renewable energy capacity is 3.4% and thereby significantly higher than the share in renewable electricity generation.

Demand for electric power is projected to increase slightly over the next decade. Until 2015 electricity is expected to grow by 1.7% per year and by 1% until 2030.[329] Especially oil will increasingly loose in importance and by 2030 will only account for around 4% of generated electricity (2007: 15.2%). Wind and solar energy will gain in importance but still only provide 3% of electricity in 2030. Nuclear energy, however, will provide a significantly larger share with 35% (2007: 23%).

The impact of Japan's renewable energy policies can be seen in Fig 4-12. Between 1992 and 2006, Japan's installed PV capacity skyrocketed from 19 MW to 1776 MW.

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[329] International Energy Agency (2007), *World Energy Outlook 2007*, p. 612.

Geothermal power generation also increased significantly, albeit less steadily. From 1992 to 1997, geothermal generation more than doubled from 1.7 to 3.7 TWh. Since 2002, geothermal energy generation has been decreasing. One main reason for this decrease can be found in the massive reduction of R&D spending for geothermal energy since the late 1990s. Since the year 2003, geothermal R&D spending has virtually been terminated (see section 4.4.3). The introduction of the renewable portfolio standard (RPS) was especially important for wind generation. From 2002 until 2006, wind power has increased from 415 to 1753 GWh.

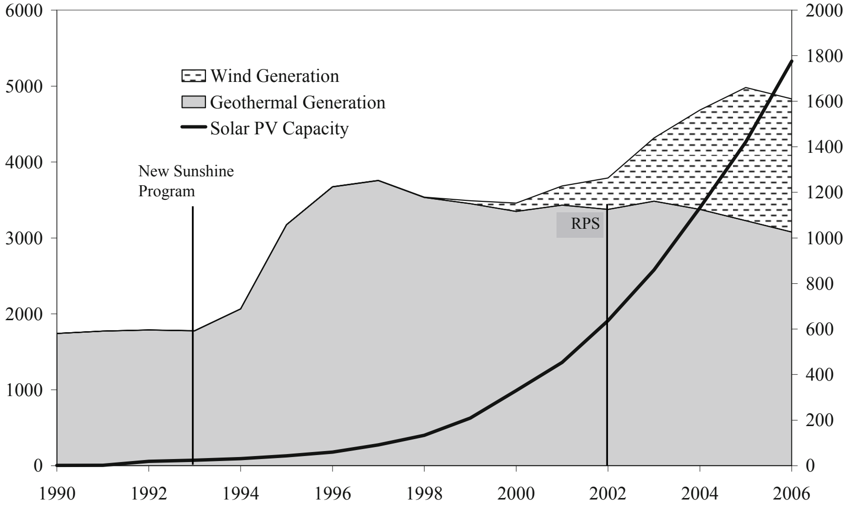

Fig 4-12: Japan – Electricity Generation from Geothermal and Wind in GWh, Solar PV Capacity in MW, 1990-2006

Source: International Energy Agency, Gross Electricity Production (GWh), OECDSource.

4.6.4 Comparison of Renewable Power Generation in Germany, Japan and the United States

The data presented so far analyzed the development of renewable power compared to other energy sources within the three respective countries. It could be shown that renewable electricity generation grew most dynamically in Germany (14.8% annual growth since 2000) compared to the development in Japan (1.1% annual growth since 2000) and the United States (0.9% annual growth). A second way to look at the data is to compare renewable power generation between the three countries. Which country produces most renewable power? Which country was more successful to increase the share of renewables in total electricity production?

Table 4-13 gives first insights by showing that, while the United States produces most renewable power both in absolute as well as in per capita terms, this picture changes completely when hydro power is excluded. The United States still produces most non-hydro renewable power in absolute terms (108 GWh), but significantly less in per capita terms (0.36 GWh) than Germany (0.8 GWh). Per capita data are the more relevant indicator because absolute numbers are only of limited use when comparing the performance of different countries among each others. Japan generates significantly less non-hydro renewable power per capita compared to its two competitors.

Tab 4-13: Germany, Japan, United States: population and (renewable) electricity, 2007, per capita (per 1 mio.) in brackets

	Germany	**United States**	**Japan**
Population in mio.	82.3	299.2	128
Electricity Generation (TWh)	636 (7.7)	4388 (14.6)	1154 (9.03)
Renewable Electricity Generation (TWh)	96 (1.1)	374 (1.2)	108 (0.84)
Renewable Electricity Generation except large hydro (TWh)	69 (0.8)	108 (0.36)	22 (0.17)

Source: OECD Statistics Portal, www.oecd.org/statistics.

How has renewable energy generation per capita developed over time? Fig 4-13 shows that Germany was behind both Japan and the United States in terms of renewable power generation per capita until 1999. Since then, however, the situation changed abruptly. Whereas renewable power generation per capita remained fairly constant for Japan and the US, the renewable electricity generation per capita in Germany skyrocketed and is now far ahead of its two competitors.

Moreover, Germany is the only country that managed to increase the share of renewables in its electricity mix significantly. For the other two countries, the growth in renewable energy sources was not large enough to offset the increases in other fuels. Between 1990 and 2007, the share of renewables in total electricity generation in Japan decreased from 13% to below 10%. Likewise, the share in the US is lower today than it was in the early 1990s.

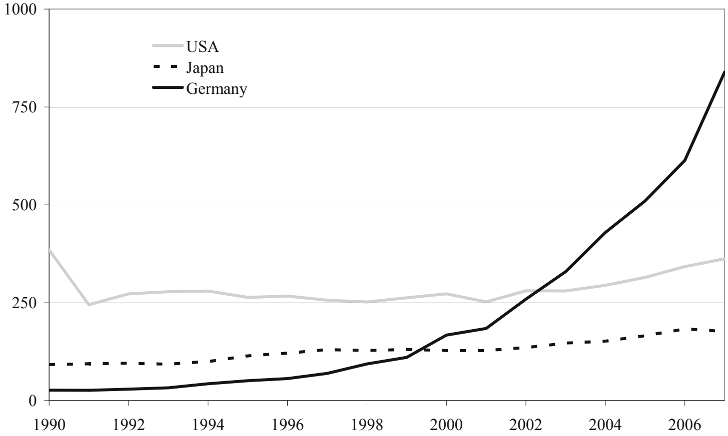

Fig 4-13: Renewable Power Generation (excl. hydro) in Germany, Japan and the United States, 1990-2007, in GWh per capita (per 1 mio.)

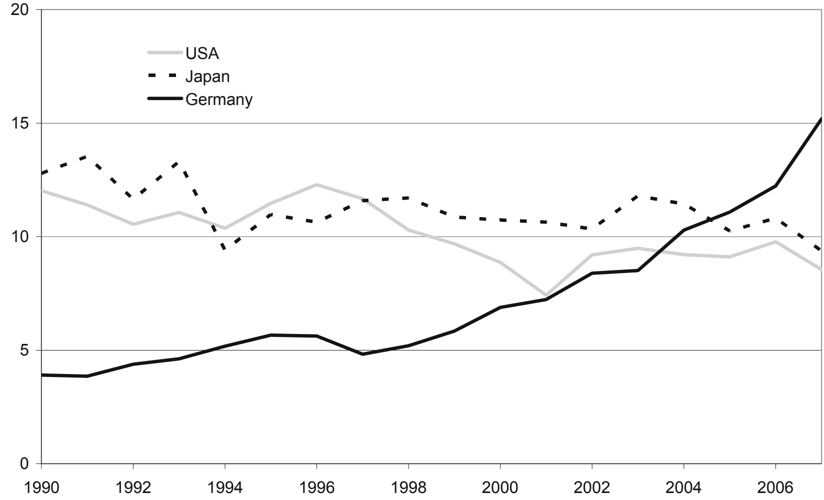

Fig 4-14: Share of Renewable Power Generation in Total Electricity Generation, 1990-2007, in %

Source: International Energy Agency, Gross Electricity Production (GWh), OECDSource.

Looking at the development by technology reveals that Germany today is ahead in the production of renewable power from the two most dynamic sources in all three countries: solar and wind power generation. Japan used to be the world leader in PV solar generation capacity per capita until 2004.[330] In 2005, Germany took this position from Japan and today has more solar PV generation capacity both in absolute as well as in per capita terms than its two competitors. The same is true for wind power generation. With regard to hydro energy and geothermal energy, the United States generates most electricity from these sources among the three countries. However, the development of these sources both within the three case countries as well as worldwide has not been very dynamic in the past decades and future potential is also limited.

Tab 4-14: Germany, United States and Japan: Renewable electricity generation by source, in GWh 2000 and 2007, per capita (per 1 mio.) in brackets

	Germany		Japan		United States	
	2000	2007	2000	2007	2000	2007
Wind	9,352 (114)	39,500 (479)	109 (1)	2,806 (22)	5,650 (20)	32,293 (108)
Hydro Energy	25,962 (316)	27,535 (334)	96,817 (763)	85,590 (670)	279,986 (992)	266,531 (891)
Geothermal	0 (0)	0 (0)	3,348 (26)	3,040 (24)	14,621 (52)	16,902 (56)
Biomas	4,331 (53)	26,114 (317)	12,762 (101)	16,731 (131)	56,180 (199)	58,584 (196)
Solar PV Capacity* (in MWh)	114 (1,4)	2,831 (34)	330 (2,6)	1,776 (14)	139 (0,5)	697 (2,3)

* Because of the difficultities to capture solar energy generation, solar capacity is shown (2000 and 2006)

Haas et al. offer a further indicator to look at and to compare renewable energy market development. The authors measure the average additional electricity generation from renewable energy (excluding hydro) per year and per capita.[331]

This indicator shows that Germany succeeded in increasing additional non-hydro renewable power generation per year and per capita to a much larger extent in both time periods.

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[330] For an in-depth and recent discussion of the Japanese PV market, see Shum/Watanabe (2007), *Photovoltaic Deployment Strategy in Japan and the USA*.

[331] Haas/Meyer/Held et al. (2008), *Promoting Electricity from Renewable Energy Sources - Lessons Learned from the EU, United States, and Japan*, p. 460.

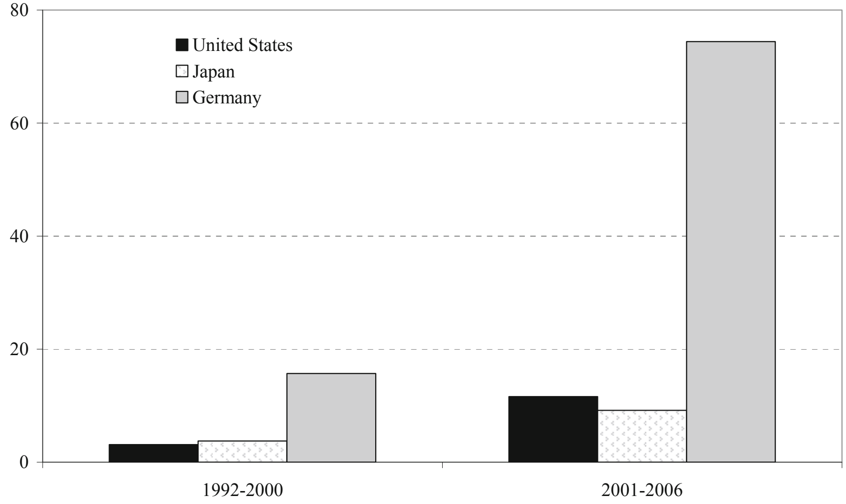

Fig 4-15: Additional Non-Hydro Renewable Power Generation, per year and per capita (GWh/year*capita)

Furthermore, calculating the indicators for wind generation and solar PV capacity also show the superior development from 2001 to 2006 in Germany both in comparison to the other two countries and also to the development from 1992 to 2000 in Germany.

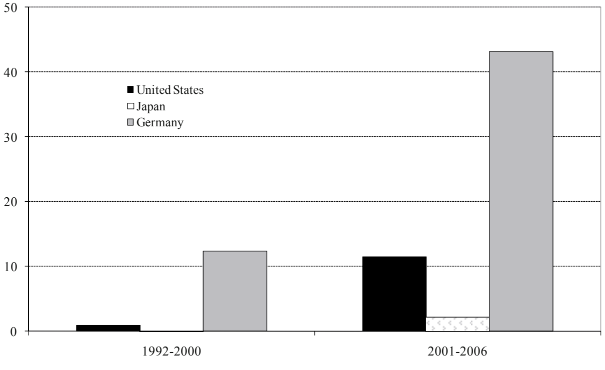

Fig 4-16:Additional Wind Power Generation, per year and per capita (GWh/year* capita)

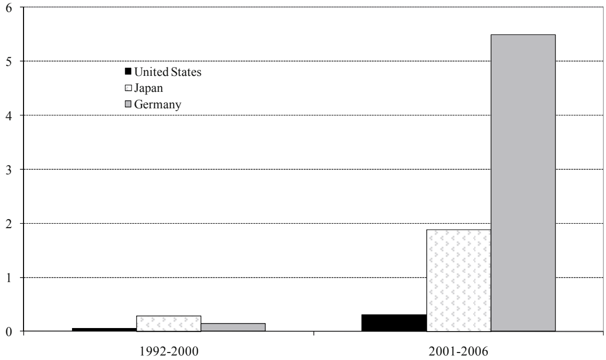

Fig 4-17:Additional Solar PV Capacity, per year and per capita (GWh/year* capita)

4.6.5 Summary

This chapter traced renewable energy markets for power generation in Germany, Japan and the US. The overview of renewable energy markets in Germany, Japan and the United States helped to get a better understanding of the specifics of each country in terms of renewable energy use domestically. Several lessons can be learned from the presented data:

Germany's approach was more effective in increasing renewable energy generation. The deployment of renewable energy sources in Germany has been very dynamic both compared to other sources in the country as well as compared to the development in the US and Japan. Germany is ahead of the other two countries with a 15% share of renewables in power generation (Japan: 9.4%; USA: 8.5%). The differences become even more obvious when looking at the growth rates of renewable energy use. Since 2000 Germany succeeded in increasing renewable energy use by 140%, compared to 5% for both Japan and the United States.[332]

Germany has been especially successful in increasing the deployment of wind and solar power, the two renewable energy sources with the greatest dynamic in the past years and with the highest future potential. The US is still the most important producer of electricity from less dynamic and "older" renewable energy sources, such as hydroelectric and geothermal.

The introduction of the EEG in Germany clearly marked a watershed in German renewable energy generation. Since 2000, renewable energy generation in Germany has skyrocketed. The EEG provides high investment security for renewable energy generators

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[332] For Japan, growth from 2000 to 2006 was calculated since the data for 2007 is incomplete (in January 2009).

and is thus largely responsible for the strong and continuous growth in renewable energy electricity

The importance of policies could also be shown by the development in the United States. The approach of the United States is characterized by different measures at both the federal and the state level. The United States lacks a comprehensive approach to renewable energy use and therefore the development in the US is far less dynamic than in Germany. Moreover, the uneven development of wind power generation in the United States exemplifies that planning security is important to create a continuing development. Planning security cannot be achieved if financial incentives need to be confirmed every couple of years. Still, the introduction of renewable portfolio standards in many US states, resulted in a cautious uptake of renewable energy development in the past six years.

The development in Japan has not been very dynamic despite the introduction of a renewable portfolio standard (RPS) in 2002. Some problems in the design of the RPS have been discussed in the previous chapter (limited competition because of price limit of renewable energy certificates, uncertainty on the duration of the RPS, insufficient penalties for non-compliance). The analysis of market development hints at further weaknesses in the design of the Japanese RPS: First, the targets are set too low. A target of 1.35% renewables in electricity generation is not high enough to stir a dynamic development, even if geothermal and hydro energy are excluded. Second, there is no differentiation by technology. This reduces the incentive to invest in more expensive renewable energy sources, which might have much greater future potential than technologies that are close to cost-competitiveness today. Third, planning security is reduced because of the lack of long-term targets. The RPS sets targets for the next eight years which are revised every four years.[333] However, due to the long period until investments in renewable energy plants become profitable, eight years does not provide sufficient planning security. Moreover, market entrance for new renewable energy facilities is difficult since they have to compete with existing facilities, which have already long-term power purchase contracts with power companies and already generated renewable electricity profitably. Thus, the Japanese RPS should be increased to create additional dynamics.[334] Moreover, different targets for different technologies should be mandatory in order to encourage investment in all technologies.

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[333] Ohira (2006), *Measures to Promote Renewable Energy and the Technical Challenges Involved*, p. 102.

[334] Elder/Bhattacharya/Romero (2007), *The Puzzle of Japanese Renewable Energy Policy: Why Japan is Lagging and How It Can Catch Up* propose to increase the target to at least 10% of TPES by 2020. Maruyama/Nishikido/Iida (2007), *The Rise of Community Wind Power in Japan: Enhanced Acceptance Through Social Innovation* come to a similar conclusion, see p. 2762.

4.7 Capacity to Induce a Decline in Generation Costs

A second main criterion to evaluate renewable energy instruments besides effectiveness is the efficiency of such policies. For the purpose of this study and as explained in chapter 1, efficiency is understood as the capacity to reduce generation costs.[335]

A main justification for public renewable energy policies is that they stimulate technological learning (see chapter 2). Technological learning results in a reduction in the costs of renewable energy systems. Since a main goal of any renewable energy policy instrument has to be to render renewable energy sources cost-competitive with conventional fuels, the capacity to induce a decline in generation costs is of central importance in the analysis of renewable energy policies.

The theoretical discussion of renewable energy instruments in chapter 3 found that both price-based as well as quantity-based systems include some incentives to innovate and thereby to reduce costs. In the case of price-based systems such as feed-in tariffs, there is no direct price competition between generators. The surplus of lower costs, however, goes to producers, which provides an incentive to innovate in order to reduce generation costs. Quantity-based systems such as renewable portfolio standards provide direct price competition since only the most competitive renewable energy generators are able to sell their electricity on the market. The rent of reduced generation costs for generators is limited, however.

In addition to these theoretical considerations, also empirical analysis has found that feed-in tariffs have insufficient incentives to lower costs while tender systems and quota obligation have been more efficient in this regard.[336]

In order to examine these assumptions and the efficiency of feed-in tariffs and renewable portfolio standards empirically, the development of costs for onshore wind and solar PV are analyzed. However, the analysis and the comparison of renewable energy generation costs among different countries pose methodical problems. The failure of an instrument to stir technological change could be clouded by imported technology and equipment from foreign countries, which may have benefited from other instruments. Accordingly, in an open economy the cost reduction aim of policies can be reached by importing the best available technology on the international market.

This is especially relevant for Japan's wind energy industry. The majority of turbines in use are imported. In 2004, only about one fifth of wind turbines used were Japanese-

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[335] Following the methodology developed in Haas/Meyer/Held et al. (2008) the capacity to reduce renewable energy generation costs can be used as an indicator for dynamic efficiency. Other indicators for efficiency include absolute support levels and total costs to society, see Haas/Meyer/Held et al. (2008), *Promoting Electricity from Renewable Energy Sources - Lessons Learned from the EU, United States, and Japan*, p. 461.

[336] Mitchell (2000), *The England and Wales Non-Fossil Fuel Obligation: History and Lessons*, p. 309.

made.[337] In the case of solar PV systems, the impact of imports is less strong since all three countries have solar PV manufactures.[338] Therefore, unfortunately, the data of onshore wind energy concentrate on Germany and the United States.[339]

The development of wind energy costs in Germany and the United States are shown in Fig 4-18 and 4-19. For Germany, the development of renumeration rates for onshore wind power is depicted. This approach has been chosen since historical data for wind power generation costs in Germany could not be obtained. This approach is feasible, however. As Haas/Meyer/Held et al. (2008) have shown renumeration rates have always been slightly above generation costs.[340] For the purpose of this analysis the development of costs is important and the renumeration rates depict the trend in the development of generation costs. Accordingly, the chosen data are adequate.

The data for wind energy prices the United States are taken from the annual report "U.S. Wind Power Installation, Cost, and Performance Trends" by the US Department of Energy. The data are based on a database of wind power sales prices maintained by the Lawrence Berkeley National Laboratory, which contains price data for about 130 wind power projects installed between 1998 and the end of 2007. The prices shown are average, cumulative prices of electricity sold by wind project owners. The prices, however, do not reflect wind energy generation costs since they are suppressed by the receipt of available state and federal incentives (such as the Production tax credit (PTC), see section 4.2.2.b), as well as by the sale of renewable energy certificates. If wind power projects would not receive any financial incentives, their wind energy sale prices would be higher.

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[337] Japan External Trade Organization (JETRO) (2006), *Wind Power on the Increase in Japan*, p. 3.

[338] Japan External Trade Organization (JETRO) (2006), *Wind Power on the Increase in Japan*, p. 3.

[339] See Haas/Meyer/Held et al. (2008), *Promoting Electricity from Renewable Energy Sources - Lessons Learned from the EU, United States, and Japan*, pp. 464-466 who also concentrate on wind onshore generation costs in Germany and the United States.

[340] Haas/Meyer/Held et al. (2008), *Promoting Electricity from Renewable Energy Sources - Lessons Learned from the EU, United States, and Japan*, p. 465.

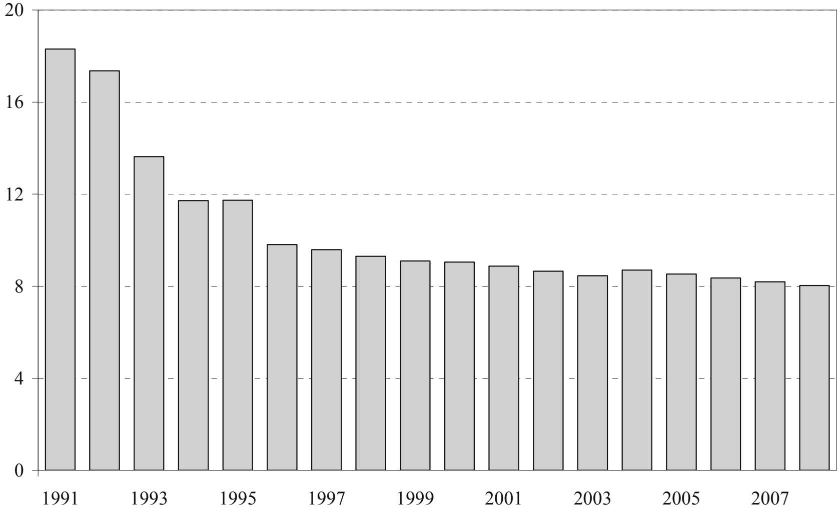

Fig 4-18: Renumeration rates for onshore wind power in Germany, 1991-2008, € cent/KWh (real terms)

Source: Bundesverband WindEnergie e.V., Vergütung von Windstrom:

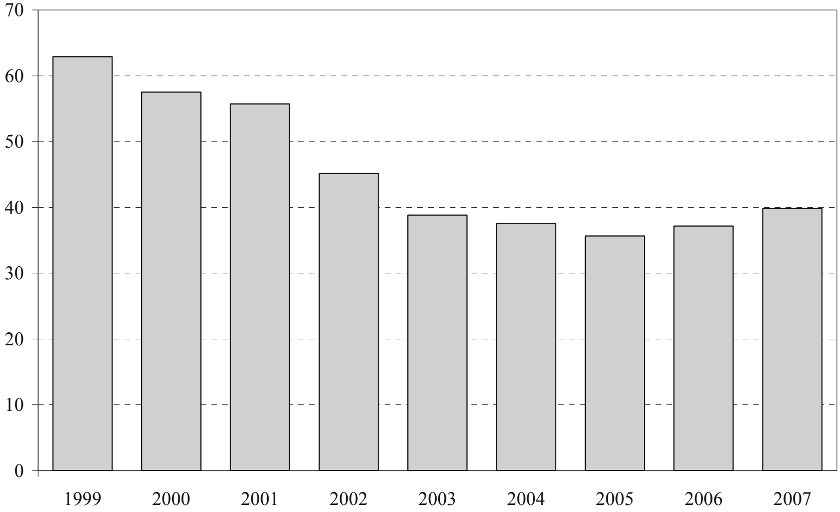

Fig 4-19: Average onshore wind power price in the United States, 1999-2007, US$/MWh (real terms)

Source: US Department of Energy (2008), Annual Report on U.S. Wind Power Installation, Cost, and Performance Trends: 2007, p. 17.

In both Germany and the United States wind energy generation costs have dropped significantly. Generally wind energy generation costs have dropped with larger and more efficient turbines. For Germany this is reflected in the decrease of the renumeration rates for onshore wind power. Since 1991, renumeration rates have decreased by more than 50 percent. Since the late 1990s, however, renumeration rates have been relatively stagnant. It is impossible, of course, to relate the data to actual generation costs since the renumeration rates are politically decided upon. Nevertheless, the politically chosen renumeration rates are based on the historic and expected developments of generation costs and therefore serve to show the trend of wind energy costs in Germany.

The development of wind prices in the United States is shown in Fig 4-19. In the United States wind energy prices have also dropped significantly. The average price of wind in 1999 was almost US$ 63 per MWh. In 2007, prices stood at nearly US$ 40 per MWh. Accordingly, from 1999 to 2007 prices decreased by 36%. Since 2003, however, costs have stagnated and since 2005 there has been a rise in generation costs. The latest increase can be explained by rising material costs and a shortage of wind turbines on world markets (compare section 3.3).

Similar trends can be observed for PV systems. The systems costs in all three countries have first decreased, than stagnated and in the last years costs have been rising.[341] Prices for PV Modules vary widely depending on different factors such as the type of application, system size, location and connection to the electricity grid. The prices shown in Fig 4-20 are for small PV systems (2-5 kW).

In Germany, prices decreased from 1995 until 2002 by more than 50 percent (from US$ 11.4/W in 1995 to US$ 5.3/W in 2002). From 2003 onwards, however, there has been an increase in PV system prices. From 2003 until 2007 prices have increased by 30 percent. This price increase reflects the high demand for PV modules in the past years. The 2008 IEA report on PV applications in Germany states:

> "It is assumed that the huge demand for modules determines the selling prices and the effect of cost reduction in production were not referred to the consumers. An indication for this effect on prices can be seen in the record earnings of PV producers and manufactures."[342]

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[341] PV systems constitute of costs for PV module prices, which represent about 40-60% of the total installed costs, costs for inverters and batteries, see Solarbuzz (2009), Solar Energy Costs/Prices, http://www.solarbuzz.com/statsCosts.htm (access date: 24/02/2009).

[342] International Energy Agency (2008), *National Survey Report of PV Power Applications in Germany 2007*, p. 17.

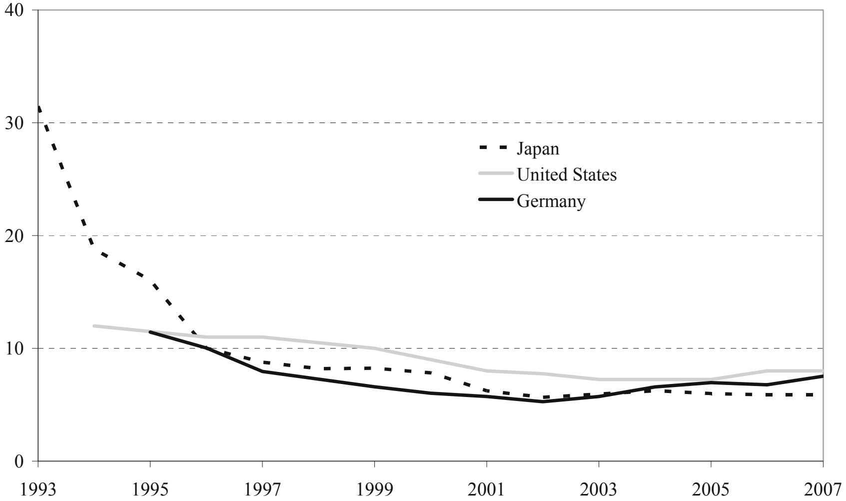

Fig 4-20: Costs of solar PV systems in Germany, the United States and Japan, US$/W (2007 prices and exchange rates), 1993-2007

Source: International Energy Agency (2008), *National Survey Report of PV Power Applications in Germany 2007*, p. 17, International Energy Agency (2008), *National Survey Report of PV Power Applications in Japan 2007*, p. 33 and International Energy Agency (2008), *National Survey Report of PV Power Applications in the United States 2007*, p. 27. Currency exchange rates were taken from the OECD Main Economic Indicators website.

In Japan, the costs for small PV system have dropped by more than 80 percent since 1993. Installed costs of grid-connected PV systems have fallen from US$ 31.5/W in 1993 to just under US$ 6/W in 2007. In the five years from 1993 until 1997 alone, prices slumped by 70 percent. Since 2005 costs have increased by around 5 percent. Adding to the demand pressure for modules, a shortage of silicon material needed for the production of PV modules also drives up prices.

In the United States, PV system costs have also dropped, albeit not as dynamically as in Japan. Since 1994, costs have decreased by 40 percent from US$ 12/W in 1994 to US$ 7.25/W in 2004. In recent years there is an upward trend in prices. In 2007, solar systems prices stood at US$ 8/W.

Since 1995, the first year for which data from all countries are available, the reduction of costs has been most dynamic in Japan (63 percent). Germany achieved a reduction of 34 percent of solar system costs from 1995 until 2007. In the United States, the reduction of 30 percent of solar system prices over the same time period was lower than in the other two countries.

In 2007, solar PV system costs were highest in the United States (US$ 8/W). In Germany grid-connected PV costs stood at US$7.5/W and costs were lowest in Japan with just under US$ 6/W. When comparing the data it becomes clear that it is difficult to draw conclusions on the efficiency of renewable energy policy instruments in the three countries. The trends of the development of costs have been relatively similar in all three countries.

One conclusion that can be drawn from the analysis of solar PV system prices is, however, that the theoretical assumption that quota system generally lead to lower prices cannot be supported. The data discussed here do not translate into the superiority of one policy instrument in terms of efficiency.

4.8 Lessons for the Design of Renewable Energy Promotion Instruments

Renewable energy policy instruments have to be effective in order to increase the deployment of renewable energy sources and efficient (understood here as the capacity to reduce generation costs). The effectiveness and efficiency of renewable energy support instruments was assessed based on the historical evolution of renewable energy markets in Germany, the United States and Japan and the implemented renewable energy policies in the three countries.

Most of the studies conducted on renewable energy policy instruments so far intend to decide which type of renewable policy instrument is better suited to increase effectiveness and efficiency of renewable energy markets. It seems, however, that such an approach is not appropriate since the effects of instruments always depend on many other factors and conditions. Moreover, the specific designs of the same type of renewable energy instruments vary widely and therefore yield very different results. Some authors postulate best practice design requirements for feed-in tariffs and renewable portfolio standards separately.[343] However, there are some general lessons to be learned from the empirical analysis *regardless* of the type of instrument in place. Therefore, the conclusions to be drawn here are essential for an effective and efficient implementation of renewable energy policy instruments regardless of the choice of feed-in tariff or renewable portfolio standard.

The most important design requirements for any renewable energy policy instrument include (a) incentives for sufficient deployment, (b) differentiated promotion, (c) incentives to reduce generation costs and (d) an adequate balance between planning security and competition.

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[343] Ragwitz/Held/Resch et al. (2007), *Assessment and Optimisation of Renewable Energy Support Schemes in the European Electricity Market*, pp. 126-128 and 146-147.

(a) *Sufficient deployment*: The sufficient increase of renewable energy use is one of the main aims of any renewable policy instrument. Feed-in tariffs are effective instruments to stir renewable energy use as could be shown by analyzing the development of renewable energy sources in Germany. The effectiveness of renewable portfolio standards still remains to be proven. In comparison the renewable portfolio standards used in US states and in Japan resulted in less dynamic renewable energy deployment.

Ambitious, long-term targets as well as the enforcement of penalties for non-compliance are important design criteria for any renewable energy instrument to secure sufficient growth of renewable energy sources.

As the Japanese case shows, a mandatory instrument such as a renewable portfolio standard alone is not sufficient to stimulate long-term growth. The Japanese target of a 1.35% renewable share in electricity generation by 2010 is clearly insufficient. Furthermore, the lacking long-term target did not provide sufficient planning security for investors. An ambitious target is especially relevant in quota obligations (renewable portfolio standards) with tradable renewable energy certificates. Since there is no incentive to generate more than the politically fixed target, targets have to be set high enough. Ragwitz/Held/Resch et al. (2007) propose the implementation of a target monitoring process in order to set the target correctly: “Since the level of the quota target has an important influence on the certificate price as well as on the deployed renewable energy technology mix, it is important to compare the targets with the market price and renewable energy capacity development and to adopt the target if necessary.”[344]

Furthermore, sufficient renewable energy deployment can only be achieved if penalties for non-compliance are rigidly applied. The implementation of penalties is only relevant in quota systems since under feed-in-tariffs utilities are required to purchase all renewable power produced and are not assigned individual targets. The insufficient and inconsistent appliance of penalties has been a hindrance for sufficient deployment in both Japan as well as in US states. Setting the right level of the penalty is thereby important. In any case, the penalty has to be high enough to make non-compliance unattractive.

(b) *Differentiated promotion*: Differentiated promotion is necessary in order to ensure sufficient deployment of different renewable energy sources at different points of technological sophistication. Several factors call for a differentiation by technology. Only with differentiated promotion will less mature technologies enter the market. Otherwise the most competitive technologies would be chosen but this would hinder market uptake for other technologies that are currently less competitive but which have great future potential.

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[344] Ragwitz/Held/Resch et al. (2007), *Assessment and Optimisation of Renewable Energy Support Schemes in the European Electricity Market*, p. 146.

With feed-in tariffs differentiated promotion can be implemented through different renumeration rates for different technologies. In this case, the differentiated promotion should reflect different generation costs for different technologies. The main disadvantage of such an approach is the relatively high administrative costs since each renumeration rate for each technology has to be administered. Moreover, total system costs could be higher, at least as long as some technologies are still very expensive. The German EEG includes a mechanism to limit the total costs for consumers: If total PV production is higher than a certain amount, the annual degression rate of the renumeration is increased

Moreover, higher total generation costs can occur in the long-term if only the most cost-competitive technologies are promoted. The further increase of the use of some cost-competitive technologies such as wind power in Germany is very limited. Most areas that can effectively be exploited for wind energy generation are already in use. If the potential of less mature or currently still more expensive technologies is not sufficiently developed then these technologies (such as solar PV) will not be available in the necessary amount in the future to reach long-term targets.

Tariffs should further reflect different power generation costs within the same technology (stepped tariffs). The generation costs of the same renewable energy technology vary widely mostly depending on plant size and geographical conditions (e.g. wind yield or solar radiation). Stepped tariffs allow the exploitation of different sites using different plant sizes.[345]

Setting the right technology-specific target is especially difficult in quota systems. To set a target that is neither too high nor too low the government would need information on the possible future potential of different technologies. Under feed-in tariffs, governments “only” need information on the current potential and costs of different technologies. Still, also under quota obligations differentiated promotion is necessary to ensure sufficient deployment of currently less cost-competitive technologies. Ragwitz/Huber/Resch et al. (2007) propose the introduction of a technology-specific factor which changes the value assigned to one MWh of renewable power.[346] This implies that one MWh generated with a less cost-competitive technology will be translated into renewable energy certificates with a value higher than one MWh for other technologies. This would mean an interference with the free trading of renewable energy certificates, but it is still an interesting option to ensure the diffusion of all renewable energy technologies.

(c) *Incentives to reduce generation costs*: Government promotion of renewable energy use should be gradually reduced to ensure that the public intervention serves as an

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[345] Ragwitz/Held/Resch et al. (2007), *Assessment and Optimisation of Renewable Energy Support Schemes in the European Electricity Market*, p. 127.

[346] Ragwitz/Huber/Resch (2007), *Promotion of Renewable Energy Sources: Effects on Innovation*, p. 49.

initial stimulation of renewable energy use and does not result in long-term public support. The main aim of degressive promotion is, however, to create enough incentives for a reduction in generation costs.

Price models such as feed-in tariffs should include an annual reduction of renumeration rates for new plants by a certain percentage which reflects technological learning and accordingly declining generation costs. Otherwise, the surplus from technological innovations that result in reduced generation costs would only accrue to the renewable energy investors and would not be passed on to the public.

The direct price competition in quota system should result in a reduction of generation costs and accordingly decreasing renewable energy certificate prices over time. However, the incentives to invest in innovation in quota models are limited since renewable energy producers have to pass on the surplus from reduced generation costs. This has limited the motivation of renewable energy generators to invest in innovation. Generators use the best available technology rather than investing in the development of new technologies. This emphasizes the necessity especially in quota systems for public renewable energy R&D. Therefore, the reduction in government renewable energy R&D in the United States is particularly troublesome.

The greatest effect on the development of generation costs has been achieved, however, because of strong growth in renewable energy capacity. In that sense, the design requirement of enough incentives for sufficient deployment and incentives to reduce generation costs are closely linked.

(d) *Balance between competition and planning security*: Essential for a successful promotion of renewable energy use is an adequate balance between necessary competition on the one hand and sufficient planning security on the other hand. Competition is important to create incentives for renewable energy investors to compete for the best technology and to reduce generation costs. Long-term planning security is essential to secure a stable investment climate and thereby to lower risk premiums.

Feed-in tariffs offer greatest planning security. Since the sale of all renewable power produced is guaranteed there is no competition between renewable energy generators. The empirical analysis for Germany showed that the lack of competition did not result in higher renewable energy generation costs. The long-term planning security is the main reason for the strong growth of renewables in Germany. This dynamic development of renewable energy sources and resulting technological learning effects more than offset the lacking competition. Moreover, the competition among renewable energy suppliers put pressure on equipment prices and added another factor responsible for the reduction of generation costs under feed-in tariffs.

Quota systems with tradable renewable energy certificates offer low planning security. The development of renewable energy certificates is uncertain and difficult to forecast and accordingly investors are faced with greater risks compared to feed-in tariffs. This is actually a main hindrance for strong growth in renewable power generation under quota systems. The long time period until investments in renewable energy plants become profitable, further increases investors' risk. The higher risks for renewable energy generators might also effect the development of generation costs since generators in quotas systems demand a higher risk premium.

One possibility to provide more planning security in quota systems is to set long-term quota targets. These would give a long-term perspective for renewable energy investors. Risks can further be reduced by establishing a price floor for tradable renewable energy certificates. Such an approach would again interfere with the free trading of renewable energy certificates but this would be justified by more planning security for investors.

5 International Markets for Renewable Energy Technologies and Export Promotion Policies

This chapter analyzes international markets for renewable energy technologies and government promotion measures.

In order to evaluate export promotion instruments, this chapter:

- depicts and analyzes government promotion of renewable energy technology exports and
- examines international trade flows and competitiveness of renewable energy technologies.

5.1 Public Promotion of Renewable Energy Technology Exports

Governments try to influence trade patterns of renewable energy technologies in order to support national manufactures in international trade. Typically, governments either create barriers to renewable energy technology imports or aim to support national producers in their exports.

5.1.1 Export Promotion of Renewable Energy Technologies

This section looks at export promotion measures in Germany, Japan and the United States. The policies considered in the previous chapter aim at increasing the market deployment of renewable energy sources in the domestic electricity markets. Such measures also affect the export position of domestic industry on international markets through the creation of competitive domestic industries. The effect on international export opportunities of these measures is, however, only a welcomed by-product. In the past years, though, some countries, including Germany, Japan and the United States, have initiated programs to directly promote exports of renewable energy technologies. The range of instruments used and the level of funding differ between the three countries.

Export assistance has historically played a significant role in shaping international trade patterns. Export credit agencies (ECAs) and other institutions have been created by governments to facilitate and to further exports of the domestic industry into markets abroad. In the 1990s, ECAs allocated US$ 100 billion per annum in loans and guarantees.[347]

There is also a long history of export assistance for conventional energy technologies through ECAs and other institutions. The World Resources Institute estimates that from 1994 to 1999, ECAs provided US$ 44 billion for conventional energy investments, mostly

K. Jordan-Korte, *Government Promotion of Renewable Energy Technologies,* DOI 10.1007/978-3-8349-6587-5_5,

carbon-based electric power projects as well as oil and gas development.[348] Renewable energy exports by contrast have only received a fraction of this financial support with US$ 2 billion in the same period.

Attempts have been undertaken to establish a more balanced allocation of export assistance for energy technologies both internationally and nationally. Many national ECAs as well as the World Bank are now required to assess the environmental impacts of financed projects.[349]

The overall aim of any national export assistance is to increase the exports of their domestic industry on overseas markets. The following are the most important instruments of export promotion generally as well as renewable energy export promotion specifically:

- export-credit guarantees to reduce the deficiency risk of export trade,
- analysis of export potential and feasibility in target countries,
- the provision of relevant information for the domestic industry to close knowledge gaps concerning the industrial structure and political systems of target countries,
- assistance in the processing of exports and
- informational activities at trade fairs etc. in target countries.

Accordingly, export assistance generally refers to three main instruments: credit guarantees, international market research and assistance in processing of exports.

5.1.1.1 Renewable Technology Export Promotion in Germany

Generally, German export promotion is pursued through three channels: German Chambers of Commerce Abroad (AHKs), German embassies and the German Office of Foreign Trade (bfai).

Germany intends to strengthen its competitive position through measures that further opportunities for energy technologies exports.[350] Because of the growing importance of the renewable energy industry, the German parliament decided to establish a special program to promote renewable technology exports. Consequently, the renewable energy export initiative was created in 2002. The initiative is administered by the Federal Ministry of Economics and Technology (BMWi) and coordinated by the German Energy Agency (Deutsche Energie Agentur, dena). Dena is responsible for the promotion of energy efficiency and renewable energies, both nationally and internationally. It is jointly owned by

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[347] G8 (2001), *Renewable Energy: Development that Lasts*, p. 39.

[348] G8 (2001), *Renewable Energy: Development that Lasts*, p. 40.

[349] See Multilateral Investment Guarantee Agency, a member of the World Bank Group, "Environmental and Social Impact Assessments", http://www.miga.org/policies/index_sv.cfm?stid=1655 (access date: 10/21/2008) and the US Export-Import Bank, "Ex-Im Bank & the Environment", http://www.exim.gov/products/policies/environment/environment.cfm (access date: 10/21/2008).

[350] See German Federal Ministry of Economics and Technology (2007), *Energieforschung - Das strategische Element der Energiepolitik*, p. 28.

the German government, the KfW Bankengruppe and by three other financial institutions (Deutsche Bank, Allianz, DZ Bank).

Through the renewable energy export initiative, dena provides support for German companies in opening up foreign markets and in their renewable technology export activities. The overall goal of the initiative is to increase renewable technology exports, but the export initiative further aims at:

- strengthening the competitiveness of German renewable energy technologies,
- climate protection and
- the promotion of sustainable energy policy in Germany's development assistance.

The main export barriers for renewable energy technologies can be differentiated between export barriers on the domestic and on foreign markets. The most important export barriers on the domestic market are: insufficient export credit insurance, insufficient information on financing possibilities, existing financing instruments that do not fit the specific characteristics of renewable technology exports, lack of skilled labor and insufficient information on foreign markets. The main export barriers on foreign markets include: complex bureaucratic regulations, lacking government promotion of renewable energy, lack of skilled labor, difficulties in business matching, and a lack of knowledge on the use of renewable energy technologies.[351]

To address these export barriers, support is provided through the renewable energy export initiative in three areas (see Fig 5-1):

1. Network building and coordination

The export initiative brings together decision makers from politics, public institutions and industry, thus creating a network to create strategic and comprehensive approaches as well as providing contacts and information.

2. Export expertise for German companies

Dena provides an internet database with information on potentials of different technologies, country information and renewable policy instruments of foreign governments. Dena further provides publications with information on target markets for specific technologies as well as newsletters and forums.

3. Development of foreign markets

The export initiative aims at opening up new markets. Through technology exhibitions and marketing packages, German renewable energy technologies are presented overseas. Furthermore, the German Chambers of Commerce Abroad (AHKs) prepare market entry through contacts and lobbying. The export initiative also finances some showcase projects, such as solar roofs on German schools abroad. The German Office for Foreign

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[351] VDI/VDE (2007), *Stand und Bewertung der Exportförderung sowie Evaluierung der Exportinitiative Erneuerbare Energien. Endbericht Teil II: Evaluation*, p. 22.

Trade (bfai) organizes networking events abroad to inform about German renewable energy technologies and the Federal Ministry of Economics and Trade organizes trade fairs.

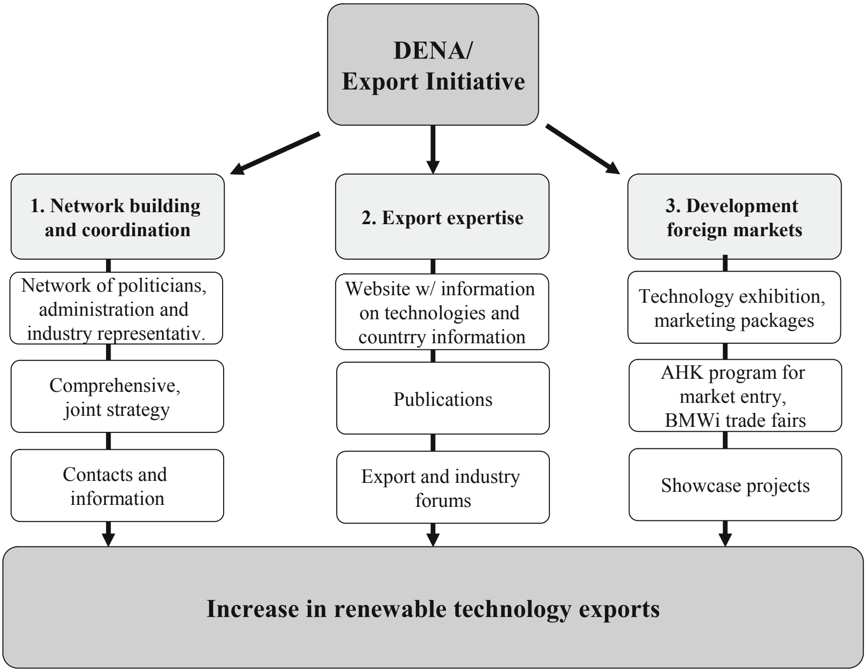

Fig 5-1: German renewable energy export initiative
Source: Deutsche Energie-Agentur (dena) (2007), Exportinitiative Erneuerbare Energien. Exportchancen steigern - Zukunftsfähigkeit sichern, pp. 2-3.

Funding for the export initiative is provided by BMWi. The ministry assigned € 11.6 million in 2004, € 9 million in 2005 and € 8.7 million in 2006 for the export initiative.[352]

The export initiative is mainly used by medium-sized companies. Large companies generally have subsidiaries or relevant business contacts abroad and are thus capable of exporting without the support of the initiative. Relatively few companies in the wind and hydro energy sector use the initiative, since these sectors are generally dominated by a number of big companies. The large majority (60 to 70%) of the companies that use the initiative are in the solar PV sector. These companies are generally relatively young and thus have few experiences in providing exports to foreign markets.[353]

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[352] VDI/VDE (2007), *Stand und Bewertung der Exportförderung sowie Evaluierung der Exportinitiative Erneuerbare Energien. Endbericht Teil II: Evaluation*, p. 6.

[353] Interview with Dr. Konrad Bauer, Project Director Renewable Energies, dena, January 28, 2008.

The renewable energy export initiative is foremost concentrated on providing information and support. Dena as the coordinating agency is the first contact point for businesses interested in exporting their renewable energy technologies. Dena also provides information on financing instruments available and refers interested parties to the relevant institutions, most notably the KfW Bankengruppe.

Export financing is provided by the KfW Bankengruppe and its project finance subsidiary, KfW IPEX-Bank. IPEX's division "Power, Renewables and Water", founded in 2003, provides financing worldwide for projects and companies in the sectors of wind energy, hydropower, biomass, geothermal and solar power.[354] Financing includes export financing and project financing. IPEX-Bank provides favorable interest rates and credit terms of normally 10 years.[355] Export credit insurance is provided in cooperation with Euler-Hermes Credit Insurance, the official German export credit agency. In one of its biggest renewable energy project, IPEX-Bank provided project financing of € 46.8 million for Taiwan's first commercial wind farm project in 2005. The wind farm was initiated by the German investors VWind AG and WPD AG.[356] In 2007, the "Power, renewables and water" division of IPEX-Bank provided € 1.9 billion for export and project financing, down from 2.5 billion in 2006.[357]

An external evaluation of the export initiative found in a 2007 report that the initiative is an important instrument of foreign trade promotion which should be continued.[358] One of the main strengths of the dena initiative is the concentration of different promotion instruments in one agency. This decreases the number of access points that companies have to contact for information and support and thus makes it easier for companies to find the relevant information. The main weakness of the initiative arises from the fact that its instruments are ill-equipped to address the needs of small-sized companies. Export financing under the terms of IPEX-Bank generally starts at € 10 million which often is too high for such companies.[359] Moreover, the costs for the examination of credit worthiness of small companies are very high in comparison to the size of their export projects. One solution to this problem could be to bundle smaller projects in order to achieve a higher distribution of risk.

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[354] KfW Bankengruppe (2004), *Investing in Clean Energy*, p. 6.

[355] Pabsch (2006), *Cross-Border Financing of Wind Projects Risks and Risk Mitigation - European Perspective*.

[356] Pabsch (2006), *Cross-Border Financing of Wind Projects Risks and Risk Mitigation - European Perspective*.

[357] KfW Bankengruppe (2008), *Semi-Annual Report*, p. 3.

[358] VDI/VDE (2007), *Stand und Bewertung der Exportförderung sowie Evaluierung der Exportinitiative Erneuerbare Energien. Endbericht Teil II: Evaluation*, p. 178.

[359] Interview with Dr. Konrad Bauer, Project Director Renewable Energies, dena, January 28, 2008.

5.1.1.2 Renewable Technology Export Promotion in the United States

Export promotion and financing in the United States is performed by many agencies. The most important agencies are the Department of Commerce, the US Export-Import Bank (Ex-Im Bank), the Overseas Private Investment Corporation and the Trade and Development Agency.[360] Other agencies, such as the Office of the US Trade Representative, the Department of State and the US Treasury are important in developing the general trade policy agenda.

There has been a debate in US Congress and the US administration since the mid-1980s to promote renewable energy exports in order to support US business in their external activities and in market penetration.[361] Today, the US government agencies administer a number of programs to promote and to finance renewable energy exports. The US Ex-Im Bank provides export financing and export credit insurance. The US Department of Commerce concentrates on providing relevant information and technical assistance. The US Department of Energy is also involved in renewable energy export promotion to further its specific agency mission.

The Ex-Im Bank, a government agency founded in 1934, finances non-defense exports. Its products include direct loans, guarantees, export credit insurance, working capital grants and tied aid funds.[362] The Export Enhancement Act of 1992 created a new mandate for the Bank to support exports “that have beneficial effects on the environment or mitigate potential adverse environmental effects.”[363] The resulting environmental exports program, which was renamed in renewable energy and environmental exports program in 2007, offers special grant and loan programs for environmental projects, as well as short-term environmental export insurance. The Bank continues to refine the list of technologies covered by the term “environmental”. Nuclear power was removed from the list in 1994.[364]

Transactions under the renewable energy and environmental exports initiative grew from 13 in fiscal year 1994 to 68 in fiscal year 2007, totaling over US$ 3 billion.[365] Among these, renewable energy exports represent more than a third of total environmental

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[360] US Congress (1993), *Development Assistance, Export Promotion and Environmental Technology*, p. 9.

[361] Brauch (1997), *Energiepolitik: Technische Entwicklung, Politische Strategien, Handlungskonzepte zu Erneuerbaren Energien und zur Rationellen Energienutzung*, pp. 239-242.

[362] O'Connor (2007), *Financing Renewable Energy, Ex-Im Bank*, slide 2.

[363] Export Enhancement Act of 1992, Public Law 102-429, Sec. 106.

[364] Pemberton/Renner (1998), *A Tale of Two Markets: Trade in Arms and Environmental Technologies*, p. 65.

[365] O'Connor (2007), *Financing Renewable Energy, Ex-Im Bank*, slide 3 and Ex-Im Bank website, http://www.exim.gov/products/policies/environment/index.html (access date: 11/12/2008).

transactions. From 1994 to 2007, over 65 renewable energy projects were supported, totaling over US$ 1.3 billion in exports.[366]

Renewable energy projects are given favorable credit terms such as reduced interest rates and long-term repayment terms. Through Ex-Im's Export Credit Insurance, US exporters can offer short- and medium-term credits directly to their customers abroad, enabling them to place larger orders than otherwise possible. In 2007, repayment terms of up to 15 years were extended for US renewable energy exports for two more years.[367] Such extended repayment terms are especially important for renewable energy projects, since – due to their high upfront costs – they generally require longer to generate the revenue needed to repay the loan.

Within the Department of Commerce (DoC), the International Trade Administration (ITA) is the main agent of export promotion. ITA operates the US and Foreign Commercial Service and is mostly responsible for distributing information and data on foreign markets. The main instruments are: export education, market/sector reports, and trade fairs.[368] Trade missions are a further instrument. In 2007, for example, ITA organized a renewable energy and alternative fuels trade mission to Europe for US firms interested in entering European markets.[369]

The energy industry team is part of the Office of Energy and Environmental Industries (OEEI) within the ITA. The team aims to help analyze and improve the international trade position of US energy technologies firms. It mainly provides support and guidance to such firms through trade missions and information. The trade team has renewable energy industry experts that assist companies interested in exporting renewable energy technologies. OEEI also publishes the "Energy and Environmental Export News". This newsletter offers information on industry trends, export opportunities, and other developments of interest to US companies active in these sectors.[370]

The Department for Energy (DoE) is the third main agency involved in the promotion renewable energy exports. DoE administers an International Renewable Energy Program under its Weatherization and Intergovernmental Program which aims at increasing the market share of US exporters on international markets for renewable energy technologies.[371] The program is concentrated on policy as well as technology guidance and assis-

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[366] Ex-Im Bank website, http://www.exim.gov/products/policies/environment/2007prog highlights.html (access date: 11/12/2008).

[367] Ex-Im Bank (2007), *Ex-Im Bank Extends Offer of 15-Year Repayment Terms to Support U.S. Exports for Renewable Energy and Water Projects, Press Release July 11, 2007*.

[368] US Congress (1993), *Development Assistance, Export Promotion and Environmental Technology*, p. 84.

[369] US Department of Commerce (2007), *Renewable Energy and Alternative Fuels Trade Mission to Europe*.

[370] See US Department of Commerce (2007), *Energy & Environmental Export News, Fall 2007*.

[371] See its website at http://apps1.eere.energy.gov/wip/international.cfm (access date: 11/19/2008).

tance for foreign countries in order to create a favorable environment for US exports. It further aims to help companies identify export opportunities and financing, and further assists in coordinating activities with other agencies. This program received a funding of US$ 9.4 million in fiscal year 2007.[372] For fiscal year 2008, however, no funding was allocated to the program.

In 1984, the Committee on Renewable Energy Commerce and Trade (CORECT) was setup to coordinate federal programs to promote renewable technology exports.[373] CORECT was under the umbrella of DOE and brought together 14 federal agencies and industry representatives.[374] CORECT has been very successful in bringing together federal agencies and industry but failed to present a comprehensive plan for increasing renewable energy exports. This program was closed in 2001, however, and funding has not been reauthorized since.[375] An attempt has been made by several members of the US Congress to re-authorize CORECT.[376] This attempt failed, though, and CORECT has not been re-established.[377]

Whereas Brauch (1997) states in 1997 that the United States is leading in its attempts to promote renewable energy exports[378], this is clearly not the case anymore. The United States has some programs to promote renewable energy technologies, but it lacks a comprehensive approach and a coordination of the various activities. CORECT was an attempt to concentrate the US efforts in renewable energy export promotion. However, since the closure of CORECT and compared to the German renewable energy export initiative, Germany has today the more coordinated and more advanced system of export promotion.

5.1.1.3 Renewable Technology Export Promotion in Japan

Japan has a long history of export promotion. Since the 1980s, import promotion has gained similar importance.[379] In Japan several institutions are involved in export promotion, but METI formulates Japan's export policy. The Japan External Trade Organization

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[372] US Department of Energy (2008), *FY 2009 Congressional Budget Request, Volume 3, Energy Supply and Conservation*, p. 455.

[373] Brauch (1997), *Energiepolitik: Technische Entwicklung, Politische Strategien, Handlungskonzepte zu Erneuerbaren Energien und zur Rationellen Energienutzung*, p. 239.

[374] US Congress (1993), *Development Assistance, Export Promotion and Environmental Technology*, pp. 86-87.

[375] HR 2884, http://thomas.loc.gov/cgi-bin/bdquery/z?d107:h.r.02884: (access date: 11/19/2008).

[376] HR 2884, dissenting view, http://energycommerce.house.gov/legviews/106lvhr2884.shtml.

[377] The U.S. Export Council for Renewable Energy (US/ECRE) is a further former program that no longer exists. US/ECRE was partially funded by DOE and was founded in 1982. It was a consortium of non-profit industry trade associations to support the export activities of the domestic renewable energy and energy efficiency industries.

[378] Brauch (1997), *Energiepolitik: Technische Entwicklung, Politische Strategien, Handlungskonzepte zu Erneuerbaren Energien und zur Rationellen Energienutzung*, p. 242.

[379] See Sakurai (2007), *JETRO and Japan's Postwar Export Promotion System*, p. 7.

(JETRO), METI's export promotion division, provides information and training. Other government agencies relevant for export promotion are: Japan International Cooperation Agency (JICA), responsible for technological assistance and Japan Bank for International Cooperation (JBIC), responsible for financing and loans.

Japan's foreign trade promotion is closely linked to its Official Development Assistance (ODA). Japan traditionally views aid more as economic "cooperation" than purely development assistance.[380] Japan's bilateral aid is still highly concentrated on Asian countries, even though in the past years, aid is becoming more geographically diverse. The largest share of its aid goes to economic infrastructure projects and the development of basic industries. Since the early 1990s, Japan has concentrated on a technology-based approach to address environmental problems at home and abroad while simultaneously creating business opportunities for its industries.[381] In this context, the promotion of renewrenewable technology exports has also gained in importance.

JETRO is a government agency under METI and aims to promote mutual trade and investment relations between Japan and its trading partners worldwide. JETRO's focus in export promotion is on helping small to medium size Japanese firms to maximize their global export potential through the provision of information. It provides overseas market surveys, business matching and exhibition projects. JETRO further gives support in the implementation of business deals. Data on export promotion are generally not explicitly expressed in Japanese programs and budgets. This has to do with the pressure of many governments worldwide, most notably the United States, to cease aggressive export promotion. Nevertheless, JETRO's budget hints at the de-facto export related budget. In fiscal year 2004, JETRO had a budget of ¥ 42.1 billion.[382]

Japan Bank for International Cooperation (JBIC), a government agency, is the most important agency for supporting renewable technology exports. Generally, JBIC provides assistance in two areas: international financial operations and overseas economic cooperation operations. The latter program aims to assist developing countries in their economic and social development. More important for renewable technology exports is the former program which aims to promote Japanese exports, imports and economic activities abroad through loan programs.

With regard to renewable technology exports, JBIC:

- provides financing support for exports of Japanese equipment such as wind turbine generators, solar panel systems, and energy conservation equipment and

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[380] US Congress (1993), *Development Assistance, Export Promotion and Environmental Technology*, p. 59. See this paper for an in-depth overview of Japan's foreign assistance, pp. 59-64.

[381] US Congress (1993), *Development Assistance, Export Promotion and Environmental Technology*, p. 61.

[382] See JETRO UK at, http://www.jetro.go.jp/uk/about/ (access date: 11/19/2008).

- offers special repayment periods and interest rates for renewable energy projects for foreign governments, power companies or financial institutions (see Fig 5-2).[383]

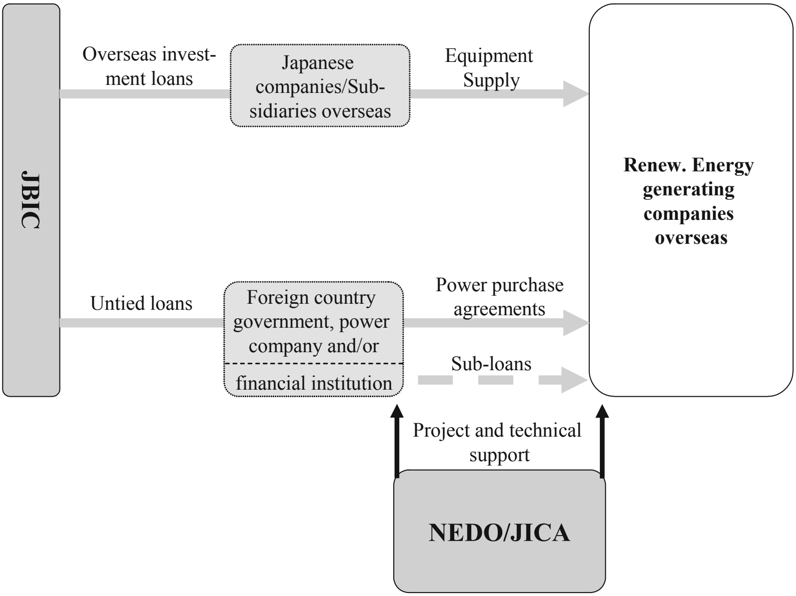

Fig 5-2: Japan's renewable energy export promotion
Source: Adopted from Japan Bank for International Cooperation (JBIC) (2007), *Japan's Policy for Promotion of New Energy Sources and Energy Conservation*, p. 5.

JBIC offers favorable loans for renewable projects of less than 50 MW.[384] Further, JBIC provides a 50% discount on technical consulting fee and loans repayable up to 12 years from completion.[385] In January 2008, JBIC announced programs under the "Cool Earth Partnership".[386] This loan scheme will provide financing for developing countries for projects aimed at reducing GHG emissions. Under this program, JBIC provided a ¥ 30,768 million loan for Indonesia to finance climate change projects.[387] JBIC is also an ac-

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[383] Japan Bank for International Cooperation (JBIC) (2007), *Japan's Policy for Promotion of New Energy Sources and Energy Conservation*, p. 5.

[384] Perez (2006), *Renewable Power in Emerging Countries. A Business Case for Investing in Renewable Power in Emerging Countries*, p. 54.

[385] Perez (2006), *Renewable Power in Emerging Countries. A Business Case for Investing in Renewable Power in Emerging Countries*, p. 54.

[386] Japan Bank for International Cooperation (JBIC) (2007), *Invitation to "Cool Earth 50": Moving Away from Carbon Emissions*, p. 1.

[387] Japan International Cooperation Agency (JICA) (2007), *JBIC Signs Japanese ODA Loan Agreement with Indonesia, Press Release September 2, 2008*, p. 1.

tive lender in geothermal projects in the Philippines. However, not all the loans can be ascribed to climate change projects, let alone renewable energy projects. Still, commitments for energy and natural resources finance reached ¥ 384.3 billion in fiscal year 2007. This amount accounted for 33% of the total commitments in international financial operations (excluding guarantees).[388] Export insurance is also important and is provided by the Nippon Export & Investment Insurance (NEXI).

JICA is Japan's development agency. JICA provides technological cooperation and assistance. Since October 2008, JICA is also responsible for loan assistance operations. Thus, JICA will provide both technical assistance as well as loan cooperation assistance.[389] With regard to renewable technology exports, JICA is mostly active in the investigation stage of overseas investments and exports and is supporting Japanese companies that are selling renewable energy equipment and implementing energy projects. Renewable energy projects pursued by JICA include the development of geothermal power generation in Tibet, support with renewable electric power plants in Laos and the connection of rural households in the Philippines to renewable power.[390] In fiscal year 2007, JICA had a budget of ¥ 161 billion.[391] However, only 1.3% of this budget was allocated to the energy sector.

Japan identified renewable technology exports as an important export sector for its industries and it thus striving to support its business to increase their exports. However, different agencies are involved in this process, making it difficult for Japanese companies to gather the relevant information. To better promote Japanese renewable technology exports, it would be more efficient to create more centralized support. It is difficult to gather data on the budgets for renewable technology promotion of the relevant agencies. The data presented in this section give first hints that the level of Japanese funding is lower than in Germany.

5.1.2 Restrictions of Renewable Energy Technologies Imports

Governments may try to hinder the imports of renewable energy technologies to favor domestic producers relative to foreign producers in the home market. Barriers to trade can either consist of tariffs or of non-tariff barriers to trade. Tariffs make the foreign product more expensive relative to domestic products. Non-tariff barriers such as technical or en-

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[388] Japan Bank for International Cooperation (JBIC) (2008), *JBIC Reports on FY 2007 Operations*, p. 1.

[389] See Japan International Cooperation Agency (JICA) (2008), *New JICA is Born, Press Release October 1, 2008*.

[390] See Japan International Cooperation Agency (JICA) (2008), *Current National Resources and Energy Projects*, p. 1.

[391] Japan International Cooperation Agency (JICA) (2007), *Annual Report 2007*, Statistical Overview of JICA Activities, p. 31.

vironmental standards also increase the costs for importers who have to adapt their producers to be consistent with these standards.

This section looks at applied tariffs for renewable energy products that Germany[392], the United States and Japan charge on imports. The data on applied tariffs are taken from the WTO's Integrated Database, available through the WTO website. WTO member governments provide these data annually on the tariffs that they apply under WTO's most-favored nation (MFN)[393] clause.

Non-tariff barriers to trade may also impact the trade flows of renewable energy technologies.[394] However, this section focuses on tariff data since the data on non-tariff barriers are incomplete and the international comparability of standards is limited. The research in this area should be intensified in order to determine to what extent non-tariff barriers might distort international trade in this sector.

Table 5-1 shows ad valorem tariffs[395] for renewable energy technologies[396] as applied in the three countries.

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[392] Germany, as a member of the European Union, has transferred its competence in trade policy to the European level. Accordingly, its tariff rates are equal to tariffs in all other EU member countries.

[393] The MFN principle is one of the main principles of the WTO and means that a WTO member has to grant all trade advantages that one WTO trading partners receives to all other WTO members as well.

[394] Compare US International Trade Commission (2005), *Renewable Energy Services: An Examination of U.S. and Foreign Markets*, p. ix. See also Howse (2005), *World Trade Law and Renewable Energy: The Case of Non-Tariff Measures*. Howse's study on world trade law and renewable energy examines the compatibility of government policies to promote renewable energy with WTO law.

[395] Ad valorem tariffs state the tax as a percentage of the import value.

[396] The list of goods selected is based on the methodology of the analysis of international markets for renewable energy technologies as elaborated in section 5.2.1.

Tab 5-1: Applied tariff rates on selected renewable energy technologies in Germany, the United States and Japan

HS no.		HS description	Germany	United States	Japan
730820	Wind Power Plants	Towers and lattice masts	0	0	0
841280		Other engines and motors	4.2	0	0
841290		Parts of other engines and motors	2.7	0	0
841381		Pumps for liquids, whether or not fitted with a meauring device, other pumps	1.7	0	0
848340		Gears, ball or roller screws, gear boxes (specifically for wind turbines)	3.7	3.8	0
848360		Clutches and shaft couplings (specifically for wind turbines)	2.7	2.8	0
850231		Generating Sets, Wind-Powered	2.7	2.5	0
841581	Geothermal or biomass plant	Incorporating a refrigerating unit and a valve for reversal of the cooling/heat cycle	2.7	1	0
841861		Compression type refrigeratg/freez equip	2.2	0	0
841950		Heat exchange units	1.7	4.2	0
841869		Other refrigerating or freezing equipment	2.2	0	0
850239		Other power generation sets	2.7	2.5	0
841181		Other gas turbines, not exceeding 5,000 kW	4.1	2.5	0
841182		Other gas turbines exceeding 5,000 kW	4.1	2.5	0
840681		Steam turbines and other vapour turbines, other turbines, of an output > 40 MW	2.7	6.7	0
840682		Steam turbines and other vapour turbines, other turbines, of an output < 40 MW	2.7	6.7	0
840690		Parts of steam turbines	2.7	6.7	0
841011	Hydro power plant	Hydraulic turbines and water wheels of a power not exceeding 1000 KW	4.5	3.8	0
841012		Hyd turbines and water wheels of a power exc 1000 KW but not excedg 1000	4.5	3.8	0
841013		Hydraulic turbines and water wheels of a power exceeding 10000 KW	4.5	3.8	0
841090		Parts of hydraulic turbines & water wheels including regulators	4.5	3.8	0
854140	Solar Power	Photosensitive semiconductor devices, incl. photovoltaic cells, light emitting diodes	0	0	0
850440		Photovoltaic system controller	3.3	1.5	0
853710		Other static converters	2.1	2.7	0
850161	Renewable Energy Plant	AC generators not exceeding 75 kVA	2.7	2.5	0
850162		AC generators exceeding 75 kVA but not 375 kVA	2.7	2.5	0
850163		AC generators not exceeding 375 kVA but not 750 kVA	2.7	2.5	0
850164		AC generators exceeding 750 kVA	2.7	2.4	0

Source: WTO (2009), Tariffs, http://www.wto.org/english/tratop_e/ tariffs_e/tariffs_e.htm (access date: 03/03/2009)

Japan is the most open economy with regards to renewable energy technology imports among the three countries. All selected goods enter Japan duty free. In comparison, in 2008 the average applied MFN tariff rate for all industrial goods was 3.6%.[397]

German tariff rates are higher with an average tariff rate of 2.8% for the goods analyzed. Average MFN tariffs on manufactured imports average 6.8%, however, in the European Communities.[398] Still, only two renewable energy technology goods (photosensitive semiconductor devices and towers and lattice masts) enter Germany duty free. It is interesting, however, that these two goods constitute the main parts of solar power and wind power plants respectively.

US applied tariffs for renewable energy technologies are relatively low (average of 2.5%). By comparison, in 2007 the average applied MFN rate for non-agricultural products was 4%.[399] The tariffs for renewable energy technologies are zero in 7 of the 28 HS codes in Table 5-1. However, there are some products (mostly steam turbines) in which the US tariffs of 6.7% are the highest among all tariffs compared here.

The data show that the three countries do not try to influence international trade patterns by setting high tariffs to a larger extent. Accordingly, tariffs in Germany, the United States and Japan are not a significant impediment to trade in renewable energy technologies.[400] However, since the tariff data in Table 5-1 pertain only to industrial goods, this result does not come as a surprise. Tariffs for industrial goods are generally relatively low in industrialized countries.

5.2 International Markets for Renewable Energy Technologies

Historically, electricity itself has not been traded across borders to a large extent. This has changed, however. Germany for example imports significant amounts of electricity from France. The data on electricity trading are not differentiated by energy sources, however. This means that looking at traded electricity does not allow an analysis of the development of electricity trading by source. The relative success of different energy sources including renewable energy sources cannot be determined when looking at traded electricity. What can be done, however, is to look at trade in goods and services that are inputs in the production, distribution, transmission and sale of electricity. Alongside the expansion of renewable electricity generation in many countries in the world, the trade of

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[397] World Trade Organization (2009), *Trade Policy Review Japan*, p. x.

[398] World Trade Organization (2007), *Trade Policy Review European Communities*, p. 79.

[399] World Trade Organization (2008), *Trade Policy Review United States of America*, p. 23.

[400] The situation is different, though, for many developing countries. Tariffs for renewable energy technologies are 15% or higher in many developing countries, see OECD (2006), *Liberalisation of Trade in Renewable-Energy and Associated Technologies: Biodiesel, Solar Thermal and Geothermal Energy*, p. 8.

technologies used in the harvesting of renewable power has also increased and is expected to continue to expand in the future.[401] Still, a systematic analysis of the development of trade in renewable energy goods, as well as the most dynamic renewable energy sectors, the most important trading countries and an overview of sectoral export performance in renewable energy technologies does not yet exist in the literature.[402]

This section answers the following questions:

- How has international trade with renewable energy goods developed since 1996?
- Which are the most dynamic sectors within renewable energy trading?
- Which are the leading trading countries in this sector?
- How specialized and how competitive are Germany, Japan and the United States in renewable energy goods trading?

The statistical analysis of flows of commodities in international trade offers two main advantages: it allows for a detailed examination of different markets on a disaggregate level and is also useful in identifying the competitive stance of different countries on these markets. Moreover, the competitive relations between different economies on disaggregated markets can be exemplified.

One assumption derived from the literature on international competitiveness and renewable energy discussed in Chapter 2 (compare section 2.4.3.c) is that home market size is positively correlated to international trade performance. This would imply that Germany should be relatively more successful in trading wind and solar technologies, while the United States should put more focus on trading geothermal and hydro technologies and Japan's main trading focus should be on solar energy devices. The analysis of international renewable energy technology markets also examines if these assumptions are supported by empirically data.

5.2.1 Methodology

This section presents the indicators used to analyze international trade in renewable energy goods. It further discusses important restrictions for the analysis and then presents the relevant renewable energy goods with their respective trade codes.

The trade data are taken from COMTRADE of the United Nations Statistics Division. This database contains values and to a limited extent quantities of exports and imports for 184 countries, capturing 95% of world trade in goods in over 5.000 products. The data used are based on the 6-digit-level of the Harmonized System (HS), 1996 and 2002 editions, an international commodity classification system (with six-digit codes) of export

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[401] See German Institute for Economic Research (DIW) et al. (2008), *Economic Analysis and Evaluation of the Effects of the Renewable Energy Act* for a survey among German renewable energy companies and their perspective on sales of products and services on international markets.

[402] The studies that deal with certain aspects of renewable energy trading are presented in section 5.2.1.4.

and import statistics. The data availability is very different though for different countries. For this reason, world exports or world imports refer to the exports and imports of OECD countries plus China (Mainland and Hong Kong) and Russia. What is not included is the trade between non-OECD countries among themselves, which represents about one fifth of world trade.[403] The share of renewable energy trading of OECD countries (plus China and Russia) can be expected to represent a similar share of total trade in renewable energy goods (four-fifth of world trade). This assumption has been checked and confirmed for the year 2004, for which data availability for all countries is comparably good.[404]

The International Trade by Commodities Statistics (ITCS) database of the OECD also offers trade data on the 6-digit-level of the Harmonized System, but the coverage of the most recent years is less complete compared to the UN database. Moreover, the ITCS does not allow searching for aggregated world exports and imports. This means that computing world export data requires the adding up of all the individual countries exports to the world. This involves great risk for statistical errors and is considerably more time-consuming.

Thus, the UN database has been chosen for the purpose of this study.

5.2.1.1 Indicators

This section presents the indicators used in this analysis of renewable energy trade and the positions of Germany, Japan and the United States on international markets in order to answer the questions outlined above.

In the public debate the success of a country’s trade performance is often reduced to a strong export performance. Export profitability and the ability of the firm to maintain its market share remain the ultimate indicators of international competitiveness. In the same way, the term international competitiveness is frequently restricted to this meaning. Even some economists measure international competitiveness only after the export market share of countries.[405] However, it is long accepted that export performance alone is a poor indicator of trade performance more generally and that the success of a certain industry and its competitiveness cannot be measured in export performance alone.[406]

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[403] Schumacher/Lucke/Schröder (2004), *Wechselkursveränderungen und Außenhandelsposition bei forschungsintensiven Waren*, p. 7.

[404] The trading of non-OECD countries represent about one fifth of total merchandise trade and renewable energy trade.

[405] See Gundlach/Nunnenkamp (1994), *The European Union in the Era of Globalisation: Competitive Challenges, Structural Unemployment, and Policy Responses*, p. 202-205.

[406] See Holtfrerich (2007), *Wo sind die Jobs?: Eine Streitschrift für mehr Arbeit* for a debate on the negative aspects of the German current account surpluses. The surpluses are, as Holtfrerich argues, the result and the symptom of the problems of the German economy such as reduced investments and large net capital exports, and represent reduced standards of living in Germany.

In order to make the terms trade performance, specialization and competitiveness meaningful it is important to state the indicators computed clearly. The empirical section of this chapter first presents the development of renewable energy trading since 1996. The analysis is broken down by the different renewable energy categories examined (wind, biomass, geothermal, hydro and solar PV). The most important indicators here are growth rates and the changes of market shares. Secondly, the positions of Germany, Japan and the United States are analyzed in detail. The indicators used in this section are divided in two categories: trade performance indicators and specialization indicators.

I) Trade Performance Indicators

These indicators provide information on country's flows of trade (exports and imports) either in total trade or in a specific sector such as their growth in values or volumes, the share in world's trade flows or per capita exports.

Annual growth rates:

Annual growth rates[407] are used for comparing rates of growth of exports and imports of good i in one country with the growth rates in other countries or the average world growth rate. The annual growth rate (G) over a certain period of time is computed as follows:

$$G_i = \left[\left(\frac{V_2}{V_1} \right)^{\frac{1}{n}} - 1 \right] * 100$$

where V_1 and V_2 are the trade values of product i in period 1 and 2, and n is number of years. Growth rates are also helpful in identifying the most dynamic products or sectors. Such products may not constitute a large share of exports in a country, but above-average growth indicates which products and sectors are likely to gain further importance in the future.

Net exports:

The balance of exports and imports in renewable energy goods describes whether countries are rather a supplier of these goods to the world or a demander.

Exports per capita:

In general, the level of exports is determined by the demand for a country's products in other countries and the country's ability to satisfy that demand. As stated earlier, high exports surpluses are often regarded as a clear indicator for a competitive advantage and a strong trade performance. However, high absolute exports have only very limited significance in explaining trade performance, since bigger countries naturally also exhibit larger

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[407] See Hoekman/Nicita/De Melo (2002), *Development, Trade, and the WTO: A Handbook*, Appendix I Trade Indicators and Indices, p. 585.

trade volumes.[408] Accordingly, a more suitable and more reliable indicator measures exports and imports per capita in order to reassess the development of trade flows relative to a country's size (here measured in population size).[409] The change in per capita exports indicates changes in a country's performance for the products or sectors examined.

II) Specialization Indicators

The second group of indicators include those which provide information on the degree of export specialization and thus indirectly a competitive ability of a country.

Share in national exports (imports):

This indicator refers to the share of exports (imports) by product or sector in relation to total country exports (imports). Computing this indicator reveals the relative export performance of one sector in comparisons to other sectors. It masks out the size of a country and also the general export success of a country and is therefore a helpful indicator when examining the trade performance of certain sectors of a country's economy:

$$\frac{X_{ij}}{X_{tj}}$$

where X_{ij} is the export value of product i of country j and X_{tj} stands for total export value of country j.

World market share:

The world market share for a specific country in a specific product is the ratio of a country's exports in product i and world exports in product i:

$$\frac{X_{ij}}{X_{iw}}$$

This indicator reveals the export structure of an economy and the importance of certain sectors for countries over one year.

However, the interpretation of this indicator is problematic and ambiguous. First of all, the export values for Germany include all international trading partners, meaning also those exports destined for its European neighbors. In other countries such as the United States with a much larger area trading between the different regions (the states) is not included. A smaller size of the economy and the membership in supranational organization with its effect of trade creation (internally) and trade diversion (externally)[410] among other factors, increases trade intensity without any implications for trade performance. This

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[408] Diekmann/Horn/Ziesing (1997), *Energiepreise als Standortfaktor für die deutsche Wirtschaft*, p. 121.

[409] Schumacher/Lucke/Schröder (2004), *Wechselkursveränderungen und Außenhandelsposition bei forschungsintensiven Waren*, p. 40.

[410] View Viner (1950), *The Customs Union Issue* for the most fundamental discussion of trade effects of custom unions.

makes the comparison of the values for Germany on the one hand and for the United States but also Japan on the other hand difficult.

The comparison over years is also problematic since the values are given in current prices and exchange rates. For the very disaggregated level of trade data used in this study, there are no deflators available, especially not for all countries taken into account. This implies that fluctuations in the business cycle and also exchange rates changes, which very often represent the general trust in a country's currency and financial and economic stability, deteriorate the data to a certain extent. A low absolute export level, measured in current prices and exchange rates, can be underestimated in times of an undervalued currency. On the contrary, a high export level can be the result of an overvaluation of the currency and not of technological innovation. Time lags between the impulse, the reaction and the evaluation also have to be considered.[411] This is described by the j curve effect, which states that in the short term a devaluation of the exchange rate may not increase exports and decrease imports. There can actually be a worsening of the deficit for some time after a decline in the currency, as the rise in the price of imports is greater than the effect on exports. This can be explained by the low price elasticity of demand for imports and exports in the short term. In the longer term, the trade balance will improve after a depreciation of the exchange rate. This also means however, that increases in trade volumes can be the result of exchange rate changes of previous years. For these reasons, the world market shares are not evaluated over a period of years, but for the latest year available.

Revealed Comparative Advantage (RCA):

One of the most widely accepted approaches in analyzing trade data and the relative positions of countries on certain markets is the RCA (Revealed comparative advantage index). This index dates back to Balassa (1965). The original RCA index of country j for product i is measured by the products' share in the country's exports in relation to its share in world trade:

$$RCA_1 = \frac{\left(\dfrac{X_{ij}}{X_{tj}}\right)}{\left(\dfrac{X_{iw}}{X_{tw}}\right)}$$

where X_{ij} and X_{iw} are the values of country's j exports of product i and of world exports of product i and where X_{tj} and X_{tw} refer to the country's total exports and world total exports. If the RCA takes a value of less than 1 this implies that the country has revealed compara-

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[411] Baily/Lawrence (2006), *Competitiveness and the Assessment of Trade Performance*.

tive disadvantage in the product. Similarly, if the index exceeds 1, the country has revealed comparative advantage in this sector's exports.

Accordingly, the assumption of the original RCA index (RCA_1) is that countries that have a comparative advantage in the production of a good should be found to export a higher proportion of that good relative to other countries. Thus, this index is rather an indicator of specialization. The main advantage of this indicator is that it looks at the relative position of sectors within countries and not the absolute values of exports or the level of net exports, which are poor indicators for trade performance as has been discussed earlier. For example the comparative disadvantage of the German textile industry does not result from much cheaper textiles from Asia, but from the relative strength of the German machinery sector such as the automobile sector.

Since the original publication of Balassa's index in 1965, there has been a vast literature dealing with both theoretical and empirical improvements of measuring comparative advantages relative to the original index described above.[412] One problem of the original index is that it is asymmetrical and accordingly, not comparable on both sides of unity, since the index ranges from zero to one for a comparative disadvantage and from one to infinity for a comparative advantage. Vollrath (1991) suggests taking the logarithm of the RCA to solve this problem. Moreover, Vollrath (1991) argues that the original RCA index is biased due to the omission of imports and proposes a different index, which is also widely used today:

$$RCA_2 = \ln \frac{\left(\dfrac{X_{ij}}{M_{ij}} \right)}{\left(\dfrac{X_{tj}}{M_{tj}} \right)}$$

where X_{ij} and M_{ij} are the values of country's j exports and imports of product i where X_{tj} and M_{tj} refer to the country's total exports and imports.

The RCA_2 measures how the export-import relation of country j for good i differs from the overall foreign trade position of the country. A positive index indicates a comparative advantage that is a strong competitive position of the examined sector in the country. This indicator thus *reveals* which trade sector succeeded in penetrating foreign

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[412] See for a discussion on RCA Siggel (2006), *International Competitiveness and Comparative Advantage: A Survey and a Proposal for Measurement*, Bowen/Hollander/Viaene (1998), *Applied International Trade Analysis*, pp. 15-24 or Greenaway/Milner (1993), *Trade and Industrial Policy in Developing Countries*, pp. 181-211.

markets to a larger extent than foreign competitors in this sector entered the national market.[413] A negative index shows a revealed comparative disadvantage.

In the literature many more forms of RCA indicators have been proposed[414], but this study concentrates on the two RCA indicators presented so far, since they capture the most important aspects of trade performance: firstly, the relative trade performance of one specific sector (here the renewable energy sector) in one country compared to this sector worldwide and secondly, the relative trade performance of one specific sector compared to the general trade performance of one country.

However, the interpretation of these indicators is difficult and has to be pursued cautiously. The level of specialization revealed by the indicators does not allow conclusion to be drawn on its causes, such as industrial policy, national economic growth rates or tariff or non-tariff barriers to trade. All these restrictions have to be taken into account when interpreting the empirical findings.

5.2.1.2 Identifying Renewable Energy Goods

The analysis of international trade patterns in renewable energy technologies poses several methodological problems; the two most important being the question of which goods to include in the analysis and the related problem of dual use of goods.

Compiling the relevant data to analyze import and exports of renewable energy technology is fairly difficult since the relevant goods are not identified in a set list with the specific trade codes. One reason for this is that there have been little efforts to create a continuing and well defined list for renewable energy goods. In the past years, however, international organizations such as the WTO and the OECD, which discuss renewable energy goods as a subcategory of environmental goods, have realized the importance of creating such a list.

The debates thereby center on the definition of environmental and renewable energy goods. The starting point for the discussion was the 1996 definition of environmental industry by the OECD:

> “The environmental goods and services industry consists of activities which produce goods and services to measure, prevent, limit, minimize or correct environmental damage to water, air and soil, as well as problems related to waste,

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[413] Gehrke/Krawczyk/Legler (2007), *Forschungs- und wissensintensive Wirtschaftszweige in Deutschland: Außenhandel, Spezialisierung, Beschäftigung und Qualifikationserfordernisse*, p. 22.

[414] Compare among many Utkulu/Seymen (2004), *Revealed Comparative Advantage and Competitiveness: Evidence for Turkey Vis-a-Vis the EU15*, Laursen (1998), *Revealed Comparative Advantage and the Alternatives As Measures of International Specialisation* and Gehrke/Krawczyk/Legler (2007), *Forschungs- und wissensintensive Wirtschaftszweige in Deutschland: Außenhandel, Spezialisierung, Beschäftigung und Qualifikationserfordernisse* for a discussion on different RCA indicators.

> noise and eco-systems. This includes cleaner technologies, products and services that reduce environmental risk and minimize pollution and resource use."[415]

Based on this definition, the Asia Pacific Economic Co-operation (APEC) and the OECD developed two different lists of environmental goods, which have framed the debates in the WTO.[416] The mandate of the latest WTO trade round that started in 2001 in Doha includes the aim to reduce or eliminate trade barriers to environmental goods and services (Para 31 (iii) of the Doha Ministerial Declaration).

The member states of the WTO have put forward positive lists of environmental goods that should be included in the final list. The submission of Canada[417], the European Communities[418], New Zealand[419] and the United States[420] to the WTO Committee on Trade and Environment include subsections on products relevant for renewable energy plants. In 2005, the secretariat of the WTO published a synthesis of its member states submissions on environmental goods including a list of environmental goods and a subsection on renewable energy goods.[421]

Still, there is no commonly agreed definition of renewable energy goods so far and accordingly no accepted list of renewable goods with their respective trade codes. However, a list of "renewable goods" is essential in order to analyze international trade patterns and also levels of tariff protection.

To create a list of renewable energy goods, lists of goods produced and used by the renewable energy industry must be assembled. Internationally traded goods are based on the Harmonized System (HS). So far, however, no HS chapter exists for "renewable energy goods" just as there is no chapter for "environmental goods". Thus, some renewable energy technologies and their components are not separately identified at the six-digit level in the HS. Moreover, national nomenclatures are often developed to levels of 8, 10 or more digits. Accordingly, identifying renewable energy goods on the basis of six-digit HS trade codes – which presents the only valid basis for an international comparison – involves capturing categories of goods at a higher level of aggregation than the national level and their distinct code.

While this is not a problem for some unequivocally identifiable renewable goods, such as hydraulic turbines (HS 841011), using the six-digit levels is more problematic for

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[415] OECD (1996), *Interim Definition and Classification of the Environment Industry*.

[416] See OECD (2003), *Environmental Goods: A Comparison of the APEC and OECD Lists*.

[417] World Trade Organization (2005), *Canada's Initial List of Environmental Goods*.

[418] World Trade Organization (2005), *EC Submission on Environmental Goods*.

[419] World Trade Organization (2005), *Revised New Zealand Provisional List of Environmental Goods*.

[420] World Trade Organization (2005), *Initial List of Environmental Goods: Submission by the United States*.

[421] World Trade Organization (2005), *Synthesis of submissions on environmental goods*.

other renewable energy goods. However, more differentiated trade codes than the HS6 category, which might be helpful in clearly identifying certain renewable energy goods, are not internationally harmonized. Accordingly, limiting renewable energy goods to six digit categories is for now the only practical way to compare trade patterns across countries and the resulting relative impreciseness will have to be accepted.

5.2.1.3 Dual or Multiple Use

A second methodological challenge in the attempt to analyze international trade patterns in renewable energy technologies is the dual or multiple use of goods.[422] Many goods used for harvesting renewable energy can also be used for other purposes and thus have a multiplicity of possible uses. For example, a turbine can be used in a wind power plant, but also in a power plant producing electricity from conventional fuels. This dual or multiple use problem complicates the process of estimating trade flows. Again, as long as there is no more accurate classification, researchers will have to deal with this problem, because there is no sound method for separating trade data for items classified under the same six-digit HS number. Inevitably, the sample of trade codes used in the analysis must either exclude certain products with clear renewable energy uses or risk to include some trade flows that are of non-renewable energy use.

In order to keep the data as reliable as possible, two lists are developed for the purpose of this study: one which includes unequivocally identifiable renewable energy goods and one which includes goods, which are essential in producing renewable energy but which might also be used to some degree for other appliances.

5.2.1.4 Relevant Trade Codes

The International Harmonized Commodity Coding and Classification System (HS) was established by the World Customs Organization and the HS code was first adopted in 1988. HS is an international standard for world trade at different levels of detail used by about 200 countries worldwide. The data for this analysis are taken from the 1996 version, the first revision of the HS. The HS-1996 with 6-digit trade code (HS6), the most detailed level internationally, represents a total of 5,113 separate categories of goods identified, under 97 different chapters. The latest revision took place in 2007. 260 HS6 codes have been added and 431 were deleted, but nothing changed for renewable energy goods. This implies that none of the limitations of analyzing renewable energy trade flows were addressed in the latest revision of the HS. The data for the year 2007 were assembled from the 2002 version of the HS.

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[422] See OECD (2005), *Liberalising Trade in "Environmental Goods": Some Practical Considerations*, p. 7-10 and OECD (2006), *Liberalisation of Trade in Renewable-Energy and Associated Technologies: Biodiesel, Solar Thermal and Geothermal Energy* for a further discussion on the dual use of products.

This study intends to contribute to creating a statistical base for cataloging renewable energy goods according to the 6-digit harmonized system. This analysis mostly builds on several earlier studies which were faced with the same methodological problems in identifying the relevant trade codes.

One of the first studies was commissioned by the European Commission and was published in 2002.[423] This study used the export data for EU15 countries and the period 1995-1999 to provide an assessment of renewable energy trade in and out of the EU. The aim of the study was to allow an analysis of developments and trends in the past, giving information on expected trends in the future. This study focused mainly on solar subsectors, such as solar thermal water heaters and photovoltaic products, and hydropower components. The authors did not include trade data for wind power and biomass technology. In total, the authors identified only 7 renewable energy trade codes under the HS6 and the trade data were provided by EUROSTAT.[424]

In 2005, the United States International Trade Commission (USITC) published a study on „Renewable Energy Services" and analyzed the US and foreign markets.[425] The definition of renewable energy services which is used in the report is very broad: "renewable energy services include the generation, transmission, distribution, and sale of heat and electricity produced through the use of wind, solar, biomass, geothermal, or ocean energy."[426] The authors identify 34 internationally traded goods that are essential in the provision of such services.[427] Included in their lists are also goods relevant for the heating sector, such as solar water heaters (HS 841919). Because of the dual use problem, the authors call these products "environmental goods" instead of renewable energy goods. In the actual empirical analysis, however, the author focuses on renewable energy electricity production and generation capacity in the United States and selected foreign countries and do not offer an examination of actual trade flows in renewable energy technologies. Accordingly, the title of the study is to some extent misleading since normally the generation of renewable energy is not considered as a service and the analysis of international trade with renewable energy has to focus on goods anyhow, since renewable energy services in the sense of the title of this study are not traded.

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[423] ECOTEC (2002), *Renewable Energy Sector in the EU. Its Employment and Export Potential*.

[424] See Appendix Table A-3 for a list of the trade codes used in the study.

[425] US International Trade Commission (2005), *Renewable Energy Services: An Examination of U.S. and Foreign Markets*.

[426] US International Trade Commission (2005), *Renewable Energy Services: An Examination of U.S. and Foreign Markets*, p. 1-2.

[427] See Appendix Table A-4 for a list of environmental goods identified in this study.

The OECD examined trade in renewable products in two papers which were published in 2005[428] and 2006.[429] The 2005 publication examined the implications of liberalizing trade in renewable energy with a focus on solar photovoltaic systems, wind turbines and wind pumps. The 2006 report focuses on biodiesel, solar thermal and geothermal energy. Both reports do not feature a detailed analysis of trade flows in renewable energy technologies, but do include lists of renewable energy goods with their respective trade codes.[430] Since both renewable fuels (such as charcoal and biodiesel) and technologies for harnessing renewable energy are included, the studies identify more relevant trade codes than the USITC study. In total, the author include 27 six-digit trade codes for primary renewable energy products for harnessing renewable energy and 14 trade codes for common components of renewable-energy based systems.

The German Federal Environment Agency (UBA) commissioned a study on the international competitiveness of the German environmental and climate protection industry, which was published in 2006.[431] It comes to the conclusion that Germany still holds an outstanding position in environmental technology compared internationally. The study also included renewable energy goods in their empirical dataset, restricting the goods analyzed to only eight different renewable energy goods[432], however. This study does not use the HS, but a national nomenclature on the basis of the "Systematischen Güterverzeichnisses für Produktionsstatistiken" of the German Federal Statistical Office. Still, this study is very interesting since it is the only major study that actually uses the compiled data to estimate different trade indicators (such as RCA) in the relevant industry sectors for Germany and internationally.

In 2008, the World Bank published a study on climate change and international trade.[433] The study identifies 43 products as climate-friendly.[434] According to this study, the removal of tariffs and non-tariff barriers for these goods could increase trade up to 13 percent annually.[435]

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[428] OECD (2005), *Liberalisation of Trade in Renewable-Energy and Associated Technologies: Charcoal, Solar Photovoltaic Systems, and Wind Pumps and Turbines*

[429] OECD (2006), *Liberalisation of Trade in Renewable-Energy and Associated Technologies: Biodiesel, Solar Thermal and Geothermal Energy*.

[430] See Appendix Tables A-5 and A-6 for the renewable energy goods identified in the reports.

[431] Legler (2006), *Wirtschaftsfaktor Umweltschutz: Leistungsfähigkeit der deutschen Umwelt- und Klimaschutzwirtschaft im internationalen Vergleich*.

[432] See Appendix Table A-7.

[433] World Bank (2008), *International Trade and Climate Change: Economic, Legal and Institutional Perspectives*.

[434] See Appendix Table A-8.

[435] World Bank (2008), *International Trade and Climate Change: Economic, Legal and Institutional Perspectives*, p. 10.

Two main restrictions have been applied in the choice of trade codes for the purpose of this study.[436] Firstly, only those renewable energy technologies are included that are used in the electricity sector. Products relevant for the heating or transportation sector are excluded. As an example, trade code HS 841911 (Instantaneous gas water heaters, non-electric), which is classified a renewable energy good in all mentioned reports, is not used in this study, because it is relevant for the heating and not the electricity sector.

International trade in renewables falls into two categories: trade with actual energy units (e.g. bio fuels) and trade in goods or equipment used to generate or collect energy from renewable sources (PV cells or wind-driven turbines). The second main restriction requires that solely goods used in the production process of renewable energy are included and not renewable energy fuels as such. Two lists of relevant trade codes have been developed for this study: one with a very narrow understanding of renewable energy products (see Table 5-2), and a second list with complementary renewable energy goods (Table 5-3). For the second list, the risk and probability is higher that the share of products that are also used for non-renewable energy purposes is larger than for the first list. Thus, the resulting data of the second list might overestimate the trade flows in renewable energy products.

Tab 5-2: Primary renewable energy goods

HS no.	HS description	Renewable Energy Application
854140	Photosensitive semiconductor devices, incl. photovoltaic cells, light emitting diodes	Solar plant
850231	Generating Sets, Wind-Powered	Wind power plant
841011	Hydraulic turbines and water wheels of a power not exceeding 1000 KW	Hydro power plant
841012	Hyd turbines and water wheels of a power exc 1000 KW but not excedg 1000	Hydro power plant
841013	Hydraulic turbines and water wheels of a power exceeding 10000 KW	Hydro power plant
841090	Parts of hydraulic turbines & water wheels including regulators	Hydro power plant
840681	Steam turbines and other vapour turbines, other turbines, of an output exceeding 40 MW	Geothermal or biomass plant, low-temperature and low-pressure steam turbines
840682	Steam turbines and other vapour turbines, other turbines, of an output not exceeding 40 MW	Geothermal or biomass plant, low-temperature and low-pressure steam turbines
840690	Parts of steam turbines	Geothermal or biomass plant

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[436] See Appendix Table A-9 for a comparison of the renewable energy goods of the different studies.

Tab 5-3: Complementary renewable energy goods

HS no.	HS description	Renewable Energy Application
853710	Boards, cabinets and similar combinations of apparatus for electric control or the distribution of electricity, for a voltage <= 1.000 V	Photovoltaic system controller
850440	Other static converters	Photovoltaic: Inverters for photovoltaic solar
730820	Towers and lattice masts	Wind power plant
841280	Other engines and motors	Steam engines; windmills without pumps
841290	Parts of other engines and motors	Parts for steam engines and windmills
841381	Pumps for liquids, whether or not fitted with a meauring device, other pumps	Wind power plant, wind turbine pumps
848340	Gears, ball or roller screws, gear boxes	Gears and gearing and other speed changers (specifically for wind turbines)
848360	Clutches and shaft couplings (incl. universal	Clutches and universal joints (specifically for
841581	Incorporating a refrigerating unit and a valve	Geothermal plant, heat pumps
841861	Compression type refrigeratg/freez equip	Geothermal plant, heat pumps
841869	Other refrigerating or freezing equipment	Geothermal plant, heat pumps
841950	Heat exchange units	Geothermal power generation
841181	Other gas turbines, not exceeding 5,000 kW	For biomass plants
841182	Other gas turbines exceeding 5,000 kW	For biomass plants
850239	Other power generation sets	Other generating sets (specifically gas turbine
850161	AC generators not exceeding 75 kVA	Specifically for all electricity generating renewable energy plants
850162	AC generators exceeding 75 kVA but not 375 kVA	Specifically for all electricity generating renewable energy plants
850163	AC generators not exceeding 375 kVA but not 750 kVA	Specifically for all electricity generating renewable energy plants
850164	AC generators exceeding 750 kVA	Specifically for all electricity generating renewable energy plants

Source: World Customs Organization (2007), Harmonized System Nomenclature, www.wcoomd.org/ie/EN/en.html and own complilation.

5.2.2 Development by Renewable Energy Technology

This section examines international trade in renewable energy goods since 1996. To get a better understanding of international renewable energy trade, growth rates and market shares are computed for different renewable energy technologies. A country perspective is included as well, showing trade patterns by country and by technology.

Fig 5-3 shows the development of total merchandise exports and exports in primary renewable energy technologies. Trade in renewable energy technologies has grown significantly faster than total merchandise trade. The average annual growth rate for primary renewable energy exports is 20% since 2000, whereas for total merchandise exports it is only 12%.

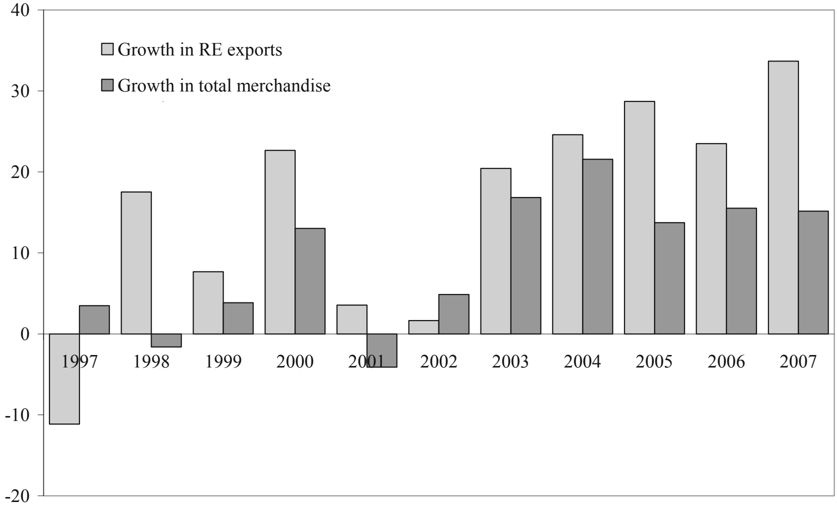

Fig 5-3: World merchandise exports and renewable energy exports, annual percentage change, 1997-2007
Source: WTO trade statistics database, COMTRADE, own calculations.

Exports in renewable energy technologies[437] make up about 1.4% of total manufacture exports in 2007. This share has grown from about 1% in 1996.

There are great differences in the development of the different renewable energy technologies (see Fig 5-4). Wind energy technologies are the most dynamic sector of renewable energy trade. Exports of wind energy products are almost 9 times larger than in 1996. In the last year alone, wind energy exports grew by 33%. Exports in PV technologies grew only slightly less dynamically. Solar exports are today more than 7 times larger than in 1996. In 2007, solar energy exports grew by 37%.

In contrast, exports in hydro power technologies, but also biomass and geothermal technologies[438] increased only slightly since 1996. In 2004, hydro technology exports had even decreased compared to 1996. In the past two years, however, both hydro and geothermal and biomass exports exhibit greater dynamic. In 2006 and 2007, hydro technology exports grew by 12.7 and 15.5 percent. Geothermal and biomass exports grew on average by 11% in the past two years. Still, compared to wind and solar technology exports the development is much less dynamic.

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[437] Data for primary and complementary renewable energy technologies.

[438] Due to statistical limitations it is impossible to differentiate between geothermal and biomass technologies, which are mostly turbines and thus the trade numbers for these two technologies have been added together (see also section 4.2.4).

The lower dynamic of hydro and geothermal and biomass exports can be explained by the development of renewable energy power generation on national markets (compare section 4.6). Solar and wind power have been the most dynamic renewable energy sources in domestic power generation in all three case countries. By contrast, hydro power generation did not increase significantly in the past 10 years. Also its future potential is regarded as very limited due to the fact that most waterways that can be efficiently used to generate power are already being used, at least in the OECD countries. Thus, the relatively flat growth rate of hydro power exports is not surprising but goes alongside the development in hydro power electricity generation and the high level of maturity of hydro technologies. Geothermal and biomass technologies have not grown very dynamically either.

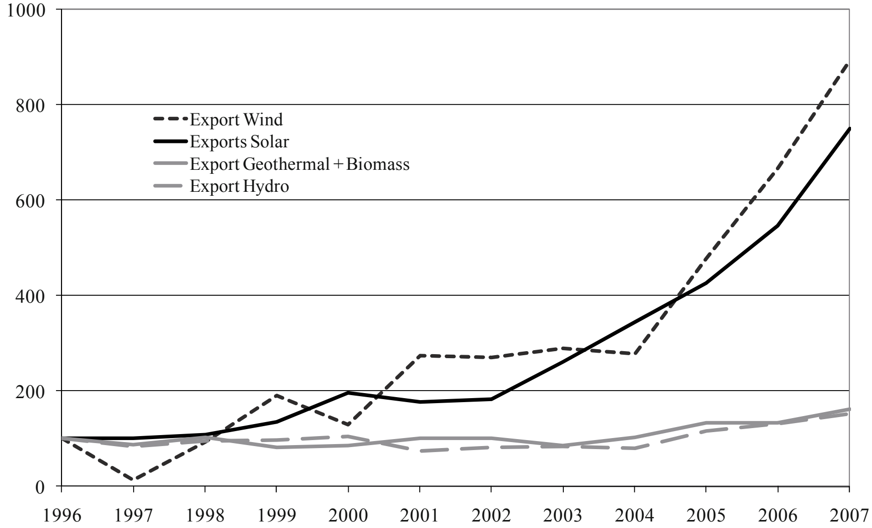

Fig 5-4: Growth in renewable energy trade, 1996=100

Are the most dynamic renewable energy technologies also the most important ones in terms of market size? Since 1996, the shares of different renewable energy technologies in total renewable energy trade remained relatively constant. The greatest change was in the share of PV exports in total renewable energy exports, which increased from 44% in 1996 to 54% in 2007. Geothermal and biomass exports lost in relative importance and now represent less than 25% of renewable energy exports.

The share of wind exports in total exports remained fairly constant with approximately 20%. Hydro exports represent the smallest share in total exports with only about 1%. This is slightly surprising, since it does not mirror the relatively greater importance of hydro in electric power generation in OECD countries. One explanation could be that hydraulic turbines have reached a very mature stage and need relatively less technological sophistication which means that even though the quantity of hydraulic turbines traded is bigger than 1% its value only stands at 1% of total renewable energy exports. Moreover, hydro power electricity generation has reached a level which is close to its full potential. Except for some large-scale new constructions such as in China, few new hydro power plants are being built worldwide.

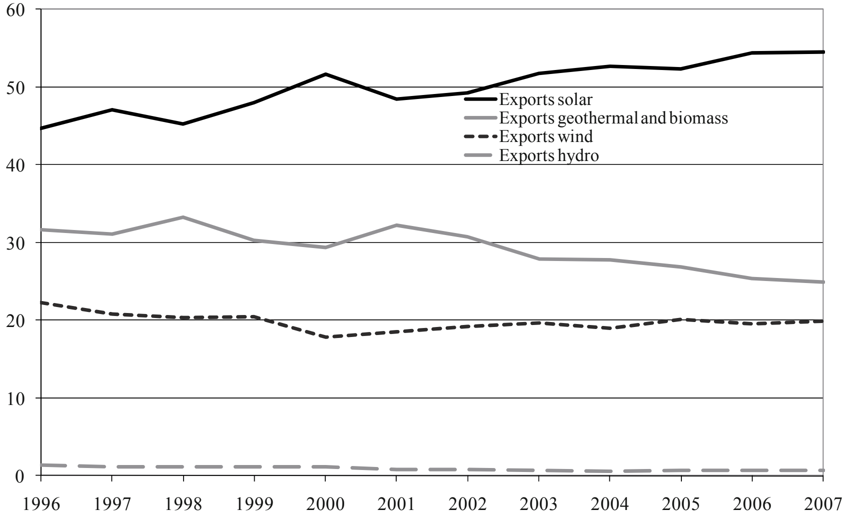

Fig 5-5: Market shares in total renewable energy exports by technology, in %, 1996-2007

In sum, wind and solar technology exports exhibit the greatest dynamic among all renewable energy exports. Solar technology export are also the most important renewable energy exports in terms of market size and constitute more than 50% of all renewable energy technologies.

5.2.2.1 Wind Power

The development of the modern wind power industry began in the 1970s, after the first oil price shock. Today, modern wind turbines produce mechanical power from the wind's kinetic energy. Electricity is then generated by converting the rotation of turbine blades into electrical power by means of an electrical generator.[439]

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[439] For more information on the technicalities of wind power generation, see US Department of Energy (2007), *How Wind Turbines Work* or European Wind Energy Association (2007), *Wind Power Technology*.

Global trade in primary and complementary wind energy technologies is the third largest of the four renewable energy sectors examined. In 2007, US$ 48 billion in wind energy technologies were traded.

The dynamic of trade with primary and secondary[440] wind energy technologies differs remarkably. Whereas trade in primary wind energy technologies is today close to nine times larger than in 1996, trade in complementary products grew much less dynamically and increased only 2.5 times in the same time period.

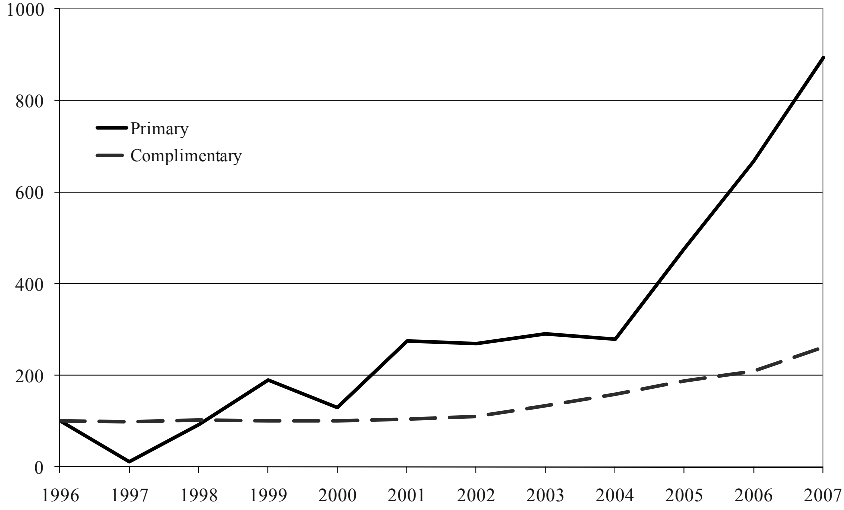

Fig 5-6: Growth of wind energy technology exports, 1996=100

World trade with wind energy technologies shows further remarkable characteristics. The trade of primary wind energy technologies is the most concentrated of all renewable energy sectors. Denmark is by far the leading trading nation with an export market share of 46% of all primary wind energy technologies. This implies that Denmark managed to defend its international leading position in wind energy production over a sustained period of time. Denmark has been the most important pioneering country in the past decades in electricity production from wind energy but also in the production of the necessary technologies to produce electricity from wind. However, Denmark's market has been much higher in the past. In fact, until 2004 Denmark always had a market share above 80%. In 1996, Denmark's share in wind technology exports stood at 92%. Accordingly, in relative terms Denmark has lost significantly. By contrast, Germany was able to increase its mar-

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[440] The terms secondary and complementary are used interchangeably.

ket share significantly in the past years. Until 2004, Germany always had had a market share below 10%.

In 2007, Germany is second to Denmark in the rank of wind technology exporters with a market share of 28%. Japan follows with 10% and Spain with 5.7%. In total, international trade in wind-powered electric generating sets (HS 850231) is highly concentrated with European companies accounting for 86% of global exports.

Japan's high share is somewhat surprising, since it has not built up a significant wind energy industry yet. In 2006, Japan's share had only been 5.5% and one year earlier only 0.4%. In the past years, however, more and more foreign companies (mostly Danish and German firms) invested in Japan. These companies together with the newly established Japanese wind energy industry are responsible for the increase in Japan's market share in wind energy technologies.

Tab 5-4: Country market shares, 2007 in %, primary wind energy technologies

	Exports	Imports
Denmark	49.6	0.0
Germany	28.0	9.2
Japan	10.2	1.3
Spain	5.7	5.4
China	2.3	7.6
United States	0.4	48.2
Other	3.8	28.2

By far the most important importer of primary wind technology is the United States with an import market share of over 48%.

5.2.2.2 Solar Photovoltaic

The modern usage of solar power experienced its breakthrough in 1954, when the Bell Laboratories developed the first photovoltaic cell.[441] With these PV or solar cells it was possible to convert light from the sun into electricity. In terms of trading of products necessary to produce solar power, the most relevant goods are solar cells (HS 854140). In 2007, the trade of solar cells amounted to US$ 44 billion.[442]

This trade code, however, includes photosensitive semiconductor devices and light-emitting diodes (LEDs), which are not only used in on-grid and off-grid PV applications. According to a study by the OECD, only about 11% of the goods traded under HS 854140

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[441] See for more information on solar power, Knier (2002), *How do Photovoltaics Work?*.

[442] The trade of primary and complementary solar PV trade stood at US$ 140 billion in 2007.

are actually used for the production of electricity from solar.[443] Still, all studies that analyze trade with PV products include this trade code as the most accurate approximation of trade with PV applications there is to this date. Nevertheless, the need for a more detailed breakdown in the HS system is the most urgent for solar devices.

Similarly to the growth rates in wind energy technologies, the growth rate for primary solar technology exports grew more dynamically than the one for complementary solar exports. Compared to 1996, complementary solar exports grew by slightly more than 3 times, whereas primary solar exports are today more than 7 times larger than in 1996.

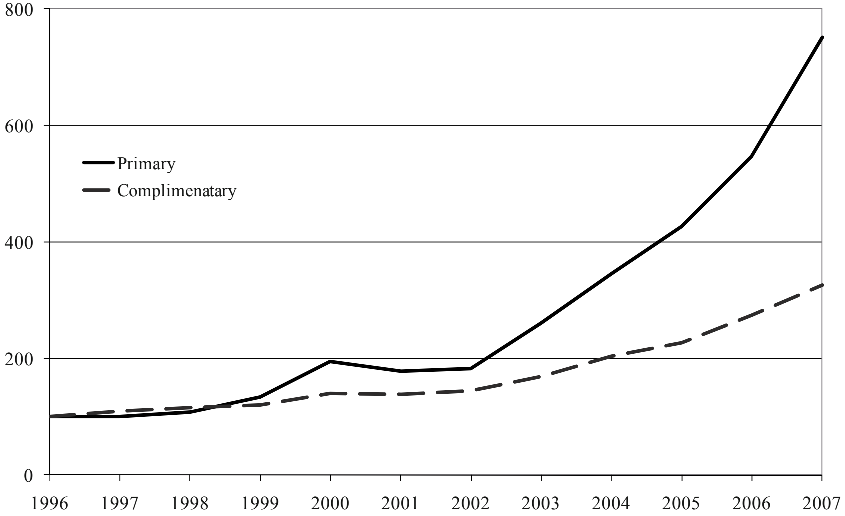

Fig 5-7: Growth of solar PV technology exports, 1996=100

Compared to the export country structure of wind energy technologies, the export structure of primary solar energy technologies is slightly more diverse. In the past, Japan has been dominating solar exports with an average export market share of 40% between 1996 and 2006. In the past year, Japan lost in relative importance and had a market share of only 25% in 2007. This is to some degree in accordance with first mover theory, since – just as Denmark in the case of in wind energy – Japan has been the most important pioneering country in both solar power and the necessary technology to produce solar power. Germany has only recently overtaken Japan in PV production and this, so far, did not translate into a higher global export market share for Germany. Surprising is the fact, that

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[443] OECD (2005), *Liberalising Trade in "Environmental Goods": Some Practical Considerations*, p. 33. For all other products included in primary renewable energy products the study states a share of 100% of renewable components of the respective HS subheading.

China is actually the second most important exporter with an export market share of 24%, followed by Germany (16%) and the United States (8.8%).

Germany is the biggest importing country of solar devices (import share of 22%). This can be explained with the sudden explosion of PV production in Germany, with which the German producers of solar devices could apparently not keep up.

Tab 5-5: Country market shares, 2007 in %, primary solar PV technologies

	Exports	**Imports**
Japan	25.1	5.1
China	24.1	17.1
Germany	16.1	21.8
USA	8.8	9.7
Hongkong	6.6	8.2
UK	3.4	2.8
Other	15.9	35.4

5.2.2.3 Hydro Power

Hydro power refers to the kinetic energy of water which is converted into electricity in hydroelectric plants. Hydro energy has been used for irrigation or to move machinery for centuries, but the modern use of hydro power to generated electricity was also developed much earlier than any other form of renewables.[444] The first commercial hydroelectric plants started proving power in the late 19th century in England and the United States.

The trade codes for hydro power technology are clearly defined. Accordingly, there is no separation between primary and complementary hydro power technologies in this study. World trade in hydraulic turbines is comparably small. In 2007, global trade (exports + imports) in hydraulic turbines[445] accumulated only to about US$ 213 Mio. According to the OECD, the market for hydraulic turbines is less open than other renewable technology markets and heavily influenced by government procurement.[446] This could explain the relatively low levels of trading in comparison to the importance of hydro power for electricity generation. The analysis of import tariffs in section 5.1.2 confirmed that the tariffs for hydro technologies are on average the highest for all renewable energy technologies in Germany and the United States. However, the most important reason for the relatively low level of hydro technologies trade has been stated earlier: the generation of

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[444] See International Energy Agency (2007), *Hydropower FAQ* for more information on the generation of electricity through hydro power.

[445] HS. 841011, HS. 841012, HS. 841013.

[446] See OECD (2005), *Liberalising Trade in "Environmental Goods": Some Practical Considerations*, p. 9.

electricity from hydro power is already close to its full potential on a global scale. Therefore, the demand for new hydro power plants is limited.

In terms of hydro technology exports, Germany used to be the leading exporting nation with an average market share of 13.5% since 1996. The export market is comparably diverse. Three more countries achieved average market share of around 10% since 1996. Switzerland exported on average 11% of hydro technologies, Austria 9.6% and the United States had an average export share of 7.5% since 1996.

In 2007, however, China overtook Germany as the most important exporter of hydro technologies with an export share of 16%. Until 2005, China only exported about 5% of global hydro technology exports. In 2007, China is followed by Germany (13.8%), France (10.5%) and Switzerland (9.6%).

Tab 5-6: Country market shares, 2007 in %, hydro technologies

	Exports	**Imports**
China	16.0	33.1
Germany	13.8	4.0
France	10.5	6.3
Switzerland	9.6	4.7
Austria	9.2	3.4
Spain	6.3	1.2
Russia	6.2	0.7
Canada	5.0	7.6
Japan	4.9	1.4
Italy	4.8	2.4
USA	4.2	8.1
Turkey	0.5	8.7
Other	9.5	27.0

China is already today the largest producer of power from hydroelectric power plants. With the beginning of hydro power production at the three gorge dam in China in 2006 and numerous smaller new hydro plants, China will remain the greatest producer of hydro electricity in the decades to come. The boom of hydro power in China in the past years explains the great share of China when it comes to hydro technology imports, which stands at 33% in 2007. Turkey is the second largest importer of hydro technologies with a share of 8.7%, followed by the United States (8.1%) and Canada.

5.2.2.4 Geothermal and Biomass Power

Geothermal power plants use the heat of the earth to generate electricity. Hot steam from the earth's heat is used to move a turbine, which then converts the mechanical energy into electricity. There are three different types of geothermal power plants: dry steam, flash steam and binary cycle with the latter two being the more important ones.[447] Flash steam plants use hot geothermal fluid to make steam, which then moves a steam turbine-generator to generate electricity. In a binary cycle plant, a fluid with a low boiling point is circulated through a closed loop to receive heat from the geothermal fluid. The heated up fluid is then used to produce steam and electricity. The main components of both types of geothermal power plants are the electric generator, the steam turbine, heat exchangers and a heat pump.

Biomass-fired steam plants are the most common way to generate electricity from biomass. Just like in other conventional or renewable-fueled power plants, the steam produced in the process of the firing of biomass is channeled through a turbine generator, which produces the electricity. Other methods of electricity generation from biomass are gasification or anaerobic digestion, but they are generally not used in large-scale, commercial biomass plants.

The most important and distinguishable elements of geothermal and biomass power plants are thus the generators and turbines employed in these plants. The greatest part of biomass and geothermal technologies are considered “complementary renewable energy technologies”, because the classification is especially difficult. The ratio for primary and complementary geothermal and biomass technologies in this study is roughly 1:6.

In 2007, global trade in geothermal and biomass technologies stood at US$ 54.6 billion, which makes it the second largest renewable energy sector after PV technologies.

In terms of growth dynamic, geothermal and biomass technologies are the only case where complementary products grew faster than the primary technologies. This could be explained by the fact that primary geothermal and biomass technologies feature a higher level of maturity. By contrast, technological advances in the past years introduced newer and more sophisticated parts for geothermal and biomass plants. These are classified as complementary geothermal and biomass technologies and could have resulted in higher trade activity. Still, compared to wind energy and PV technologies, geothermal and biomass technologies trading did not grow particularly fast compared to 1996. Complementary geothermal and biomass technologies increased by 2.8 times, whereas primary geothermal and biomass technologies grew by 1.6 times.

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[447] See US Department of Energy (2007), *Geothermal Power Plants* for more information on geothermal power generation.

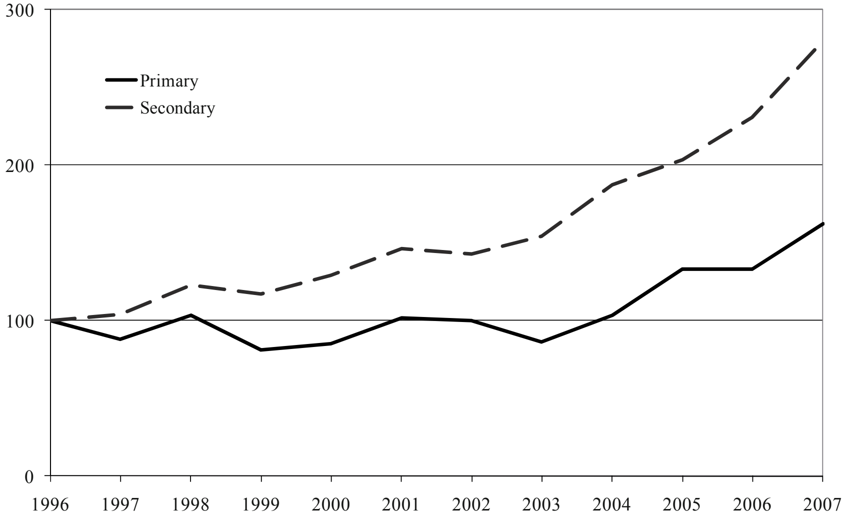

Fig 5-8: Growth of geothermal and biomass technology exports, 1996=100

Japan has the largest export market share with 29% in primary geothermal and biomass energy technologies. Germany and the United States have an export market share of 16.5 and 11% respectively. China is the fourth biggest exporter with a share of 7%. China is also by far the most important importer of geothermal and biomass technologies (20%). The second largest importer is the United States (12.5%), followed by Spain (12%) and Germany (11%).

Tab 5-7: Country market shares, 2007 in %, primary geothermal and biomass technologies

	Exports	**Imports**
Japan	28.9	4.6
Germany	16.5	10.9
USA	11.0	12.5
China	6.9	20.0
Italy	4.8	5.5
France	4.7	3.7
United Kingdom	4.6	3.4
Spain	0.5	11.9
Other	22.0	27.5

5.2.3 The Export Performance and the Level of Specialization of Germany, Japan and the United States in Renewable Energy Technologies

This section analyzes the trade flows in renewable energy technologies from a “country perspective”. Thus, it provides information on country’s flows of trade (exports and imports) in the renewable energy sector, and it analyzes per capita exports, the share in world’s trade flows and total national trade flows. This section further examines specific specialization indicators focusing on Germany, the United States and Japan. This information provides insights into the competitive position of Germany, Japan and the United States in renewable energy technology trading and their specific levels of specialization in this area.

In 2007, Germany was the largest trading country with primary renewable energy technology with a trading value of more US$ 11 billion. Germany is followed by China (US$ 10.7 billion) and Japan (US$ 8.5 billion). The United States is the fourth largest trading country in this sector with a trading value of US$ 7.4 billion.

There has been great dynamic in the past three years. In 2004, the ranking of the 10 most important trading countries in primary renewable energy trade looked remarkably different. The numbers itself cannot be easily compared since the data are given in nominal terms.[448] It is possible, however, to discuss the trends in the data. Most significant is the loss of Japan in relative importance. Only three years earlier, Japan was far ahead of its competitors. By 2007, Germany and China especially managed to increase their renewable energy trade volume substantially and to overtake Japan. In 2004, the United States was still the third largest renewable energy trader worldwide and traded slightly more than China. In 2007, China was already the second most important trading country in renewable energy technologies. And since this graph depicts trade in primary renewable energy technologies, the share of technologies with a non-renewable energy use is relatively low. This implies that China today is a main trader of renewable energy technologies with a relatively high level of sophistication and not only a provider of complementary parts which might be less technologically advanced.

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[448] As explained earlier, there are no deflators available for this level of disaggregation. This implies that exchange rate changes deteriorate the data to a certain extent.

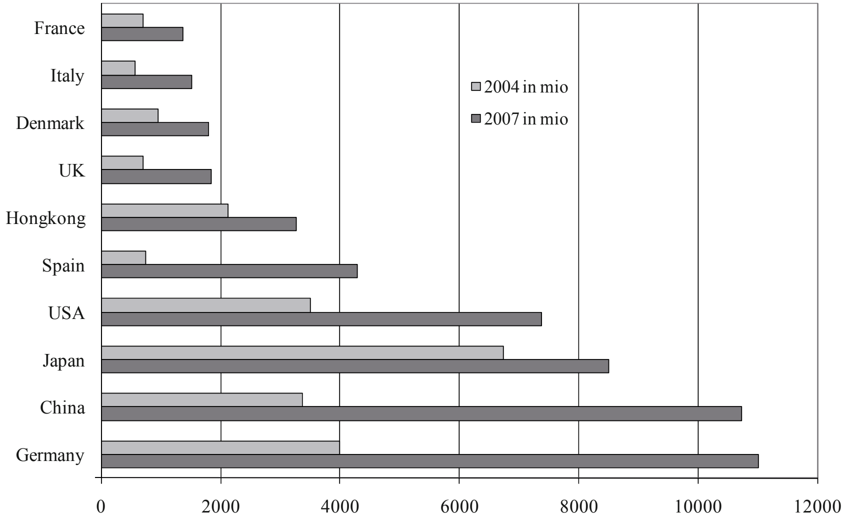

Fig 5-9: Primary renewable energy trade, 2004 and 2007 in mio. US$

It could be the case, however, that China is generally an importer of renewable energy technologies and not an exporter. That is why a look at net exports (exports minus imports) is important to determine which countries have a positive net exports balance. Some surprising results can be seen in Fig 5-10. The graph shows net exports of all countries that have at least a market share of one percent in primary renewable energy trade. In terms of primary renewable energy technologies, both the United States and Germany have a negative trade balance. Especially in the German case this outcome is unexpected. The United States has a significant negative trade balance of US$ 2.5 billion. Germany's net exports amount to a negative value of US$ 300 million. Spain has the highest negative trade balance of all countries. This outcome is in fact not very surprising since renewable electricity generation experienced very high growth rates in the past few years in Spain, while the industry that produces the devices needed to generate electricity from renewable energy sources has not been build up with the same dynamic. Accordingly, Spain has to import a large share of the technologies needed to generate renewable power.

Japan, Denmark and China can be found at the other end of the spectrum. These countries feature a positive trade balance. Especially Japan's net exports of US$ 5.8 billion are remarkable. China also has a fairly large positive renewable energy trade balance of US$ 831 million, which means that China is not only involved in renewable energy trading as an important importing but also exporting country. Denmark's net exports amount to US$ 1.68 billion in 2007.

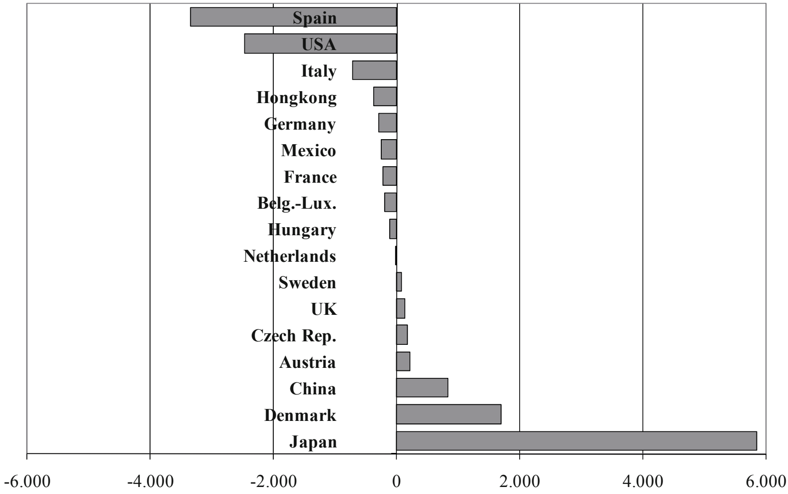

Fig 5-10: Net exports of primary renewable energy technologies, 2007 in mio. US$

Why does Germany have a negative trade balance? The main reason is that Germany imports far more solar devices than it exports. Since solar devices make up a large part of primary renewable energy trade (see above), Germany's trade balance turns negative. The impact of solar devices is visualized in Fig 5-11, which shows net exports of primary renewable energy technologies without solar cells (HS 854140).

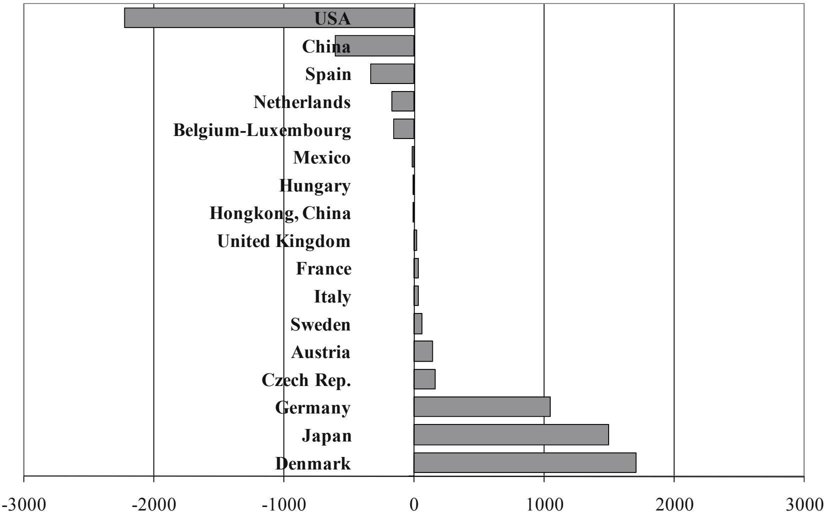

Fig 5-11: Net exports of primary renewable energy technologies without solar PV technologies, 2007 in mio US$.

In fact, Germany has a positive trade balance of US$ 1 billion when solar devices are not taken into account. Denmark has the highest positive trade balance of US$ 1.7 billion, followed by Japan with US$ 1.5 billion. The United States has the highest negative trade balance of all countries with US$ 2.2 billion. Without trade in solar devices, China's positive trade balance in total primary technologies trade turns into a negative trade balance of US$ 607 million.

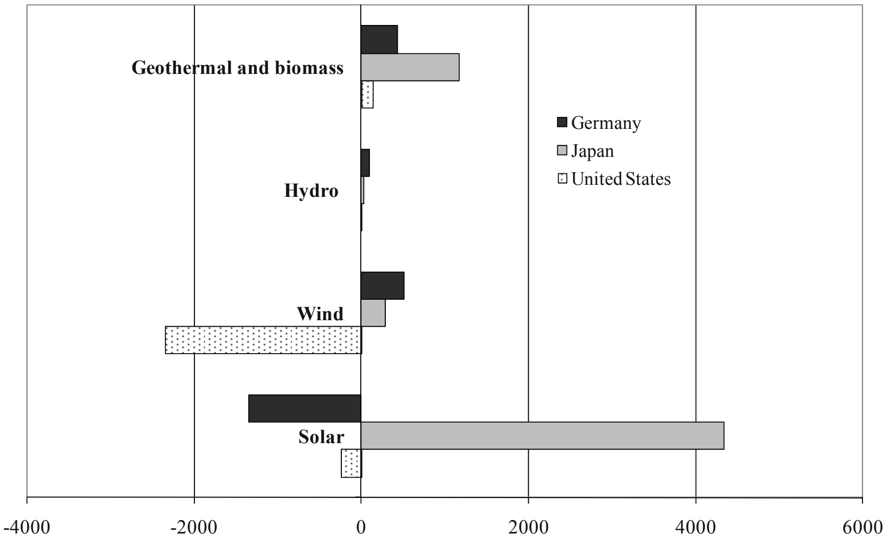

Fig 5-12: Net exports of primary renewable energy technologies by technology, 2007 in mio. US$

The great differences in the import and export structures by technology for Germany, Japan and the United States become even more obvious in Fig 5-12. Whereas all three countries have a positive trade balance for geothermal and biomass technologies, the situation for the other three renewable energy branches is more diverse. Japan and Germany have a slight positive trade balance for hydro technologies, while the United States imports slightly more hydro technologies than it exports. Germany's net trade balance of wind technologies stood at US$ 516 million in 2007 and Japan's at US$ 291 million, whereas the United States accrued a negative trade balance of US$ 2.3 billion in wind technologies. For solar technologies, both Germany and the United States feature a negative trade balance (US$ 1.3 billion and US$ 241 million respectively), while Japan's solar technologies trade balance is positive (US$ 4.3 billion).

5.2.3.1 Exports Per Capita

As discussed in the sections on indicators, the high absolute trading levels of Japan, the United States, Germany and also China in renewable energy trading could simply reflect their general economic might and trading strength.

Is the situation different if renewable energy exports per capita are considered? From those countries with a market share of at least 1 percent in primary renewable energy trading, Denmark exports the highest value of renewable energy technologies per capita, followed by Hong Kong and Austria. Still, Germany and Japan already follow in fourth and fifth place, which implies that their strong position in renewable energy trading cannot be explained by their general trading strength alone. China on the other hand exports significantly less per capita than Germany and Japan. Surprisingly, the United States only exports slightly more renewable energy technologies than China on a per capita basis and considerably less than Germany and Japan.

This means that at least for Germany and Japan it is not their overall trading strength and the size of their economies which make them important renewable energy exporters. Even on a per capita basis these two countries are relatively successful in the renewable energy sector.

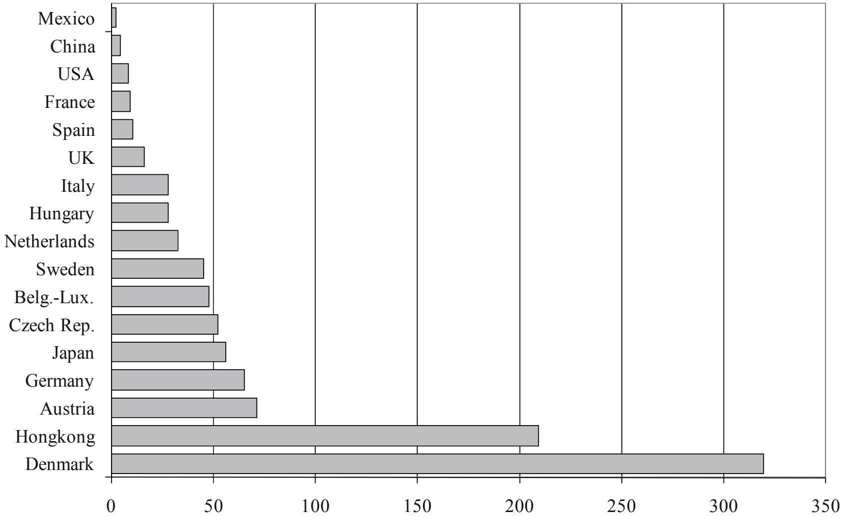

Fig 5-13: Primary renewable energy exports, 2007, per 1000 population, in thousands

5.2.3.2 Growth in Renewable Energy Trading

It has been shown above that trade in renewable energy technologies grew more dynamically than total merchandise trade. How do the three case countries rate in terms of growth in renewable energy trading? Which technologies grew most dynamically in the three countries?

The growth rate for Germany of renewable energy exports is above OECD[449] average in the years from 2005 to 2007. Japan's and the United States's exports in renewable energy technologies grew significantly below OECD average and much slower than German primary renewable energy technologies.

In 2005, German renewable energy technologies increased by 63%, while US exports rose by 22% and Japan's primary renewable energy exports solely by 8%. In 2006, US exports even decreased and Japan's growth rate was similar to the previous year (8.7%) and also to 2007 (10%). In 2007, US renewable energy exports increased by 13% and thus almost 4 times slower than German exports which grew by 49%.

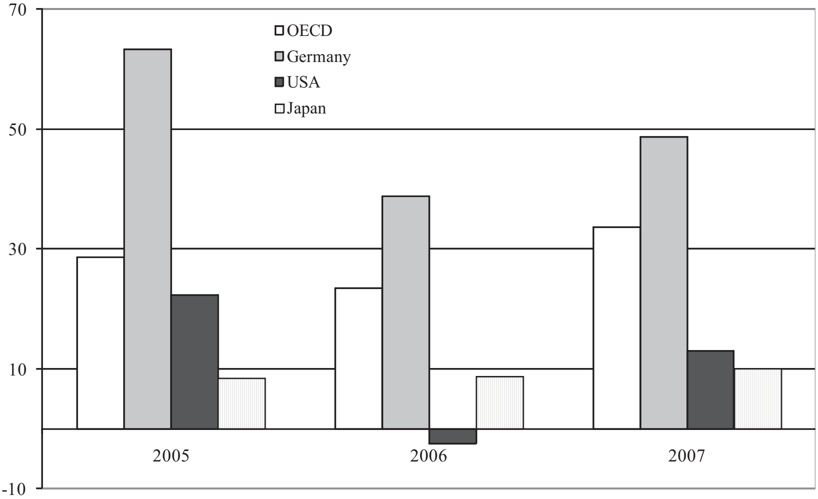

Fig 5-14: Growth rate, primary renewable energy exports, annual percentage change

China managed to increase its renewable energy exports significantly in the past years. In 2007 alone, China more than doubled its renewable energy exports compared to 2006. However, this success requires some explanations. According to a study by the OECD, 90 percent of China's high-tech exports originate from foreign-owned enterprises.[450] It can be assumed that a similar share can also be applied to renewable energy exports. Moreover, China is especially strong in the exports of solar PV cells. These are, however, produced in a non-environmental friendly way. First of all, the toxic waste of

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[449] Data for OECD plus China and Russia.

[450] OECD (2007), *OECD Reviews of Innovation Policy: China*, p. 15.

the cell production is mostly dumped rather than recycled. Moreover, the energy needed to produce the cells is provided by dirty coal-fired plants.

To discuss how trade in renewable energy technologies has developed in Germany, Japan and the United States by renewable energy category, the following graphs show growth rates for the three countries by technology.

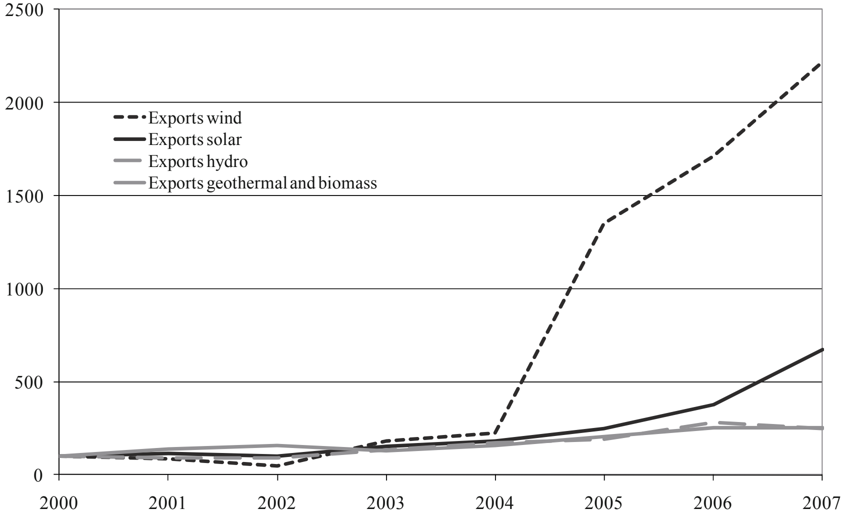

Fig 5-15**:** Growth rate by technology, Germany, 2000=100

The graph for Germany shows that until 2004 the exports of all four renewable energy categories did not exhibit great dynamic. In 2001 and 2002, growth rates for hydro and wind technology exports have in fact been negative. From 2002, the dynamic changed significantly however, and exports in all categories increased. Most extraordinary is the growth of wind technology exports since 2004 as can clearly be seen in Fig 5-15. Since 2004, wind technology exports increased close to 10 times. Solar technology exports also experienced significant growth and rose by more than 6 times. Geothermal and biomass exports growth was also fairly constant and since 2000, exports in this category increased by 2.5 times. Exports in hydro technologies also started growing in 2002 and increased 2.6 times until 2007.

Fig 5-16 shows the remarkable increase of Japanese wind technology exports in 2005 and 2006. Until 2005, growth for all renewable energy branches had been relatively modest. In 2006 and 2007, however, wind technology exports skyrocketed. Solar technology exports also increased significantly since the early 2000s, which is difficult to see in the graph because of the dominance of wind technology exports. Still, between 2002 and

2007 Japanese solar exports more than doubled. Between 2000 and 2007, geothermal and biomass exports increased by 85 percent, while hydro technology exports declined by 12 percent.

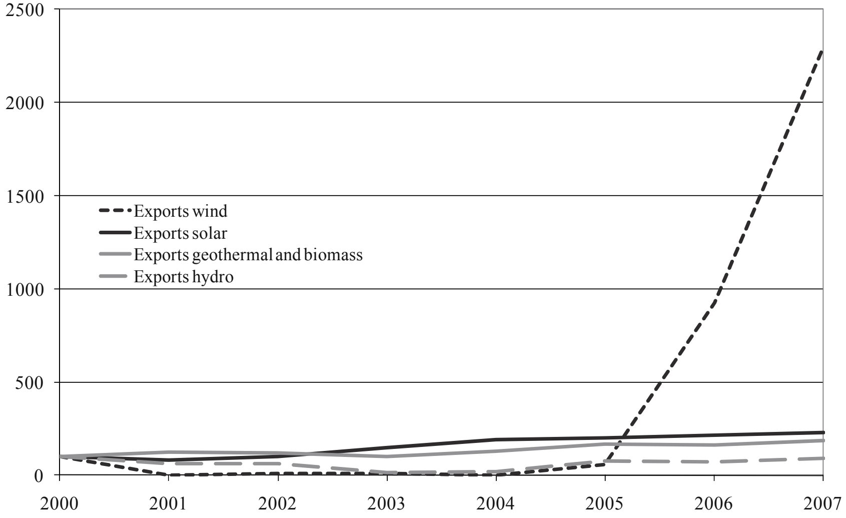

Fig 5-16: Growth rate by technology, Japan, 2000=100

The export dynamic of the United States was much slower compared to its two competitors. Among the four categories of renewable energy technologies, wind and solar technologies grew the strongest. Since 2000, wind technology exports doubled. Still, growth rates for wind technologies were much higher in Germany and Japan in this time period even though the absolute values of US wind technology exports started from a much lower base. All other three renewable energy categories experienced negative growth compared to the base year 2000 until 2003. From 2004 onwards, however, solar technology exports rose significantly. In 2007, the value of solar technologies exports increased by 50% compared to 2000. Hydro and geothermal and biomass technologies also increased slightly since 2003, but in 2007 hydro technology exports were still 25 percent lower than in 2000. Geothermal and biomass exports reached the 2000 level again in 2007.

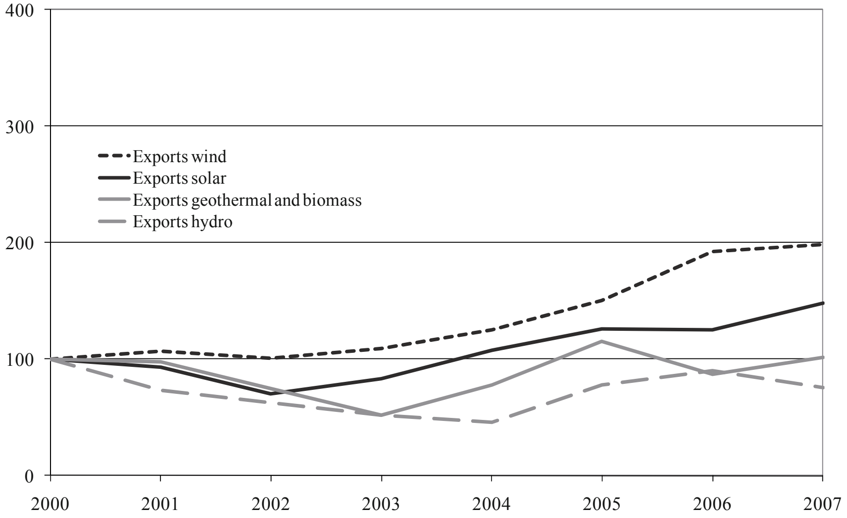

Fig 5-17: Growth rate by technology, United States, 2000=100

5.2.3.3 Destination of Exports and Sources of Imports

This section shows which are the most important export and import partners for Germany, Japan and the United States in renewable energy trading.

In terms of export destinations, Germany's single most important export partner is Spain, followed by the United States, Italy and France. Renewable imports from Spain, however, are minimal. The import and export structure between Germany and Denmark are the exact opposite. While Denmark is the third largest import source for Germany, Germany's exports to Denmark are very small. Germany's most important import sources of renewable energy technologies are China, Japan, Denmark and the United States. Only one year earlier, Japan had still been the most important import source for Germany, but lost this position now to China. The imports from China and Japan constitute almost 50 percent of total Germany renewable energy imports.

From Japan and China, Germany mostly imports solar technology and from Denmark wind energy technology.[451] Germany's exports to Spain are dominated by solar technologies. Germany's exports to Japan are primarily wind energy technologies and to China wind and geothermal and biomass technologies are exported. Trade with the United States

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[451] See also Appendix Tables A-10, A-11 and A-12 for detailed tables on sources of imports and destinations of exports by technology for the three countries.

is more diverse. Germany is a net exporter of wind, hydro and geothermal and biomass technologies and imports solar technologies from the United States.

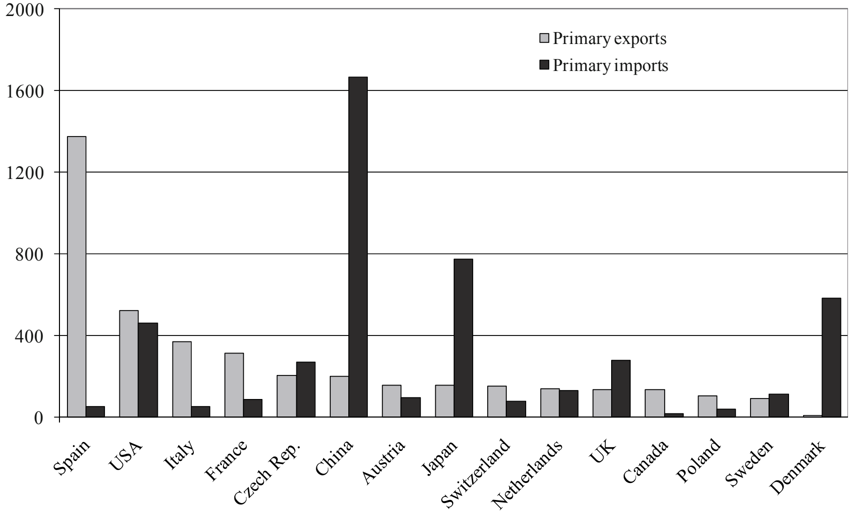

Fig 5-18: Germany: Sources of imports and destination of exports of primary renewable energy technologies, in mio. US$, 2007

Japans most relevant four export partners of renewable energy technologies are China, the United States, Hong Kong and Germany. To China the country mostly exports solar technologies and geothermal and biomass technologies. However, Japan also imports solar technologies from China but less in value. Japan's exports to the other three countries are also dominated by solar technology exports. Japan's trading with the United States is not restricted to solar energy technologies but is more diverse. Japan is, however, a net exporter of all examined renewable energy sectors with the United States.

Japan's most important export destinations are the same as its most important import partners except for Hong Kong. Among the three case countries, Japan is the only country which also trades significant amounts with trading partners outside the OECD (plus China and Russia). Important renewable energy trading partners for Japan outside the OECD world are Thailand, South Korea, the Philippines and Singapore.

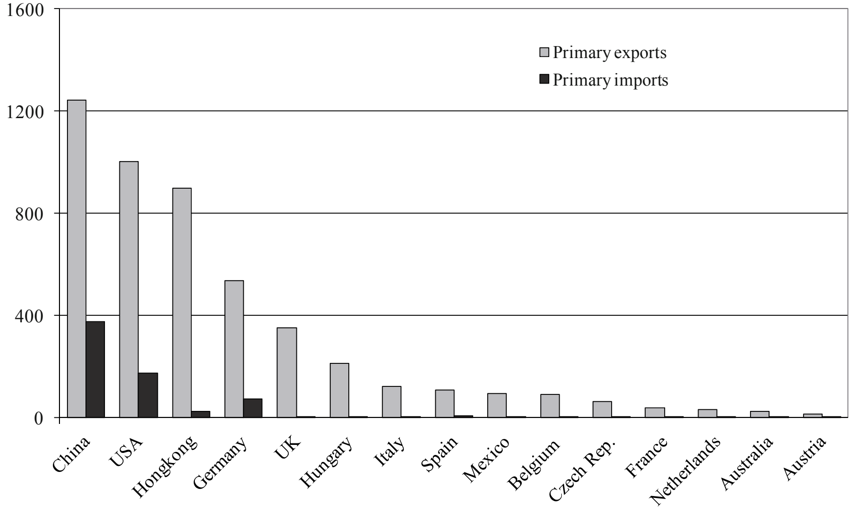

Fig 5-19: Japan: Sources of imports and destination of exports of primary renewable energy technologies, in mio. US$, 2007

The exports of the United States in renewable energy technologies go primarily to Germany, Mexico, Canada and Japan. The two most important sources of imports are Japan and Denmark. Also of relevance are China, Germany and Spain as import partners. The distribution of export and imports with Germany and Japan by technologies has been discussed in the previous paragraphs. From Denmark the US mostly imports wind energy technologies, whereas from China the US imports predominantly solar technologies. Trade with Mexico is heavily dominated by solar technologies, both by imports from Mexico and exports to Mexico. Trade with Canada is much more diverse. The US trade balance in solar technologies is positive. However, the United States imports more wind, geothermal and biomass technologies and hydro technologies from Canada than it exports to its northern neighbor.

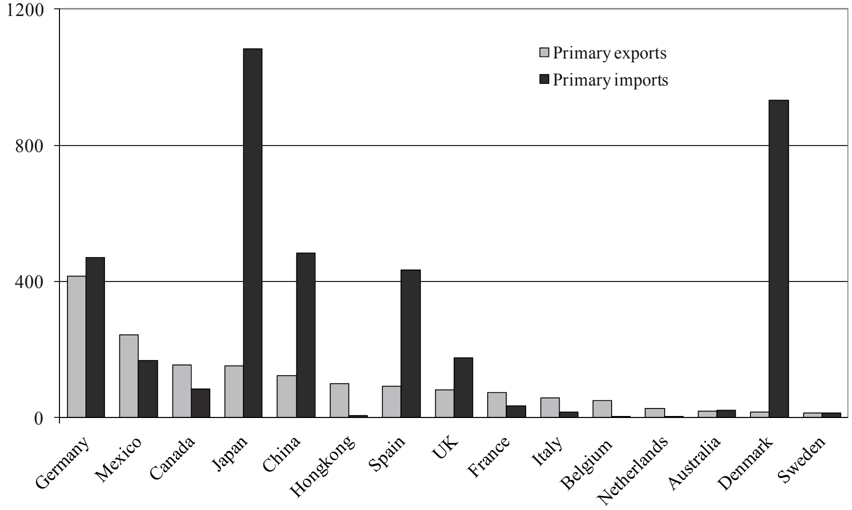

Fig 5-20: United States: Sources of imports and destination of exports of primary renewable energy technologies, in mio. US$, 2007

5.2.3.4 World Market Share

The world market share for a country in renewable energy exports shows which countries are generally the most important exporting countries in this sector.

Fig 5-21 shows that in 2007 Japan has the highest world market share in primary renewable energy exports. Japan exports 23% of all primary renewable energy technologies. This share, however, is down from 28% in 2006 and 38% only three years earlier. China experienced the highest increase in its market share and is today already the second most important exporting country in renewable energy exports with a market share of 19% in 2007. China's export development is extraordinary: in 2004 China only had a share of 5% in renewable energy exports. Germany lost its position of second most important exporting country in 2007 and now ranks third. Nevertheless, Germany managed to increase its share in renewable energy exports from 11% in 2004 to 17.5% in 2007. The US world market share in renewable exports decreased from 12.6% in 2004 to only 8% in 2007.

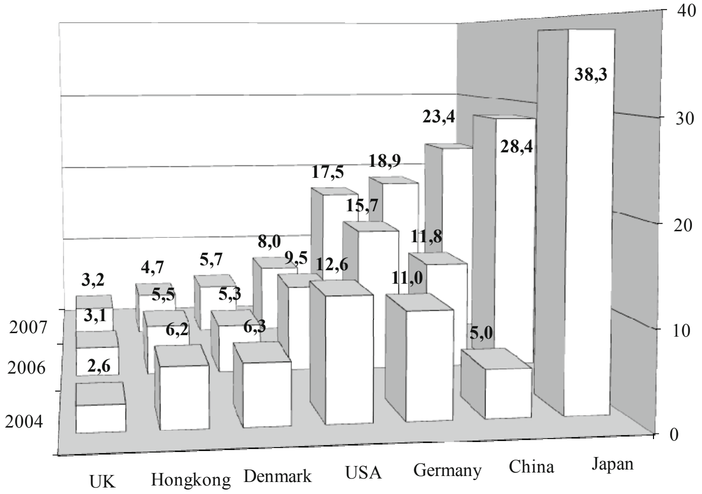

Fig 5-21: World market shares by country in primary renewable energy exports, in %, 2004, 2006 and 2007

Table 5-8 offers a more detailed look at market shares by technologies of the countries with at least a market share of one percent in renewable exports.

Tab 5-8: World market shares by country and technology in primary renewable energy exports, in %, 2007

	Total	Solar PV	Wind	Hydro	Geothermal + biomass
Japan	23.4	25.1	10.2	4.9	28.9
China	18.9	24.1	2.3	16.0	6.9
Germany	17.5	16.1	28.0	13.8	16.5
USA	8.0	8.8	0.4	4.2	11.0
Denmark	5.7	0.1	49.6	0.1	0.0
Hongkong	4.7	6.6	0.0	0.0	0.0
UK	3.2	3.4	0.4	2.7	4.6
Austria	1.9	1.6	0.0	9.2	3.4
France	1.9	1.2	0.1	10.5	4.7
Czech Rep.	1.8	1.5	0.1	2.4	4.0
Netherlands	1.7	2.2	0.5	0.3	0.8
Bel.-Lux.	1.7	2.3	0.0	0.3	0.6
Spain	1.5	0.9	5.7	6.3	0.5
Sweden	1.4	1.3	0.0	0.7	2.8
Italy	1.3	0.4	1.3	4.8	4.8

Japan has the greatest market share in solar technologies exports (25%), closely followed by China (24%), Germany (16%) and the United States (8%). These four countries alone trade over 70% of world solar exports among themselves.

Wind technology exports are the only sector where another country other than the big four (Germany, Japan, the United States and China) dominates world exports. Denmark features a market share in world wind technology exports of 49.6%. Far behind Denmark is Germany with a market share of 28% as the country with the second biggest market share. The exports in this sector are even more concentrated than exports in solar technologies, since only these two countries contribute 75% of world exports. Spain also has a relatively large share in world exports in this sector with 5.7 percent.

Exports in hydro technologies are more evenly distributed. China has the largest world market share in this sector (16%), followed by Germany (13.8%), France (10.5%) and Austria (9.2%). Germany's high level of world exports in hydro technologies is interesting, since it does not produce electricity from hydro power to any large extent. The other three countries all have a relatively large share in the generation of hydro power as well. Germany's high export share in this sector contradicts the thesis that the performance in external trade with renewable energy technologies can largely be explained by a strong home market. On the contrary, hydro technology is a sector where German firms mainly produce for the international and not the home market.

Japan is leading world exports in geothermal and biomass technologies and has a market share of 29% in 2007. Germany's market stands at 16.5%, which makes it the second biggest provider of geothermal and biomass technologies to world markets. The third largest provider of these technologies is the United States with a world market share of 11%.

5.2.3.5 Share in National Exports

The share of renewable energy exports in relation to total country exports shows the relative export performance of one sector in comparisons to other sectors. It masks out the size of a country and also the general export success of a country and is therefore a helpful indicator when examining the trade performance of certain sectors of a country's economy.

Fig 5-22 shows that renewable energy exports are of relatively high importance for Japan with an export share of 1.97 percent for renewable energy technologies in total exports. This share has increased from 1.5 percent in 2000. The share for Germany has been below the shares of its two competitors and also below the average share of all countries. Still, since 2004 Germany's share of renewable energy export in total exports increased significantly and now stands at 1.4 percent (1 percent in 2000).

The US average share has been slightly higher than Germany's share of the past years. In 2007, the United States exported 1.5 percent of total manufacturing exports in renewable energy technologies. In 2000, this share has been 1.2 percent.

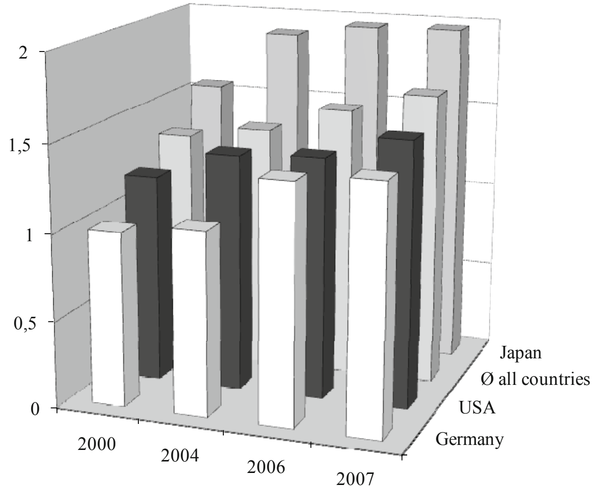

Fig 5-22: Share of renewable energy exports in total national exports, in %

The share of renewable exports in total exports is still small, but the trend of the past years is clear: renewable technology exports are gaining in importance.

For all three countries the export of renewable technologies[452] is already in the range of billions of US$. In 2007, Germany exported renewable energy technologies worth more than US$ 16 billion. In absolute numbers this is much higher than the value for Japan (US$ 12.6 billion in 2007) and for the United States (US$ 13.9 billion). Since Germany's total exports are higher than Japan's and the United States' exports, its share of renewable energy exports in total exports is lower than Japan's or the US' share.

One additional limitation of the data is that the numbers for Germany are not external-EU. This means that Germany is directly compared to the other two countries and the specific situation of Germany within the EU is not considered. In many trade studies, export and import data for European countries are given without the data for intra-EU trade. However, a large share of Germany's exports goes to non-EU countries and it is thus justifiable not to distinguish between internal and external EU trade. This is especially true for the relative share of renewable energy exports in total exports, since for total exports also

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[452] Data for primary and complementary renewable energy technologies.

the number for Germany's trade with the world not excluding EU-internal trade is taken as the numerator for the ratio.

5.2.3.6 Revealed Comparative Advantage

This section uses specific indicators to reveal the competitiveness of Germany, Japan and the United States in renewable energy trading. As presented in the section on indicators the original indicator to reveal a comparative advantage (RCA_1) is calculated as follows:

$$RCA_1 = \frac{\left(\frac{X_{ij}}{X_{tj}}\right)}{\left(\frac{X_{iw}}{X_{tw}}\right)}$$

where X_{ij} and X_{iw} are the values of country's j exports of product i and of world exports of product i and where X_{tj} and X_{tw} refer to the country's total exports and world total exports.

If the RCA_1 takes a value of less than 1 this implies that the country has a revealed comparative disadvantage in the export of the specific product or sector. If the index is higher than 1, the country has a revealed comparative advantage in this sector's exports.

Table 5-9 reveals that the country with the greatest comparative advantage in exports of renewable energy technologies is Denmark with an RCA_1 of 5.65. Worldwide there are in fact only 7 countries that have a comparative advantage in renewable energy exports. All other countries, including the United States (RCA_1 of 0.7) have a comparative disadvantage. Besides Denmark the other countries, which exhibit a comparative advantage in renewable energy exports, are: Japan, China, the Czech Republic, Hong Kong, Germany and Austria. Japan has a much greater revealed comparative advantage than Germany in renewable energy exports as is shown by an RCA_1 of 3.37 compared to 1.35 for Germany.

Japan draws its competitive edge in total primary renewable energy exports from solar, wind and geothermal and biomass technologies. In hydro technology exports, Japan features a comparative disadvantage.

Germany has a comparative advantage in wind power technologies (2.17), but also hydro (1.07) and geothermal and biomass technologies (1.28). In exports of solar technologies, Germany also has a comparative advantage (1.25).

The United States has a comparative disadvantage in all examined renewable energy sectors. The single most striking result of the RCA analysis is Denmark's comparative advantage of 49.26 in wind energy technologies.

Tab 5-9: RCA_1, primary renewable energy technologies, 2007

	Total RE	Solar	Wind	Hydro	Geoth. + biomass
Denmark	5.65	0.10	49.26	0.07	0.04
Japan	3.37	3.61	1.47	0.70	4.16
China	1.59	2.03	0.19	1.35	0.59
Czech Rep.	1.47	1.29	0.05	2.05	3.33
Hongkong	1.39	1.95	0.00	0.00	0.00
Germany	1.35	1.25	2.17	1.07	1.28
Austria	1.22	1.04	0.02	5.82	2.17
Hungary	0.99	1.21	0.00	0.00	0.84
Sweden	0.82	0.78	0.02	0.45	1.69
UK	0.76	0.80	0.10	0.63	1.09
USA	0.71	0.77	0.04	0.38	0.97
Spain	0.65	0.38	2.44	2.69	0.20
Poland	0.45	0.07	0.00	0.14	2.68
Belgium	0.41	0.54	0.00	0.08	0.15
Switzerland	0.38	0.15	0.00	5.72	0.81
Australia	0.35	0.34	0.77	0.31	0.08
Norway	0.35	0.47	0.00	0.27	0.03
France	0.35	0.23	0.02	1.94	0.87
Mexico	0.33	0.35	0.00	0.26	0.49
Netherlands	0.33	0.41	0.08	0.05	0.14
Italy	0.27	0.09	0.27	1.00	1.01
Russian Fed.	0.16	0.03	0.00	1.80	0.63
Finland	0.15	0.17	0.01	0.69	0.01
Portugal	0.14	0.19	0.00	0.05	0.03
Canada	0.14	0.10	0.02	1.21	0.18
Luxembourg	0.08	0.11	0.00	0.08	0.00
Greece	0.07	0.00	0.63	0.02	0.00
Slovakia	0.04	0.01	0.00	0.07	0.24
Ireland	0.03	0.03	0.00	0.01	0.09
New Zealand	0.02	0.01	0.03	0.31	0.03
Turkey	0.02	0.01	0.00	0.45	0.02

How have the RCA_1 values changed over time for Germany, the United States and Japan?

Germany’s exports of primary renewable energy technologies had a slight revealed comparative disadvantage from 1998 until 2004. The RCA_1 values in this time period have been fairly constant at values slightly below 1. From 2004 on, however, there has been a clear upward trend. Germany’s RCA_1 values increased from 0.85 to 1.35 in 2007. Germany’s exports of geothermal and biomass revealed a comparative advantage in all the examined years.[453] Its highest RCA_1 in this renewable energy branch was in 2006 (RCA_1 of 1.6). The RCA_1 values for wind energy exports include an outlier in 1997 (RCA_1 of 5.7). Besides this outlier, Germany did not have a comparative advantage in its wind energy exports until 2005. Currently, wind technologies have the highest comparative advantage among all renewable energy branches in Germany (RCA_1 value of 2.17 in 2007). The RCA_1 values for solar energy remained fairly constant at values slightly below 1. Since 2005, Germany also has a comparative advantage in solar technologies and the RCA_1 value reached 1.35 in 2007. The development of RCA_1 values for hydro power technologies was less steady and reveals a comparative advantage for the years 1996, 1999 and from 2003 onward.

The trend of RCA_1 values for the United States has been the opposite. For the United States, the revealed comparative advantage of renewable energy technologies exhibits a downward trend for all renewable energy technologies. Until 2002 the United States had a comparative advantage in the exports of renewable energy technologies. From 2004 on, RCA_1 values constantly decreased and fell below one (comparative disadvantage) in 2006. Compared to the United States' highest RCA_1 value of 1.7 in 1997, the comparative disadvantage of 0.71 in 2007 is striking. Until 2005 the United States had a comparative advantage in the exports of solar technologies, but the RCA_1 value is now clearly below one (0.77 in 2007). The downward trend in geothermal and biomass technologies is especially striking, despite a small upward lift in 2004 and 2005. In 1997, the United States had had an RCA_1 value of 2.1 in geothermal and biomass technologies. The United States' competitive position in hydro power exports has remained comparably constant since 1996, albeit negative. For most of the years since 1996, wind power exports constituted the renewable energy sector where it was least competitive and this is the case until today.

The RCA_1 values for Japan show that the country has a much greater revealed comparative advantage in renewable energy trading than its two competitors. Over the period from 1996 to 2004, Japan had a high comparative advantage which reached a value of 4.7 in 2004. However, the revealed comparative advantage decreased since 2004 and now stands at 3.37. Especially the revealed comparative advantage in solar technologies has decreased from 5.8 in 2003 to 3.6 in 2007. On the other hand, Japan is very competitive and increasingly so in geothermal and biomass exports (RCA_1 value of 4.16 in 2007). In the two other renewable technology sectors (wind and hydro technologies), Japan had a comparative disadvantage until 2006. This changed, at least for wind technologies, in 2007 and Japan now also has a comparative advantage in this sector.

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[453] See Appendix Table A-13 for detailed tables on RCA1 values since 1996 by technology.

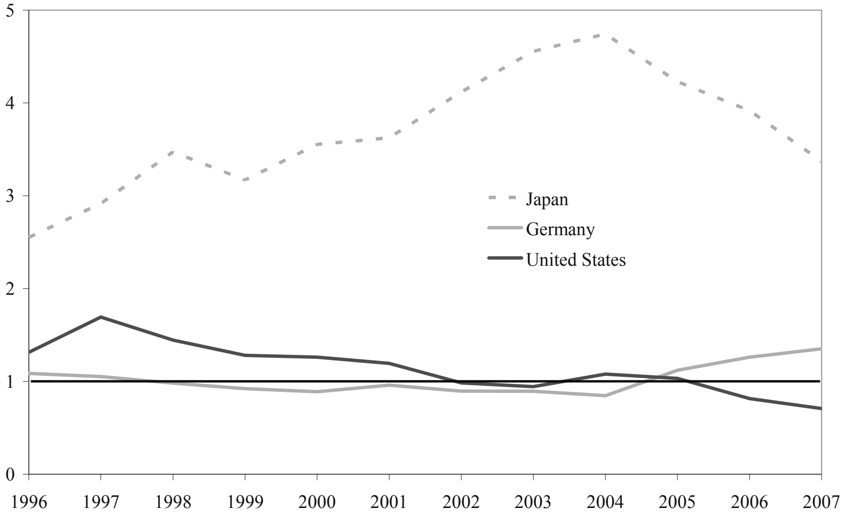

Fig 5-23: RCA_1 for primary renewable energy technologies, Germany, the United States and Japan, 1996-2007

As discussed in the section on the choice of indicators to use for the purpose of this study, it has been argued that besides the original RCA index, which only includes export values, a different indicator to reveal comparative advantage (RCA_2) is analyzed as well, which is computed as:

$$RCA_2 = \ln \frac{\left(\dfrac{X_{ij}}{M_{ij}}\right)}{\left(\dfrac{X_{tj}}{M_{tj}}\right)}$$

where X_{ij} and M_{ij} are the values of country's j exports and imports of product i where X_{tj} and M_{tj} refer to the country's total exports and imports. Taking the logarithm secures comparability on both sides of unity. The original RCA is asymmetrical since the index ranges from zero to one for a comparative disadvantage and from one to infinity for a comparative advantage. The RCA_2 index has the same range in the negative and positive values.

This indicator mirrors that it is insufficient to only look at absolute export levels when analyzing comparative advantages. Instead the relative performance of one sector in comparison to all other industries in the economy is examined using the RCA_2 indicator.

A positive index indicates a comparative advantage of the analyzed industry; a negative index shows a revealed comparative disadvantage.

Tab 5-10: RCA_2, primary renewable energy technologies, 2007

	Total RE	Solar	Wind	Hydro	Geoth. + biomass
Denmark	3.29	-0.66	13.65	-1.56	-1.79
Japan	1.47	1.37	1.51	1.42	2.00
Austria	0.46	0.24	-3.15	1.35	1.31
Czech Rep.	0.37	0.05	0.91	2.64	1.39
UK	0.21	0.25	-2.94	0.62	1.09
Sweden	0.18	0.07	-2.90	-0.18	0.88
China	0.12	0.25	-1.23	-0.28	-0.47
Netherlands	-0.01	0.40	-2.29	0.95	0.33
Germany	-0.04	-0.26	0.61	1.28	0.70
Hongkong	-0.24	-0.24	1.97	-1.22	-2.31
Belgium	-0.29	-0.05	-5.11	-0.56	-0.41
France	-0.38	-0.76	-3.78	0.98	0.78
Mexico	-0.74	-0.86	-8.54	-0.96	0.15
Canada	-0.85	-0.72	-3.51	-0.05	-0.69
Italy	-1.06	-2.22	-0.82	1.09	0.34
USA	-1.21	-0.21	-8.90	-0.48	0.56
Spain	-3.25	-4.34	-0.45	3.12	-4.32

Table 5-10 shows that using the RCA_2 index, Germany does not have a competitive advantage in renewable energy industries any longer. Germany and Hong Kong are the only countries, however, that have a comparative advantage using the RCA_1 index but not the RCA_2 index. This implies that for these countries industries other than the renewable energy sector are more competitive in the respective economies. Japan's renewable energy exports, on the other hand, are at a competitive advantage compared to other industry sectors within the Japanese economy.

The competitive position of US exports of renewable energy technologies, however, is not favorable. Sectors other than renewable energy technologies have a greater comparative advantage. This has not always been the case, though, as Fig 5-24 shows. From 1996 until 1998 and again in 2004, renewable energy exports had a comparative advantage compared to other sectors in the US economy. Since 1999 (except for 2004), the trend clearly shows that renewable energy technologies are loosing competitiveness compared to other sectors. The RCA_2 value of -1.2 in 2007 is in fact the lowest since 1996.

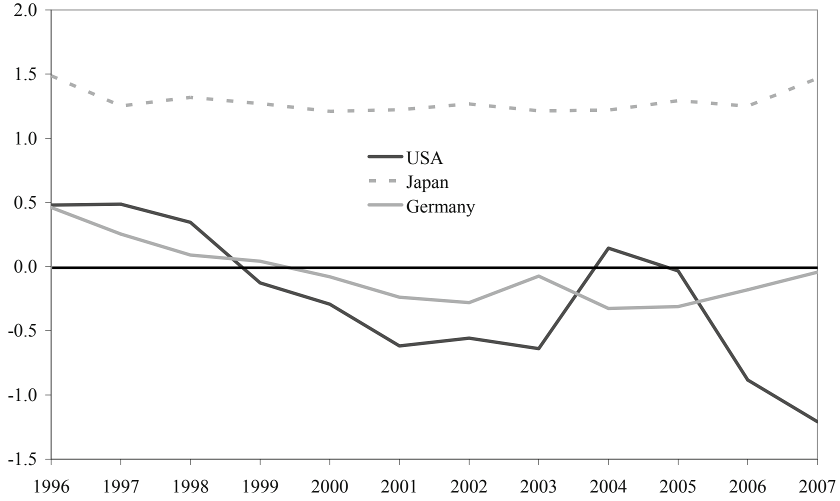

Fig 5-24: RCA_2 for primary renewable energy technologies, Germany, the United States and Japan, 1996-2007

The trend for Japan is also clear: Japan managed to maintain an RCA_2 of approximately 1.3 since 1997. This means that in comparison to other sectors in the Japanese economy, renewable energy technologies are highly competitive. In 2007, Japan's RCA_2 value for renewable energy technologies reached its highest level with 1.5. Germany's development of revealed comparative advantage is less even. From 1996 until 2004, Germany's RCA_2 values for renewable energy technologies have been decreasing, implying that in this time period other sectors gained competitiveness while renewable energy technologies lost in competitiveness compared to these other sectors. Accordingly, sectors other than renewable energy technologies, such as the automobile sector, are more competitive on international markets. Since 2004, the trend for German renewable energy technologies reversed. It remains to be seen if renewable energy technologies will be at a comparative advantage in the German economy in the next years.

5.3 Summary and Conclusions

This chapter provided a detailed analysis of government attempts to influence international trade patterns of renewable energy technologies and the development on international markets for renewable energy technologies.

The analysis of export promotion strategies in the three countries showed that all three countries a) restrict their measures to information providing, assistance in the processing of exports and the provision of export-credit guarantees and b) do not try to influence international trade patterns by setting high tariffs.

The use of trade code analysis allows for a detailed examination of international trade in renewable energy technologies. Different trade relevant indicators have been computed to get a thorough understanding of the dynamics and the development of international trade in renewable energy technologies from many different angles. The empirical data presented in this chapter demonstrate that the renewable energy industry is a strong and expanding sector that has already reached a high level of maturity. For this reason alone a comprehensive analysis of its trade flows is warranted.

To further increase the level of exactness in the analysis, however, more efforts are needed to provide a clear classification of renewable energy products and a fuller set of trade codes more generally. Whereas the classification for hydro and wind energy technologies is relatively satisfying and well-defined, such efforts are especially urgent for solar technologies, geothermal and biomass products. For now, the share of goods classified as a renewable energy good under a specific trade code with non-renewable energy use might be still significant. Therefore it is appropriate to differentiate between those technologies that are unequivocally renewable energy goods and those which are clearly used in renewable energy plants but which might also be used for non-renewable energy purposes. Such an approach has been pursued in this study with the distinction of primary and complementary renewable energy technologies.

Since 2000, trade in renewable energy technologies has been growing faster than total merchandise trade with an average annual growth rate of 20% (12% annual average growth rate for total merchandise trade). In absolute numbers, trade in renewable energy technologies is still small, but growing dynamically.

Japan is the largest exporting country in primary renewable energy technology and thus has the highest world market share in renewable energy exports. Still, Japan lost 15 percentage points in its world market share in primary renewable energy exports since 2004 (2004: 38%, 2007: 23%). Germany and China on the other hand increased their world market share in renewable energy exports between 2004 and 2007. The US world market share in renewable exports decreased from 13% in 2004 to 8% in 2007.

This means that while Japan and the United States are losing in relative importance on world markets, China and Germany are gaining in importance. Still, looking at revealed comparative advantage indices, Japan's renewable energy exports still have the highest comparative advantage among the three case countries on world markets. But again, Japan's index for RCA1 (which depicts the revealed comparative advantage of domestic exports on world markets) showed a decline in the past years, while the index for

Germany increased. The RCA_1 values for the United States also decreased in the past three years.

For all three countries, however, renewable energy exports have continuously gained in importance for the domestic export sector and make up a larger share of total domestic exports than in the early 2000s. Still, looking at RCA_2 values (which show the relative competitiveness of the renewable energy sector compared to other sector of the same economy in international trade) shows that only Japan's renewable energy exports have a comparative advantage compared to other Japanese export sectors. Since 1996, Japan's RCA_2 values have been very constant, which implies that renewable energy exports did not increase their competitiveness nor did they loose in competitiveness to other export sectors. The development of the US renewable energy sector has been very different. Since 2004, US renewable energy exports lost significantly in revealed comparative advantage to other exports sectors and are today at a comparative disadvantage.

Within the German economy, environmental goods including renewable energy goods have often played a pioneering role in terms of innovation and technological progress.[454] The analysis of RCA_2 values for Germany's renewable energy exports shows that this is no longer the case. The comparative advantage that renewable energy exports enjoyed until the late 1990s in comparison to other German export sectors has been lost. This means that the renewable energy sector is no longer a driving force of Germany's economic development. One explanation for this development has been discussed in the previous chapter: Germany's spending on renewable energy R&D in relation to GDP has been reduced since the early 1990s until the mid-2000s. This has a restrictive effect on innovation in renewable energy technologies since industrial dynamic in this sector in created through innovation in the research-intensive industrial sectors. In the past three years, however, there are signs of a new trend with German renewable energy exports gaining in competitiveness again (see Fig 5-24). Still, in 2007 German renewable energy exports are still at a slight comparative disadvantage compared to other German export sectors. Interestingly, Germany's renewable energy R&D spending in relation to GDP is also rising since 2004, which will increase and further technological innovations in this sector.

The development is clear: Japan's renewable energy exports are still more competitive both with regard to other countries and also compared to other Japanese export sectors, but Germany has managed to increase its competitiveness in this area in the past three years, while the United States is falling further behind.

It has been stated earlier that one important explanatory factor for the performance on international renewable energy markets, is a strong home market. The consideration of the

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[454] Legler (2006), *Wirtschaftsfaktor Umweltschutz: Leistungsfähigkeit der deutschen Umwelt- und Klimaschutzwirtschaft im internationalen Vergleich*, p. 93.

time frame is especially important in considering the importance of the home market size on international performance. In the short term, the expansion of the domestic renewable power generation can actually lead to a worsening of the international trade performance, since the necessary technology produced is then used to satisfy the demand of the domestic market. In the longer term, demand and supply are in balance again and then the exports of renewable energy technologies increase. This could explain why in the late 1990s and early 2000s, Germany's export performance in wind energy technologies did not reveal a comparative advantage, but rather a comparative disadvantage. In this time period, Germany had been a net importer of wind energy technologies since the domestic demand was so high that technologies had to be imported. Only in 2004, this trend was reversed and since then the RCA_1 indicator reveals a comparative advantage for Germany in wind energy technologies on international markets. This phenomenon is in fact also illustrated by the development in Danish demand where a large part of the wind turbines produced in the pioneering years in the 1980s were sold domestically whereas only later, in the 1990s, exports made up a substantial part of sales.[455]

To sum up, with the exception of Germany's hydro sector, where Germany is a strong exporter while not generating electricity from hydro power to any substantial extent, the data presented here confirm the assumption that a strong renewable home market is essential to develop a successful export industry with renewable energy goods. Manufacturers from countries with a relatively high share of renewable energy power in total electricity production and a dynamic development of renewable energy power, capture large shares of the international renewable technology market in many instances. As argued by Hansen/Jensen/Strojer Madsen (2003) in the case of Denmark, the early development of wind energy gave Danish producers of renewable energy technology the time to reduce production costs and improve product quality through incremental technological advances and so created first mover advantages in the world market.[456] The leading position of Denmark is only now being challenged from other countries such as Germany which is grabbing higher shares of world wind technology exports.

Japan and the solar PV industry is another case in point. Japan's leading position in solar energy exports stems from decades of solar energy research and development in Japan. Japan's solar industry was kick started by the 70,000 roof program and the focus on solar technologies in Japan's renewable energy R&D. This translated not only in a very dynamic development of renewable power from solar PV but also high world markets

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[455] Hansen/Jensen/Strojer Madsen (2003), *The Establishment of the Danish Windmill Industry - Was It Worthwhile?*, p. 1.

[456] See also Brandt/Svendsen (2004), *Switch Point and First-Mover Advantage: The Case of the Wind Turbine Industry*.

shares in solar exports. Likewise to the situation for Denmark, Japan’s leading position is only now being challenged from other countries entering the market to a higher degree.

It is also important to note that the three countries (Germany, Japan and Denmark) that capture large world market shares in the two most dynamic sectors (wind and solar technology exports) all have promotion schemes in the relevant renewable energy sectors in place. This further confirms the necessity of government involvement in renewable energy markets.

6 Explaining Differences in the Renewable Energy Policy Approaches in Germany, the United States and Japan

This chapter unravels which factors are most important in determining the development of a relatively comprehensive and strict renewable energy policy approach in Germany, a more market-based approach in the United States and the Japanese approach.

In the literature, three main arguments are proposed to explain the differences in environmental policy in the three case countries, which can also be applied to renewable energy policy. Thereafter, differences in the policy approaches can be explained by cultural differences, different geographical conditions or different institutional factors. As has already been argued in the introductory chapter, explanations focusing on cultural or geographic factors cannot explain why there has not been great continuity in renewable energy policy-making. The United States, for example, was the first country worldwide that implemented a mandatory approach in the late 1970s with the renewable energy purchase obligation in PURPA. If cultural and geographic factors would have strong explanatory power, than there should have been more continuity in renewable energy policy-making.

Political driving forces and institutional structures better serve to explain differences in renewable energy policy approaches. This argument, most prominently formulated by Schreurs (2002), states that the stronger the environmental movement in a country, the stronger the environmental regulations are likely to be. However, this approach also only holds limited explanatory power. Using the United States as an example once again, US environmental movements have been the strongest when there was almost no new environmental legislation, such as in the 1980s. Also, during the so-called environmental decade in the United States in the 1960s environmental organizations had in most cases not yet been founded. Moreover, Japan signed the Kyoto Protocol despite a weak environmental community, while the US did not ratify the protocol even with relatively strong environmental groups.

Some other factor must also be relevant. It can be argued that the emphasis on business opportunities is and was different in the three case countries. This translated into more willingness for stricter regulation in those countries that emphasized the business opportunities of the development of new and innovative technologies. Thus, those governments that promote renewables more substantially intend to create not only environmental benefits but more importantly to develop and strengthen domestic renewable energy technology industries. This argument relates to the assumption of Wiser/Lewis (2007), who argues that one factor that is clearly motivating renewable energy policy

K. Jordan-Korte, *Government Promotion of Renewable Energy Technologies,* DOI 10.1007/978-3-8349-6587-5_6,

mechanisms is "a desire for national achievement in what is viewed as an emerging industry".[457]

This chapter first looks at the domestic development in environmental policy-making, which holds some clues to explaining the development of renewable energy policies. It then proceeds to elaborate on the business aspect of renewable energy policies and the different emphasis on business opportunities in the three countries.

6.1 Development of Domestic Environmental and Renewable Energy Policies

It is possible to show that the development in renewable energy policy is largely in alignment with the general development in environmental policy in the three case countries. Therefore, it is necessary to discuss the development of environmental policy in Germany, the United States and Japan.

6.1.1 Development in Germany

Germany's modern environmental policy had its beginning in the late 1960s and 1970s. The first major issues being addressed were acid rain and the destruction of Germany's forest. Especially after the accident at a nuclear reactor in Chernobyl in 1986, a strong movement against the use of nuclear power began to develop. Local environmental groups protested against the build up of nuclear reactors in Germany. By the mid-1980s, the local anti-nuclear movement groups joined together to found a national Green party, which soon became a major force in German politics.[458] In 1983, the Green Party entered the German parliament (Bundestag) for the first time. The Green Party succeeded in strengthening environmental issues in domestic political debates and to promote policy changes.[459]

The emergence of the Green Party also had an important impact on the energy policy of the German government. Until the late 1980s, there had been little renewable energy development in Germany. The oil price hikes in the 1970s had not resulted in increased renewable energy generation in Germany. In some US states, by contrast, the oil prices hikes led to increased wind energy development. Germany's response to the worldwide oil shortage had focused on the build up of nuclear reactors. Moreover, the powerful fossil energy oligopoly had used its influence to effectively hinder renewable energy development.[460] With the Green Party's entrance in the German parliament, however, the debates changed in favor of renewable energy development. Especially parliamentary groups of

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[457] Wiser/Lewis (2007), *Fostering a Renewable Energy Technology Industry: An International Comparison of Wind Industry Policy Support Mechanisms*, p. 1846.

[458] Braunthal (1996), *Parties and Politics in Modern Germany*, pp. 89-90.

[459] Scharf (1994), *The German Greens: Challenging the Consensus*, p. 1-2.

[460] WELFI (Wind Energy Local Financing Initiative) (2008), *Wind Energy in Germany*.

the political parties pressured the government and succeeded in lessening the influence of the coal and nuclear industry.[461] This pressure led to the first important renewable energy promotion measures, such as the 1000 PV roof program (compare section 4.1.4). A breakthrough in renewable energy policy was achieved in 1991 with the enactment of the first federal Electricity Feed-In Law (EFL).

German environmental policy always also has to be seen in the context of European environmental policy as well. Initially, the European Communities had no competences in environmental policy.[462] This changed, however, with the Single European Act of 1987. The Treaty of Maastricht in 1992 gave the European Union (EU) even more competences in environmental policy and specifically aimed at the harmonization of differing environmental laws in EU member countries. This created conflicts between those member countries which already had stricter environmental laws such as Denmark, Germany and the Netherlands in place and those countries which opposed a harmonization at a high level of environmental protection such as France, Italy and the United Kingdom. The former countries succeeded, however, in imposing a harmonization of environmental standards at a relatively strict level.[463] As a result, European countries at this time superseded the United States as an environmental pacesetter and took the international leadership position in environmental policy from the US.[464]

In 1998, the Social Democratic Party (SPD) won the parliamentary elections and formed a coalition with the Green Party. The so called Red-Green Coalition brought new momentum to Germany’s environmental and renewable energy policy. In 2000, the Red-Green Government passed the Renewable Energy Sources Act (EEG), which saw a great expansion of renewable energy promotion. Still, the 1991 feed-in law had also been very important for the development of renewable energy in Germany. It had created first incentives to investors in renewables and more importantly resulted in the rise pro-renewables coalition. This coalition was essential for the enactment of the EEG in 2000. It had also prevented a rollback of the first feed-in law in the mid-1990s against the interests of the utilities, the Economic Affairs Ministry and the European Commission.[465] A powerful renewable energy policy network had been established, which was composed of environmental groups, the booming renewable energy sector, but even some “conventional” organization such as the industrial equipment manufacturers association (VDMA) or some

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[461] Lauber/Mez (2004), *Three Decades of Renewable Electricity Policies in Germany*, p. 618.

[462] Wepler (1999), *Europäische Umweltpolitik: die Umweltunion als Chance für die materielle und institutionelle Weiterentwicklung der europäischen Integration*, p. 138.

[463] Bernauer/Ruloff (1999), *Handel und Umwelt. Zur Frage der Kompatibilität internationaler Regime*, p. 122.

[464] Vogel (2004), *The Politics of Risk Regulation in Europe and the United States*, pp. 2-4.

[465] Lauber/Mez (2004), *Three Decades of Renewable Electricity Policies in Germany*, p. 618.

unions.[466] A pivotal factor in the success of renewable energy development was also the change in responsibility for renewables from the Ministry of Economic Affairs to the Environmental Ministry in 2002. The Economic Affairs Ministry had until then tried to limit the sustained promotion of renewables.[467]

By the early 2000s, renewable energy was not considered a “complimentary” energy source anymore, but its importance in Germany’s energy supply was generally accepted. Hence, when conservative chancellor Angela Merkel took office in 2005, the conservative party did not attempt a rollback of the EEG. In the first years in office, Merkel even portrayed herself as “Klimakanzlerin” (climate chancellor) and promoted Germany’s success in renewable energy development internationally. In 2008, however, Merkel risked her reputation of a firm climate protector and renewable energy promoter. She seemed to more sympathetic to the demands of the automobile and fossil fuel industry and blocked the auctioning of emission rights in the European Emission Trading System. The lobbying of the conventional fuels industry is on the rise again because due to Germany’s success both in renewable energy development and the reduction of greenhouse gas emissions, additional renewable energy capacity and additional CO_2 emission reductions will be more costly now.

Nevertheless, so far Germany still holds an international leadership position in addressing climate change and the development of renewable energy sources. Strong political pressure has made Germany a leading country in renewable energy production.[468]

Two issues in particular, that already have been touched upon briefly, were important for this development. The first issue is the phasing out of nuclear power. One of the first energy acts of the Red-Green Government was the decision to dismantle all nuclear reactors by 2020.[469] The second issue is the reduction of greenhouse gas emissions. As mentioned earlier, the German government committed itself to ambitious greenhouse gas emissions reductions targets (21% reduction by 2012 compared to 1990 levels). To avoid global warming to exceed 2°C compared to pre-industrial temperature, all industrial countries will need to set even more ambitious reduction targets than those of the Kyoto Protocol. The Germany government has stated that it is willing to reduce CO_2 emissions by 40 % by the year 2020, if the EU as a whole agrees to a reduction of 30% and other industrial countries also commit to substantial reduction targets.[470] The commitment to ambitious greenhouse gas reduction targets as well as the nuclear phase-out has and will continue to

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[466] Lauber/Mez (2004), *Three Decades of Renewable Electricity Policies in Germany*, p. 619.

[467] Lauber/Mez (2004), *Three Decades of Renewable Electricity Policies in Germany*, p. 611.

[468] Lauber/Mez (2004), *Three Decades of Renewable Electricity Policies in Germany*, p. 599.

[469] German Federal Ministry of Economics and Technology (2000), *Vereinbarung zwischen der Bundesregierung und den Energieversorgungsunternehmen vom 14. Juni 2000*.

[470] German Federal Ministry for the Environment (2008), *Kyoto Protocol*.

put pressure on the German government to use all possible ways to replace nuclear energy with other energy sources and to reduce CO_2 emissions. Hence, these two driving forces alone will ensure that Germany continues to promote renewable energy use.

6.1.2 Development in the United States

The United States was the first country worldwide with a comprehensive approach in environmental policy-making. In the so called "environmental decade" in the United States a range of ambitious environmental regulations were implemented at the federal level.[471] Until the early 1980s, the United States was a leader in environmental policy worldwide.[472] In this time period, the first regulatory promotion scheme for renewable energies was created as well (compare section 4.2.2.a). The mandatory purchase obligation of renewable energy as part of the Public Utility Regulatory Policies Act (PURPA) of 1978 initiated the first substantial increase of renewable energy use in the United States. As a result, the US led the world in renewable energy development for many years.[473]

In this time the United States relied largely on a command and control approach and not a market-based approach in its environmental policy. This already shows that geographical conditions and also regulatory tradition alone are insufficient to explain the development in US environmental and renewable energy policy. Neither the geographical factors nor the regulatory tradition have changed to a substantial degree since the 1970s.

The initial impetus of the late 1970s and early 1980s followed a phase of stagnation in renewable energy policy in the late 1980s and 1990s. Similarly to US environmental policy this time period can be called a "lost" decade for renewable energy.[474] Several reasons can be identified for this decline in the renewable energy promotion such as plummeting oil prices which lessened the immediate necessity to find alternatives to conventional fossil fuels. The backlash in US environmental policy, however, really started with the landslide electoral victory of President Ronald Reagan in 1980.[475] President Reagan initiated comprehensive efforts to reduce to role of the federal government in many policy areas, including environmental policy. This also brought a shift away from the use of command and control mechanisms. The impact of President Reagan on US en-

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[471] Hansjürgens (2000), *Umweltpolitik in den USA und in der Bundesrepublik Deutschland. Ein institutionenökonomischer Vergleich*, p. 191.

[472] The articles of Hansjürgens (2000), *Umweltpolitik in den USA und in der Bundesrepublik Deutschland. Ein institutionenökonomischer Vergleich* and Andrews (1997), *The United States* present a great overview of the development of US environmental policy.

[473] Martinot/Wiser/Hamrin (2004), *Renewable Energy Policies and Markets in the United States*, p. 1.

[474] Martinot/Wiser/Hamrin (2004), *Renewable Energy Policies and Markets in the United States* call the time from 1990 until 1997 the "stagnation era". See Rosenbaum (1998), *Environmental Politics and Policy*, pp. 11-12 and Vig (1997), *Presidential Leadership and the Environment: From Reagan to Clinton*, p. 98 for a discussion of the "lost" environmental decade.

[475] Vig/Kraft (2000), *Environmental Policy: New Directions for the Twenty-First Century*, p. 127.

vironmental policy has been elaborated extensively in the literature on US environmental policy. Rosenbaum (1998) states:

> "The environmental movement regarded the Reagan administration as the most environmentally hostile in a half century and the president's regulatory reform as the cutting edge of a massive administrative assault on the institutional foundations of federal environmental law."[476]

The hostility of the Reagan administration towards environmental regulation was followed by a period of gridlock in the 1990s. In 1992, the Democrat Bill Clinton was elected President. But since the Congressional elections of 1994, US Congress was dominated by Republicans in both the House of Representatives as well as the Senate.[477] The Republican Congress promoted a new wave a deregulation in different policy areas and a general retreat of the influence of the federal government. This affected environmental policy as well. The intention of the Republicans to dismantle environmental legislation could largely be prevented by President Clinton and his Vice-President Al Gore.[478] Still, Clinton and Gore failed to push new environmental laws through Congress. Hence there was progress in neither environmental policy nor renewable energy policy. This resulted in the United States loosing their international leadership position in environmental policy. In an international comparison, US environmental standards are generally less strict today.

The US states filled this void of federal environmental and renewable energy policies and implemented various regulations in these sectors. The result is a mosaic of a great variety of different mechanisms and levels of regulations which hinder long-term planning security for companies. These are the two main reasons why US states have generally been more successful in implementing renewable energy and climate change laws. First, the states are more directly affected by climate change and global warming such as by a potential sea level rise. Second, most states and regions (there are some exceptions) are not economically dependent on the fossil fuel industries and, therefore, have less need to consider the demands of these industries (the influence of industry lobby groups at the federal level is addressed below).

On the federal level, the lacking engagement in renewable energy policy is clearly related to its reluctance to tackle climate change via a mandatory reduction of greenhouse gases. So far, there are no CO_2 reduction targets at the national level. These would require the US government to take decisive steps to address climate change which would certainly include the promotion of renewable energy sources. The United States is today the only major industrialized country that did not ratify the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCC). In 1997, the US Senate passed by

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[476] Rosenbaum (1998), *Environmental Politics and Policy*, pp. 11-12.

[477] Vig/Kraft (2000), *Environmental Policy: New Directions for the Twenty-First Century*, p. 1.

[478] Vig/Kraft (2000), *Environmental Policy: New Directions for the Twenty-First Century*, p. 122.

a 95-0 vote the Byrd-Hagel resolution. This resolution stated that the US Senate would not sign the Kyoto Protocol or any other climate treaty that does not mandate commitments to greenhouse gas reduction or developing countries or that would "result in serious harm to the economy of the United States".[479] There is a wealth of literature as to why the United States did not ratify the Kyoto Protocol. But clearly the reluctance also has to be seen in the context of the 1990s, in which the United States was generally unwilling to surrender any sovereignty to international organizations.[480] Jonathan Bach, lecturer at Columbia University, comments this development: "Multilateral action became increasingly acceptable only if it offered clear advancement of US national interests."[481]

One further reason both for the lack of a strong federal role in renewable energy promotion and the missing greenhouse gas reduction targets can be found in the US political system. The complex set of rules of legislative procedure creates many hurdles for the enactment of substantial legislation. The Congressional procedures require draft bills to be assigned to the relevant committees for review. After considering the bill, the committee votes on a bill to report the measure to the full house or simply to let it "die" by not voting on the bill. Bills that are released from committees are voted on in both chambers of the US Congress. Differences in the bills between the two chambers have to be reconciled before the legislation can be submitted to the US president for signature or veto. In the US Senate, filibusters are often used to prevent the voting on legislation. Filibusters refer to the tactic of US Senators to prevent the vote on a bill by using their right to speak for as long as they want before the Senate. Filibusters can only be stopped by the votes of 60 Senators (three-fifths of the Senate). A bill becomes law if the president signs the bill that was passed by Congress. If the president decides to veto a bill passed by Congress, a two-thirds majority vote in both bodies of the US Congress can still secure its passage into law. It can be argued that due to the system of checks and balances between the Congress and the president and the complex legislative procedures "it is usually easier to prevent legislative action than it is to pass new policies".[482]

The 2-year terms of the Members of the House of Representatives makes the enforcement of long-term plans more difficult. The Congressmen and -women intend to

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[479] S. Res. 98

[480] See Falke (1996), *Handelspolitik. Vom Freien Handel zum Fairen Handel* for a discussion on the economic factors for the US' unwillingness to limit its sovereignty. Important reasons can be found in the relative demise of the US economy since the end of World War II, the high trade deficit and the understanding that many US competitors promote their domestic industries unfairly. Other explanations include the end of the cold war, which supposedly lessened the need for strong international cooperation.

[481] Bach (2000), *U.S.-Western European Relations. The Transatlantic Partnership in the Shadow of Globalization*, p. 180.

[482] Byrne/Hughes/Rickerson et al. (2007), *American Policy Conflict in the Greenhouse: Divergent Trends in Federal, Regional, State, and Local Green Energy and Climate Change Policy*, p. 4566.

primarily serve the most urgent needs of their constituency and these generally do not include the long-term restructuring of the energy system.

Moreover, the US political process is very open to interest groups, which try to influence policy outcomes in one way or another. The research of Rajan (2006) shows that energy lobbies at the federal level have the ability to pressure federal politics.[483] Other studies also point to the influence of the automobile and fossil fuel industries on US energy and environmental policy.[484] In the case of the Kyoto Protocol for example, US industry had started a massive campaign against the US signing it. Industry lobby groups were successful in portraying energy security as the primary goal of any (renewable) energy measures and to push aside environmental concerns. As a result, the Energy Policy Act of 2005 continues to primarily promote the fossil fuel industry through massive tax breaks for oil and gas companies.[485] The bill excludes the issue of greenhouse gas emissions even though a majority of Americans today support a stronger federal role in climate change.[486] In the recent past, however, more and more major firms realized the need for a substantial shift in US climate change and renewable energy policy also at the federal level. These firms founded US CAP (Climate Action Partnership) and call on the federal government to enact legislation requiring significant reductions of greenhouse gas emissions.[487]

More generally, the US federal government so far has largely followed a "technology push"[488] approach. The US administrations under both Bill Clinton and George Bush have emphasized the need of providing incentives for technological development rather than regulatory tools to create demand (market pull). However, the US did not pursue this approach consequently as could be shown in chapter 4. The share of renewable energy R&D in GDP was dramatically decreased since the 1970s.

In sum, despite the use of financial incentives, the US federal government lacks a comprehensive approach to promote renewable energy sources. There are signs, however,

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[483] Rajan (2006), *Climate Change Dilemma: Technology, Social Change or Both? An Examination of Long-Term Transport Policy Choices in the United States*, p. 664.

[484] See e.g. Public Citizen (2005), *The Best Energy Bill Corporations Could Buy: Summary of Industry Giveaways in the 2005 Energy Bill*, Natural Resources Defense Council (NRDC) (2002), *Heavily Censored Energy Department Papers Show Industry is the Real Author of Administration's Energy Task Force Report* and Leggett (2001), *The Carbon War: Global Warming and the End of the Oil Era*.

[485] Jordan (2005), *Changes and Continuities in U.S. Energy Policy*, p. 3. See for the text of the Energy Policy Act of 2005, http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=109_cong_public_laws&docid=f:publ058.109 (access date: 05/23/2007).

[486] Opinion Research Corporation (2006), *Global Warming and Alternative Energy: A Leadership Survey*.

[487] See the website of US CAP, http://www.us-cap.org/ (access date: 03/25/2009).

[488] See the work of Schumpeter (1934), *The Theory of Economic Development: An Inquiry Into Profits, Capital, Credit, Interest, and the Business Cycle* for the origin of the technology push approach. Schumpeter argued that economic development was the result of innovation. Accordingly, the creation of new and innovative technologies is more important than identifying existing market needs.

that the support for renewables will increase under the Obama administration in the next years. The factors for the lack of a strong federal role in renewable energy promotion are manifold, but four main reasons can be identified. First, there is no tradition of (renewable) energy promotion at the federal level and thus little expertise in this policy area.[489] Even the implementation of the renewable energy purchase obligation in PURPA was left to the states. Further, the US government still did not decide on mandatory greenhouse gas reduction targets. Such targets would put pressure on the government to use all possible ways to limit and to reduce CO_2 emissions, including a higher share of renewable energy sources in the electricity mix. The political system of checks and balances is an additional impediment for a strong federal role in renewable energy promotion. The policy-making process is vulnerable to interest groups influence. The two-year terms of the Members of the House of Representatives limit the enforceability of long-term plans which might be costly in the short-term. Lastly, the federal government so far relied heavily on a technology centered approach, which aimed at giving incentives for the development of innovative technologies but left renewable energy development to market forces.

6.1.3 Development in Japan

Just as in Germany and the United States, Japan's modern environmental policy had its beginnings in the 1960s and 1970s.[490] The rapid industrialization after World War II had resulted in massive pollution of Japan's air. Accordingly, the first environmental laws addressed air and water pollution.[491] The most important measure was the implementation of environmental standards such as emission standards. These forced the Japanese industry to change production processes in order to meet the standards. The industry opposed the standards vigorously. The Japanese government tried to facilitate the development of technological innovations that would help meet the standards through various fiscal measures such as loans and preferential taxing. In fact, the standards combined with the financial incentives sparked massive investments of the industry sector in pollution control equipment, which diffused rapidly in the industrial sector.

In the early 1970s, environmental policy was institutionalized. The Environment Agency was created in 1971 and was elevated to the Ministry of the Environment in 2001.[492] By mid-1970, Japan had among the most stringent environmental regulation in the world.[493] Japan made tremendous progress in implementing air pollution control

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[489] Schreurs (2007), *Renewable Electricity Politics in the United States*, p. 246.

[490] Fukasaku (1995), *Energy and Environmental Policy Integration: The Case of Energy Conservation Policies and Technologies in Japan*, p. 1063.

[491] The Air Pollution Regulation Law of 1962 and the Basic Law for Pollution Control of 1967.

[492] Imura/Schreurs (2005), *Environmental Policy in Japan*, p. 5.

[493] Schreurs (2002), *Environmental Politics in Japan, Germany and the United States*, p. 47.

measures and improving energy efficiency. These were areas where Japan excelled from a technological perspective.

The oil shortages in the 1970s led to a shift from pollution control to energy policy.[494] The fact that Japan has almost no indigenous energy resources emphasized the need for a swift reaction to the skyrocketing fossil fuel prices on world markets. To reduce Japan's dependence on foreign fuels energy efficiency measures were implemented. The most important policy measure was the Energy Conservation Law, which included guidelines for energy conservation in factories and buildings and standards for energy efficiency in industrial products.[495] In 1974, Japan started the Sunshine Project which primarily aimed at the development of solar and geothermal energy (compare chapter 4).

Energy efficiency is until today one of the greatest successes of Japan's environmental and energy policy. Compared to Germany (with its focus on nuclear and coal energy) and the United States (with its focus on nuclear energy but also renewable energy), Japan's response to the oil shortages and high oil prices of the 1970s, has focused on increasing energy efficiency and the development of solar PV. Technological innovations made Japan one of the most energy efficient countries worldwide. Since the oil price hikes in the 1970s, Japan has increased its energy efficiency levels (measures as energy input per unit of GDP) by about 30%.[496] In the 1990s, however, the gap in efficiency levels been Japan and European countries has narrowed.[497] According to the International Energy Agency (IEA) Japan had a higher energy efficiency level than any other industrialized country before 1990.[498] Since the 1990s, the energy efficiency increases especially in the energy-intensive industries such as steel, iron and chemicals have leveled off and in some case energy intensity is actually increasing. One explanation for that can be seen in lower investments in energy-efficiency improvements by the industry sector.[499] However, energy efficiency improvements are still seen as an important aspect of energy policy by the Japanese government. The government intends to increase energy efficiency by around 30 percent until 2030 compared to 2003.[500]

As the examples of pollution control in the 1960s and energy efficiency in the 1970s show, Japan's initial environmental and energy policy approach was typically characterized by a combination of standards or guidelines and the facilitation of technological de-

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[494] Fukasaku (1995), *Energy and Environmental Policy Integration: The Case of Energy Conservation Policies and Technologies in Japan*, p. 1075.

[495] Fukasaku (1995), *Energy and Environmental Policy Integration: The Case of Energy Conservation Policies and Technologies in Japan*, p. 1066-1067.

[496] International Energy Agency (2008), *Energy Policies of IEA Countries. Japan 2008 Review*, p. 53.

[497] Imura/Schreurs (2005), *Environmental Policy in Japan*, p. 317.

[498] International Energy Agency (2008), *Energy Policies of IEA Countries. Japan 2008 Review*, p. 53.

[499] Imura/Schreurs (2005), *Environmental Policy in Japan*, p. 317.

[500] International Energy Agency (2008), *Energy Policies of IEA Countries. Japan 2008 Review*, p. 59.

velopment through low interest loans, preferential taxing and subsidies. This combination played an important part in the sector's success in pollution control and energy efficiency in this time and other areas. Typically, the term "administrative guidance" is used to describe how the Japanese government aimed to facilitate the implementation of standards and the development of technological innovations through various measures. Administrative guidance of industry behavior refers to a process of close consultations with industry leaders to "persuade" them of the necessity of regulations and standards. In 1977, the OECD stated in its review of environmental policy in Japan that "the emission standards are enforced by persuasion rather than coercion."[501] In fact, the use of penalties is seen as the last resort only to be used if all other possibilities fail.

In the 1990s and 2000s, administrative guidance still plays a central role in Japanese policy-making. Nevertheless, the traditional combination of standards and administrative guidance was altered somewhat. Japan's environmental and energy policy now includes a greater use of market-based measures. For example The New Basic Environment Law, which was enacted in 1993 and which replaced the 1967 Basic Law for Pollution Control, incorporates market-based mechanisms alongside the traditional command-and-control measures with administrative guidance. The law includes the demand for environmental impact assessment, environmental taxes and the promotion of science and technology.[502]

The reduced relevance of command-and-control measures can also be seen in Japan's climate change policy. In the 1990s, climate change acquired a prominent position in Japan's environmental and energy policy.[503] Japan hosted the 1997 Kyoto Conference on climate change. Under the Kyoto Protocol, the main outcome of the conference, Japan has committed to reducing its greenhouse gas emissions by 6% until 2012 compared to 1990 levels. The main measure to reach this goal is the 2005 Kyoto Protocol Target Achievement Plan, which include interim targets before 2012.[504] The 2007 Cool Earth 50 initiative adds to the Kyoto Plan and calls for a global target to halve greenhouse gas emissions by 2050. The initiative also includes a national plan to reduce greenhouse gas emissions such as public awareness campaign.[505]

However, Japan relies heavily on voluntary measures to reduce greenhouse gas emissions such as a voluntary trading scheme.[506] There are no mandatory measures in place which results in weak price signals for greenhouse gas emissions in the economy. However, the country will have to increase its efforts significantly if the Kyoto targets are to be

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[501] OECD (1977), *Environmental Policies in Japan*, p. 33.

[502] Morishima (1999), *Japan's Environmental Policies Amid a Changing Global Landscape*.

[503] Morishima (1999), *Japan's Environmental Policies Amid a Changing Global Landscape*.

[504] International Energy Agency (2008), *Energy Policies of IEA Countries. Japan 2008 Review*, p. 30.

[505] International Energy Agency (2008), *Energy Policies of IEA Countries. Japan 2008 Review*, p. 46.

[506] International Energy Agency (2008), *Energy Policies of IEA Countries. Japan 2008 Review*, p. 76.

reached. According to data of the US Energy Information Administration, Japan's CO_2 emissions increased by 18% between 1990 and 2006.[507] Meeting the Kyoto target becomes increasingly unlikely.

The relatively weak measures to fight global warming are one explanation why Japan lags Germany in domestic renewable energy generation. One reason why climate change policy does not include greater incentives to increase the use of renewable energy is the lack of mandatory measures to fight climate change. However, the lack of mandatory measures is also a characteristic of Japan's renewable energy policy (compare chapter 4). In fact, Japan's renewable energy policy is a very good example of the so called "Japanese form of regulation."[508] The targets of Japan's Renewable Portfolio Standards are so small that the measure in fact cannot be seen as a binding legal obligation, but rather as clear policy statements regarding national goals.

A further specific of renewable energy policy-making in Japan is the close cooperation between business and state. As stated in Chapter 4, the Ministry of Economy, Trade and Industry (METI) is the most powerful government agency in the energy sector. It is administered with implementing national energy programs and it is helpful to understand its relationship to domestic industries. The energy-related responsibilities of METI are implemented largely through the New Energy and Industrial Technology Development Organization (NEDO). NEDO receives its funding through the METI, but its staff consists not only of government officials but also of private-sector employees on secondment, who work at NEDO for two- or three-year turns. This kind of arrangement has created a network between the state and government and this is one relevant factor explaining the specific design of Japanese renewable energy policy and its lack of mandatory regulation.[509] Similar results have been identified in environmental policy research. Schreurs (2002) describes environmental policy implementation as being focused on administrative guidance, voluntary agreements, and a mix of incentives to improve performance and penalties for non-compliers.[510] Environmental regulation is often initially comparably vague in terms of specific norms. Thus, regulation can better be described as framing guidelines to

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[507] US Energy Information Administration (2006), *International Energy Annual 2006*, table H.1co2.

[508] Schreurs (2002), *Environmental Politics in Japan, Germany and the United States*, p. 12.

[509] Samuels questions the widely held assumption that state power exaggerates private power in Japan and claims that the power of Japan's bureaucracy is widely exaggerated in most standard literature: "Intervention by the Japanese state is paradoxical – the Japanese state is pervasive in the economy, because […] private actors have learned how to limit and enhance state power simultaneously. They surrender jurisdiction to retain control", Samuels (1990), *The Business of the Japanese State: Energy Markets in Comparative and Historical Perspective*, p. 2.

[510] Schreurs (2002), *Environmental Politics in Japan, Germany and the United States*, p. 72.

change industry action. Once changes have been achieved to a certain extent, then more stringent regulations are adopted.[511]

A main hindrance for more stringent renewable energy policy measures is the great influence of industry. As explained, representatives of the industry rotate in and out of the government, especially at NEDO. METI itself argues that stricter RPS so far could not be enforced against the interests of the industrial lobby.[512] The structure of the Japanese electricity sector further restricts the development of renewable energy sources. The electricity sector is dominated by 10 regional monopolies which strongly oppose stricter RPS or any additional regulation. The lobby of the nuclear power industry additionally fights the promotion of renewable energy technologies.[513] These factors also contribute to the ambivalent position of the Japanese government which repeatedly points out the importance of more renewable energy use but cannot bring up the necessary political will to implement stricter regulation.

In sum, Japan's renewable energy policy reflects the general development in environmental policy. Both policy areas now rely strongly on market-based measures and voluntary agreements. However, Japan is especially successful in those areas, energy efficiency and solar PV, which have seen mandatory standards and administrative guidance initially. Japan's long-term expertise in these areas has resulted in its international leadership position which Japan enjoys until today.

6.2 Emphasis on Economic Benefits

The analysis of the previous section showed that the development of renewable energy policy was in alignment with the general environmental policy development – at least for Japan and the United States. Both countries implemented the first renewable energy promotion instruments in the 1970s. The United States was the first country worldwide that used a mandatory instrument to promote the development of renewable energy sources. In the past years, however, both countries have lost their leadership position in terms of renewable energy promotion and rely primarily on voluntary measures.

In Germany, however, renewable energy policy stands out as the central area in the environmental and energy policy field where regulatory instruments have been introduced in the past decade. The previous section identified historical as well as political and cultural explanations for the development. Still, these factors alone do not sufficiently explain why the development in Germany has been so remarkably different. Something else must be relevant.

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[511] Schreurs (2002), *Environmental Politics in Japan, Germany and the United States*, p. 12.

[512] Wieczorek (2007), *Energiepolitik und Klimaschutzmaßnahmen in Japan*, p. 66.

[513] Wieczorek (2007), *Energiepolitik und Klimaschutzmaßnahmen in Japan*, p. 68.

Whilst the three countries do not explicitly rank the different motivations to promote renewable energy sources, it is apparent that different emphasis is given to the different goals. While all countries name environmental benefits as well as energy security concerns as reasons to increase renewable energy use, the emphasis given to the creation of new industrial opportunities by the countries and there political actors varies.[514]

It can be argued that the degree of government promotion of renewable energy can be at least partially explained by differences in the emphasis on economic opportunities. The political sector and the industrial sector must have a common interest to promote renewable energy, so there has to be a combination of political will driven through public opinion and industry support. In the following this argument is elaborated in greater detail.

6.2.1 Strong Renewable Energy Coalition in Germany

In Germany, a powerful coalition emphasizing the economic benefits of renewable energy use and the lack of strong industry opposition against renewable energy promotion instruments explain Germany's strict renewable energy instruments.

The first feed-in law (EFL) of 1991 affected mostly utilities and renewable energy generators in northern Germany, since the 1991 EFL still included the provision that the regional utilities had to buy all renewable energy produced in their district.[515] Utilities in the relatively windless south of German were largely unaffected. The utilities in the north passed on their additional costs to their customers. There was little opposition from these customers in Northern Germany, however, because it was also the north of Germany that benefited from increased wind power generation in terms of industrial growth and employment.[516]

Because the EFL largely affected only utilities in the north, there was no common approach among utilities against the promotion of renewable energy. Moreover, the coalition in favor of renewable energy promotion gained in importance over the years, especially since the Green party became part of the German governing coalition in 1998. This pro-renewables coalition was very successful in linking environmental and economic benefits of renewable energy use in the public debate.[517] This is not to say that there was no industry opposition against the renewable energy laws. The renewable energy coalition, how-

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[514] See Connor (2003), *National Innovation, Industrial Policy and Renewable Energy Technology*. The central argument of the article is that different nation's approaches to innovation and industrial policy impact the range of renewable energy policy options available, the choices that are made and the aims that underline them.

[515] Lauber/Mez (2007), *Renewable Electricity Policy in Germany 1974-2005*, p. 193.

[516] Agnolucci (2008), *Factors Influencing the Likelihood of Regulatory Changes in Renewable Electricity Policies*, p. 152.

[517] See for example Deutscher Bundestag (2000), *Entwurf eines Gesetzes zur Förderung der Stromerzeugung aus erneuerbaren Energien (Erneuerbare-Energien-Gesetz - EEG) sowie zur Änderung des Mineralölsteuergesetzes*.

ever, was strong enough to defend the renewable energy legislation against industry opposition.

Moreover, the successor of the EFL the EEG of 2000 included several provisions that reduced hostility from utilities. For one, a mechanism was introduced to balance the costs of utilities in different regions. According to that mechanism the amount of feed-in tariffs that utilities have to pay is proportional to the electricity sold. Moreover, utilities could now also build renewable energy power plants and thus profit from the EEG.

The growth in renewable energy generation and the success of the renewable energy industries also slowly led to an adjustment in beliefs with more and more stakeholders acknowledging the importance of renewables not only for environmental but also for economic reasons.[518]

Under the current governing coalition of the Christian democrats and the social democrats, this message still shapes Germany's approach to renewable energy promotion: "We are going to prove that climate-change [measures] and economic prosperity are not contradictions, but are mutually dependent," says Environment Minister Sigmar Gabriel.[519]

6.2.2 Less Emphasis on Economic Benefits of Renewable Energy Use in the United States and Japan

In the United States, the federal level did not show great interest in renewable energy use until very recently. Energy security concerns have dominated the United States's renewable energy approach for many years. The possible economic benefits of renewable energy use received relatively less attention in the public debates.[520]

By contrast, the debate on renewable energy use at the state level focused on economic development.[521] By promoting renewable energy use, US states intended to capture the economic benefits created through additional jobs, manufacturing, investment and revenue for state economies. Job creation in particular has been one of the most important goals of states' renewable energy approach. A number of studies projected job growth from national renewable energy legislation on a state-by-state basis.[522] These studies have fueled the renewable energy job debate in US states and have helped to emphasize the economic opportunities of renewable energy use.

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[518] Lauber/Mez (2007), *Renewable Electricity Policy in Germany 1974-2005*, p. 193.

[519] Blue (2007), *Environment: Lessons from Germany*.

[520] Jordan (2005), *Changes and Continuities in U.S. Energy Policy*, p. 11.

[521] Byrne/Hughes/Rickerson et al. (2007), *American Policy Conflict in the Greenhouse: Divergent Trends in Federal, Regional, State, and Local Green Energy and Climate Change Policy*, p. 4568.

[522] Barrett/Hoerner (2002), *Clean Energy and Jobs: A Comprehensive Approach to Climate Change and Energy Policy*, Apollo Alliance (2004), *New Energy for America: The Apollo Jobs Report*.

This explains why US states have been more successful than the federal level in implementing renewable energy laws. As mentioned above, national policy debate has often been vulnerable to special interest politics. Therefore, even with the change in the national administration which clearly intends to focus more on renewable energy promotion, the gap in policy initiatives between states and the national government will be hard to overcome. The capacity of the energy and auto lobbies to influence national energy policy-making will continue to be significant.[523] The US renewable energy industry is not yet strong enough to counter the opposition from energy and automotive lobbies.

The necessity of strong industry support to establish strict regulation is also supported by evidence from US international environmental policy. While the United States rejected nearly all multilateral environmental agreements in the past decades[524], the US did sign the Montreal Protocol on Substances That Deplete the Ozone Layer in 1987. Economic aspects explain why the United States pushed the Montreal Protocol internationally. DuPont, a US chemical company and the largest producer of chlorofluorocarbons (CFCs) at the time, was the only company worldwide that produced a CFC alternative. DuPont thus fought for an international phase-out of CFC and succeeded to convince the US delegation responsible for negotiating the Montreal Protocol to follow suit. Enormous business gains resulted from the Montreal Protocol for DuPont.[525]

With regard to renewable energy, the business community in the United States is now more willing to accept the possible economic benefits of a greater renewable energy share. Giving the US expertise in technological development, many businesses realize the potential of increasing the production of green technologies. Business coalitions are forming that explicitly emphasize these economic opportunities, such as US CAP. It remains to be seen if this new movement will be strong enough to overcome opposition from other industry groups.

In Japan, the emphasis on economic benefits of renewable energy use is less pronounced despite its high level of technology and manufacturing capability in some renewable energy technologies such as solar power. As has been stated earlier Japan's focus in (renewable) energy policy is more on energy security than on economic development.[526] Japanese industry sees renewable energy technologies and global climate change only as a

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[523] Byrne/Hughes/Rickerson et al. (2007), *American Policy Conflict in the Greenhouse: Divergent Trends in Federal, Regional, State, and Local Green Energy and Climate Change Policy*, p. 4568.

[524] Jordan (2003), *Handel und Umwelt in der WTO: Erklärungsansätze für die Positionen von USA und EU*, p. 56.

[525] Brühl (2000), *Verweigerung statt Führung: Die internationale Umweltpolitik der USA*, p. 389.

[526] See for the same conclusion Elder/Bhattacharya/Romero (2007), *The Puzzle of Japanese Renewable Energy Policy: Why Japan is Lagging and How It Can Catch Up*, p. 1.

kind of “green gold”[527] as long as unwanted regulations can be avoided. Japan’s utility companies supported Japan’s climate change goals mostly because of the opportunity to gain support for its nuclear energy policies. The National Energy Strategy of 2006 clearly shows that the strategies prioritize nuclear power and fossil supply stability (compare section 4.3). Because of the lacking emphasis on renewable energy promotion and insufficient mandatory standards in Japan’s Renewable Portfolio Standard Japan failed to defend its former leadership position in solar PV capacity. Germany took this position from Japan in 2005 (compare section 4.6.4). The renewable energy industry in Japan is in comparison to Germany relatively weak, it failed to promote renewable energy use as a great economic opportunity and lastly the opposition was too strong to implement stricter renewable energy legislation.

6.3 Conclusion

The degree of government promotion of renewable energy can be at least partially explained by differences in the willingness of governments to emphasize the economic benefits of renewable energy use and to promote export industries. The political sector and the industrial sector must have a common interest in promoting renewable energy, so there has to be a combination of political will driven through public opinion and industry support. While political driving forces as well as the commitment of countries to reduce greenhouse gas emissions are important factors as well, the analysis of the driving forces of renewable energy policy in Germany, Japan and the United States showed that emphasis on business opportunities is and was much stronger in Germany than in the other two countries.

Germany’s renewable energy approach intends to create not only environmental benefits but more importantly to develop and strengthen domestic renewable energy technology industries. A powerful renewable energy coalition in Germany succeeded in linking the environmental and economic benefits of renewable energy use in the public debate. This coalition was clearly strengthened by the election of the Red-Green government in 1998, which expanded the initial renewable energy promotion under the conservative government. Germany’s renewable energy success can be explained by a decade of mandatory renewable energy promotion. These promotion measures were pushed through by the strong renewable energy coalition. The measures enabled the German renewable energy industry to build an international leadership position in the production of renewable energy technologies.

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[527] Moore/Miller (1994), *Green Gold: Japan, Germany, the United States, and the Race for Environmental Technology*.

In the United States, only debates at the state level have clearly focused on the possible economic benefits of renewable energy use. This explains why so far mandatory renewable energy promotion can only be found at the state level. On the federal level, the renewable energy debate has primarily focused on the possible positive effects on energy security of a greater share of renewable energy use. This focus was insufficient to result in mandatory promotion of renewable energy sources. The US federal government still lacks a comprehensive approach to promote renewable energy sources. It remains to be seen if the support for renewables that the new Obama administration has indicated will result in stricter renewable energy promotion. The political system of checks and balances will make it difficult to overcome the opposition from energy and automotive lobbies. Positive signs can clearly be seen in the shift in public and congressional debates which now focuses more on the possible economic benefits of renewable energy use. Once there is a clear political commitment to promote renewable energy sources more substantially, the United States will quickly be able to close the gap in terms of renewable energy development since the country can build on its capacity in advanced technologies.

Japan used to hold an international leadership with regards to solar PV and energy efficiency technologies. In terms of solar PV capacity, Germany is now ahead of Japan. Japan's renewable energy policy strongly relies on voluntary agreements or insufficient mandatory measures. Because of the lack of a more comprehensive approach in renewable energy policy, Japan risks losing its former advanced position in renewable energy technologies to other countries. Japan has to greatly increase the targets in its Renewable Portfolio Standard if Japan's long-term expertise in renewable energy technologies is not to be lost.

7 Summary and Conclusion: Implications for Renewable Energy Instruments and Markets

This research study presents the first systematic comparison of renewable energy instruments and markets in Germany, Japan and the United States. The aim of this study was to analyze government instruments used to promote renewable energy use in terms of national renewable energy market deployment, the development of renewable power generation costs (as a proxy for innovation) and international trading in renewable energy technologies. This study further asked why different approaches to promote renewable energies emerged in Germany, the United States and Japan.

This research focus answers the two central questions when considering renewable energy policies: a) which instruments are more or less effective and efficient and b) which factors explain stricter and or less strict renewable energy promotion.

This study comes to the following main conclusions:

- Government promotion is important and is warranted to secure a sufficient diffusion of renewable energy sources.
- The specific design of policy instruments is of central importance for the effective and efficient development of renewable energy market deployment and generation costs.
- The success of countries in international trade of renewable energy technologies depends on domestic market development not export promotion measures.
- The enforcement of comprehensive and mandatory renewable energy policies is more likely if there is a strong pro-renewables coalition and the emphasis on economic benefits of renewable energy use is high.

Theoretically, the study relates to theories of economic regulation. The intervention in energy markets through governments is justified as a way to correct market failures, most notably external costs of fossil fuel use. The first-best option for creating fair competition between all power generation technologies would be to ensure a complete internalization of external costs through a tax on fossil fuel use. However, as the discussion of Pigovian taxes exemplified the optimal level of taxation is difficult to determine and taxes are faced with the difficulty of public acceptance. Second-best measures provide some form of promotion to renewable energy sources which create no or little negative external costs to balance the cost-disadvantage compared to producers of negative externalities. Without government support renewable energy sources would diffuse at a less than optimal rate.

Still, even if government support for renewable energy sources is warranted because of the persistence of negative externalities on energy markets and its environmental bene-

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fits, governments in reality also promote renewables to enhance the competitive position of its domestic industry on international markets. Here the case for government intervention in renewable energy markets is less clear. Theoretically, first-mover advantages and the lead market concept emphasize the benefits of strict government promotion of renewables in terms of export opportunities and world market shares. Even if such advantages can be gained, the risk remains that governments will not promote the most competitive domestic industries, which would result in a misallocation of scarce resources.

The transformation towards a more sustainable energy system is still of prime importance. The challenges presented by global warming remain unsolved. Global energy demand will pick up again after the current slump in the global economy because of the financial and economic crisis. Dwindling fossil fuel reserves are also reinforcing the need for a greater share of renewables in the world's energy mix as Chapter 3 shows. With decreasing renewable energy generation costs, the competitive stance of renewable energy sources improves. However, government support is still needed to secure the diffusion of renewables.

The theoretical discussion of quantity- and price-based models as the two primary instruments of renewable energy promotion concludes that feed-in tariffs (price-based instruments) are more effective in triggering new renewable energy capacity since producers are able to sell all quantity produced and planning security is high. Renewable portfolio standards (quantity-based instrument) are less effective since there is less planning security and no incentives to produce above the obligated quota. Further, feed-in tariffs give incentives to reduce generation costs, but do not create direct competition between generators. RPS on the other hand induce direct price competition between generators, but the surplus of reduced generation costs is limited as it has to be passed on to consumers. This reduces the incentive to lower renewable energy generation costs for the generators of renewable electricity.

The empirical analysis of renewable energy promotion in Germany, the United States and Japan and the development of domestic renewable energy markets followed in Chapter 4. In all three countries, the push to promote renewables was first initiated by security of supply concerns after the oil price hikes in 1973/74 and 1979/80. During the 1990s, however, economic and environmental considerations, including climate change, have continued to drive policies, most prominently in Germany. Today, Germany has implemented the most substantial policies to increase renewable energy use of the three countries. The most important instrument is a feed-in tariff (EEG) guaranteeing the sale of any renewable power generated at the fixed price. The EEG includes different flexibility mechanisms such as an annual degression rate and different remuneration rates which reflect the different generation costs and cost improvement potentials of renewable energy sources.

While the introduction of renewable portfolio standards in many US states, combined with financial incentives on the national level, resulted in increased renewable energy use since the turn of the century, the development has still been far less dynamic than in Germany or other European countries. The leadership position the US once enjoyed in renewables in the wake of the 1970s oil crises was lost in the face of a lack of political priority.

Japan implemented a regulatory tool with the Renewable Portfolio Standard, but the targets are very modest. Japan's approach to renewable energy promotion thus has not been very ambitious. Japan has, however, a long history in solar energy promotion, mainly through R&D programs such as the Sunshine Project that started in 1973. Further, the use of voluntary instruments is a main element of Japan's renewable energy policy. This reflects a typical notion of the "Japanese" approach: first, measures are modest in scope to initiate first changes in industry behavior and to prevent strong industry opposition. Once changes have been achieved to a certain extent, then more stringent regulations are adopted. However, the close network between government and industry as exemplified by the rotating personnel of NEDO so far has prevented a more comprehensive renewable energy policy with more ambitious renewable energy targets.

The deployment of renewable energy sources in Germany has been much more dynamic compared to the other two countries. Germany currently has a share of 15% of renewables in power generation, while the United States and Japan only have a share of 8.5% and 9.4% respectively. Since 2000, Germany succeeded in increasing renewable energy use by 140%, compared to 5% for both Japan and the United States.

The analysis of the development of renewable energy generation costs shows that the theoretical assumption that quota system generally lead to lower prices cannot be supported by the data. Since the development of generation costs has been relatively similar in all three countries, the superiority of one policy instrument in terms of effectiveness cannot be concluded from the data.

As the analysis of renewable energy markets and renewable energy generation costs highlights, the implementation of renewable energy promotion measures alone does not secure an effective or efficient promotion of renewable energy sources. The specific design of regulatory instruments is essential. The most important design requirements for any renewable energy policy instrument include (a) incentives for sufficient deployment, (b) differentiated promotion, (c) incentives to reduce generation costs and (d) an adequate balance between planning security and competition.

Renewable energy instruments have to include ambitious, long-term targets and the strict enforcement of penalties for non-compliance in the case of quota models to secure sufficient deployment. Promotion schemes of renewable energy instruments have to differentiate between different technologies to take into account different levels of sophistication or different generation costs within the same technology due to plant size and geographical conditions. Less mature technologies either need higher renumeration rates in price-based models or technology-specific target in quota-based systems.

Government promotion of renewable energy use should be declining over time to create incentives for a reduction in generation costs. Price models such as feed-in tariffs should include an annual reduction of renumeration rates for new plants by a certain percentage which reflects technological learning and accordingly declining generation costs. The direct price competition in quota system creates incentives for reduced generation costs. However, since renewable energy producers have to pass on the surplus from reduced generation costs, for public renewable energy R&D is essential in the development of new technologies.

Renewable energy promotion measures need to create a balance between inducing competition among renewable energy generators and securing sufficient planning security. Feed-in tariffs offer greatest planning security, since the sale of all renewable power produced is guaranteed. In fact, the long-term planning security is the main reason for the strong growth of renewables in Germany. The dynamic development of renewable energy sources in Germany more than offset the lack of competition among renewable energy generators. Quota systems with tradable renewable energy certificates offer low planning security, which creates a main barrier to a more dynamic diffusion of renewable energy sources. Therefore, it is essential to include mandatory, long-term quota targets to increase planning security for renewable energy generators.

Chapter 5 provided an analysis of government attempts to influence international trade patterns of renewable energy technologies and the empirical development on international markets for renewable energy technologies. While all three countries have export promotion measures in place, the measures are restricted to dissemination of information, assistance in the processing of exports and the provision of export-credit guarantees. Moreover, the tariffs on renewable energy technology imports in all three countries are below average industrial tariffs. Only the United States applies slightly higher than average tariffs on some renewable energy technologies (steam turbines). Therefore, the risk of protectionism or a significant distortion of trade through export promotion measures or tariffs is limited. However, more research is needed on non-tariff barriers to trade such as standards, which could have a diverting effect on international trade in renewable energy technologies.

The empirical analysis shows that international trade in renewable energy technologies has already reached a high level of maturity. In absolute numbers, Germany is the biggest trading (exports and imports) country of renewable energy technologies. In exports per capita, Germany and Japan are still among the top five trading countries. The United States exports considerably less than Germany and Japan on a per capita basis and is not among the top ten trading nations. In terms of growth, Germany experienced much higher growth rates in renewable energy exports (average annual growth rate of 28 percent since 2000) in the past years than Japan (average of 17% in that time period) or the United States (8%).

The data confirm the assumption that a strong renewable home market is essential to develop a successful export industry with renewable energy goods. Japan's situation exemplifies this assumption especially well. Japan mainly trades solar PV technologies (76% of total renewable energy technologies exports), while solar PV is also the renewable energy source which Japan developed especially successfully on the domestic market. Germany is especially successful both in international trade with wind energy technologies as well as domestic wind energy generation. The analysis thus highlights that manufacturers from countries with early, long-term deployment policies, with the time to reduce production costs and improve product quality through technological advances, capture large shares of the global market. It is not Germany's or Japan's export promotion policies that give these countries a competitive advantage on international markets but their competitive domestic renewable energy industries. Accordingly, it is essential that renewable energy measures focus on the creation of the market conditions that support sustained penetration and expansion of renewable energy sources.

Chapter 6 considered the question why Germany follows a more comprehensive approach in its renewable energy policy than the other two countries. The analysis of the development of environmental and renewable energy policy in Germany, Japan and the United States shows that a very strong pro-renewables coalition in Germany managed to successful link environmental and economic concerns in renewable energy policy. This coalition succeeded in emphasizing the possible economic benefits of renewable energy promotion and the entrance on international renewable energy markets at a relatively early stage. The early development of the German renewable energy industry reinforced its positive economic benefits and slowly led to a change in beliefs, since renewables are now being accepted as important energy sources in the mainstream of public debate. However, the judgment on effectiveness and efficiency of government renewable energy policy still has to be based on the positive economic benefits of a higher share of renewables in terms of less negative externalities due to fossil fuel use. Still, it is also essential to realize that economic development and a higher level of environmental protection are not conflicting targets but can be pursued simultaneously. The renewable energy sector is a very good example to exemplify that.

This study focuses on renewable energy use in three industrial countries, but a higher share of renewables will also be essential to secure access to clean and sufficient energy for developing countries. The conclusion drawn in this study on design criteria for effective and efficient renewable energy instruments can also be applied to the developing world. However, there is no question that the transformation of the energy system towards a significantly higher share of renewables in electricity production creates costs as well as benefits. Therefore it is essential to further increase the cost-efficiency of all renewable energy instruments already in place and new instruments being implemented in countries worldwide. Still, the investment in a more sustainable energy future is wisely spent and allows for a gradual increase of renewables in electricity production.

However, renewables alone will not be able to satisfy the electricity needs of the world. In fact, no single technological solution will be able to solve global energy, economic and climate change challenges. It is encouraging that there has never been a time when so many diverse energy technologies have been in the debate and on the research agendas of governments. Besides renewable energy, research is being conducted in the field of nuclear power, clean coal technologies (such as carbon sequestration), energy efficiency, unconventional fossil fuels and hydrogen among others. This is a very promising sign since only the diversification of energy technologies and the tapping into the potential of energy saving and efficiency technologies will secure sufficient access to energy in the future.

The global economic and financial crisis also presents an opportunity to enter new paths in many areas. The crisis creates a momentum that has already led to increased cooperation of the world’s largest economies on such important issues as financial market regulation, development assistance and the strengthening of international organizations such as the International Monetary Fund (IMF). At the G20 summit in London in April 2009, the member countries have agreed on a US$1.1 trillion package of measures to restore growth, jobs and confidence in the financial system. It is also a very promising sign that countries worldwide agreed to promote renewable energy jointly. So far, there has been a lack of an international organization to promote renewable energy use. The International Renewable Energy Agency (IRENA) was officially established in January 2009 and aims to provide practical advice and support for industrial and developing countries to promote a sustainable use of renewable energy on a global scale. Until today, 136 countries have signed the statute of the agency. Germany was among the first countries to join IRENA in January 2009. Japan and the United States signed IRENA’s founding treaty in June 2009. IRENA could prove to be essential in securing the continuing expansion of renewable energy sources worldwide.

In the words of Nobuo Tanaka, Executive Director of the International Energy Agency (IEA): "We cannot let the financial and economic crisis delay the policy action that is urgently needed to ensure secure energy supplies and to curtail rising emissions of greenhouse gases. We must usher in a global energy revolution by improving energy efficiency and increasing the deployment of low-carbon energy."[528]

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[528] International Energy Agency (2008), *New Energy Realities - WEO Calls for Global Energy Revolution Despite Economic Crisis*.

Appendix

Table A- 1: Eligible renewable energy technologies, renewable portfolio standards in US States

State	Solar	Landfill Gas	Wind	Biomass	Biomass Co-firing or Cogeneration	Hydroelectric	Geothermal	Municipal Solid Waste	Ocean or Tidal
Arizona	+	+	+	+	+	+	+	NS	No
California	+	+	+	+	No	Small only	+	+	+
Colorado	+	+	+	+	No	+	+	No	No
Connecticut	+	+	+	+	+	Small only	No	+	+
Delaware	+	+	+	+	No	+	+	No	+
District of Columbia	+	+	+	+	+	+	+	+	+
Florida	+	+	+	+	NS	NS	NS	+	NS
Hawai	+	+	+	+	+	+	+	+	+
Illinois	+	+	+	+	NS	+	No	No	No
Iowa	+	+	+	+	NS	Small only	NS	+	NS
Maine	+	+	+	+	+	Small only	+	+	+
Maryland	+	+	+	+	NS	+	+	+	+
Massachusetts	+	+	+	+	+	Small only	+	+	+
Michigan	+	+	+	+	NS	+	NS	NS	NS
Minnesota	+	+	+	+	+	+	No	+	No
Missouri	+	+	+	+	No	+	No	No	No
Montana	+	+	+	+	No	+	+	No	No
Nevada	+	+	+	+	No	Small only	+	+	No
New Hampshire	+	+	+	+	No	Small only	+	No	+
New Jersey	+	+	+	+	NS	Small only	+	No	+
New Mexico	+	+	+	+	NS	Small only	+	No	No
New York	+	+	+	+	NS	+	No	No	+
North Carolina	+	+	+	+	+	Small only	+	No	+
North Dakota	+	+	+	+	NS	+	+	+	No
Ohio	+	+	+	+	+	+	+	+	No
Oregon	+	+	+	+	NS	+	+	+	+
Pennsylvania	+	+	+	+	+	+	+	+	No
Rhode Island	+	+	+	+	NS	+	+	No	+
South Dakota	+	+	+	+	NS	+	+	+	No
Texas	+	+	+	+	NS	+	+	No	+
Utah	+	+	+	+	+	Small only	+	No	+
Vermont	+	+	+	+	NS	+	No	No	No
Virginia	+	+	+	+	NS	+	+	+	+
Washington	+	+	+	+	NS	+	+	No	+
Wisconsin	+	+	+	+	+	Small only	+	No	+

NS= Not Specified

Source: Database of State Incentives of Renewables and Efficiency (DSIRE)

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Table A- 2: Public benefit funds, US States

State	In Effect since	Total Funds, in US Dollar	Charge
California	1996, changed in 2000 and 2007	1998-2001: 540 mio.; 2002-2007: 135 mio. annually, 2008-2011: 65.5 mio annually	~ 1.6 mill/kWh
Connecticut	2000	20 mio. annually	1 mill/kWh
Delaware	1999	3.2 mio. annually	0.358 mill/kWh
District of Columbia	2001	2001-2004: 2.3 mio. annually, 2005-2007: 9.5-10.5 mio annually	2 mill - 0.1 mill/kWh
Illinois	1999	1998-2015: 100 mio.	0.05 per month
Maine	1998	variable	voluntary
Massachusetts	1998	1998-2002: 150 mio, from 2003 on: 25 mio. annually	0.5 mill/kWh
Michigan	2000	84 mio. annually	varies by utility
Minnesota	2007	16 mio. annually	paid for by Xcel Energy*
Montana	1999	~ 10 mio. annually	utilities contribute 2.4% of 1995 revenue
New Jersey	1999	2001-2008: 1.23 billion	per kWh surcharge (varies annually)
New York	1996	1998-2011: 1.87 billion	utilities contribute 1.42% of 2004 revenue
Ohio	1999	2001-2005: 15 mio. annually, 2006-2011: 5 mio annually	varies by utility
Oregon	1999	12 mio. annually	3% - 1.25% charge for customers of different electricity supplier
Pennsylvania	2006	2 million annually	0.1 mill/kWh
Rhode Island	2003	2003-2013: 2.4 million	0.3 mill/kWh
Vermont	2005	6-7.2 mio. annually until 2012	paid for by Entergy
Wisconsin	2007	July 2007 - December 2008: 9.4 mio.	utilities contribute 1.2% of 2004 revenue

* Xcel is the biggest electric utility based in Minnesotta - mills: 1/1000 of a US Dollar

Source : Database of State Incentives for Renewables and Efficiency (DSIRE)

Table A- 3: Trade codes covering renewable energy sources

HS no.	Product Category	Sub-sector
841911	Instantaneous gas water heaters (excluding boilers or water heaters for central heating)	Solar Thermal
841919	Instantaneous or storage water heaters, non-electric	Solar Thermal
854140	Photosensitive semiconductor devices, including photovoltaic cells whether or not assembled in modules or made up into panels; light emitting diodes	Photovoltaics
841011	Hydraulic turbines, water wheels, and regulators therefor (of a power not exceeding 1,000kW)	Hydropower
841012	Hydraulic turbines, water wheels, and regulators therefor (of a power exceeding 1,000 kW but not exceeding 10,000 kW)	Hydropower
841013	Hydraulic turbines, water wheels, and regulators therefor (of a power exceeding 10,000 kW)	Hydropower
841090	Parts of hydraulic turbines, water wheels including regulators	Hydropower

Source : ECOTEC (2002), *Renewable Energy Sector in the EU. Its Employment and Export Potential* . Commissioned by the European Commission, DG Environment, Birmingham.

Table A- 4: Environmental goods with renewable energy application

HS no.	HTS 6 digit description	Renewable energy application
730820	Towers and lattice masts	For wind turbines
840211	Watertube boilers exceeding 45 tons of steam per hour	For biomass plants
840212	Watertube boilers not exceeding 45 tons of steam per h	For biomass plants
840219	Other vapor generating boilers, incl. hybrid boilers	For biomass plants
840220	Super-heated water boilers	For biomass plants
840290	Parts of steam or other vapor generating boilers	
840410	Auxiliary plant for use with boilers of heading No. 8402 or 8403	For biomass, geothermal, or solar concentrator systems
840420	Condensers for steam or other vapor power units	"
840490	Parts of auxiliary plant for use with boilers	"
840681	Steam turbines over 40 MW	For geothermal or biomass plants
840682	Steam turbines and other vapour turbines of an output not exceeding 40 MW	For geothermal or biomass plants
840690	Parts of steam turbines	For geothermal or biomass plants
841181	Other gas turbines, not exceeding 5,000 kW	For biomass plants
841182	Other gas turbines exceeding 5,000 kW	For biomass plants
841191	Parts of other gas turbines	For biomass plants
841350	Other reciprocating positive displacement pumps	Pumps for geothermal, biomass, solar, and ocean energy plants
841360	Pumps for liquids, whether or not fitted with a measuring device; other rotary positive displacement pumps	For geothermal and thermal solar
841919	Other instantaneous or storage water heaters	Solar water heaters
841940	Distilling or rectifying plant	For alcohol distillation from biomass
841950	Heat exchange units	For geothermal, biomass, solar, and ocean energy plants
848340	Gears and gearing, other than tooth	For wind turbines
848360	Clutches and universal joints	For wind turbines
850161	AC generators not exceeding 75 kVA	For all electricity generating renewable energy plants
850162	AC generators exceeding 75 kVA but not 375 kVA	"
850163	AC generators exceeding 375 kVA but not 750 kVA	"
850164	AC generators exceeding 750 kVA	"
850231	Generating sets, electric, wind-powered	For wind energy plants
850239	Other generating sets	Gas turbine sets for biomass plants
850300	Parts for equipment classified under 8501 and 8502	Parts of gas and wind turbines
850440	Other static converters	Inverters for photovoltaic solar equipment
854140	Photosensitive semiconductor devices, including photovoltaic cells whether or not assembled in modules or made up into panels; light emitting diodes	Solar cells
900190	Mirrors of other than glass	For solar concentrator systems
900290	Mirrors of glass	For solar concentrator systems
902680	Heat meters incorporating liquid supply meters, and anemometers	Wind speed (anemometers) indicators for wind turbines

Source : United States International Trade Commission (2005), *Renewable Energy Services: An Examination of U.S. and Foreign Markets.* Washington, D.C.

Table A- 5: Renewable energy products and technologies for harnessing renewable energy from OECD (2005), *Liberalisation of Trade in Renewable Energy and Associated Technologies*

HS code	Product description [renewables component]
3824	**Products, preparations and residual products of the chemical or allied industries, incl. those consisting of mixtures of natural products.**
4401	**Fuel wood, in logs, in billets, in twigs, in faggots or in similar wood in chips or particles; sawdust and wood waste and scrap, whether or not agglomerated pellets or similar forms.**
440110	– Fuel wood, in logs, in billets, in twigs, in faggots or in similar forms.
440200	Wood charcoal (including shell or nut charcoal), whether or not agglomerated. [Wood, shell or nut charcoal used for fuel.]
8410	**Hydraulic turbines, water wheels, and regulators therefor.**
841011	– Of a power not exceeding 1,000kW.
841012	– Of a power exceeding 1,000 kW but not exceeding 10,000 kW.
841013	– Of a power exceeding 10,000 kW.
841090	– Parts, including regulators.
8412	**Other engines and motors.**
841280 (ex)	– Other [Steam engines; windmills without pumps.]
841290 (ex)	– Parts [Parts for steam engines and windmills.]
8413	**Pumps for liquids, whether or not fitted with a measuring device; liquid elevators.**
841381 (ex)	– Other pumps; liquid elevators — Pumps —— [Windmill pumps]
8419	**Machinery, plant or laboratory equipment, whether or not heated (excluding furnaces, ovens and other equipment of heading 85.14), for the treatment of materials by a process involving a change of temperature such as heating, cooking, roasting, distilling, rectifying, sterilising, pasteurising, steaming, drying, evaporating, vaporising, condensing or cooling, other than machinery or plant of a kind used for domestic purposes; instantaneous or storage water heaters, non-electric.**
841919 (ex)	– Instantaneous or storage water heaters, non-electric — other [solar water heaters]
8502	**Electric generating sets and rotary converters.**
850231	– Other generating sets — Wind powered
850239 (ex)	– Other generating sets — Other [a generating set combining an electric generator and either a hydraulic turbine or a Sterling engine]
8541	**Diodes, transistors and similar semiconductor devices; semiconductor devices, including photovoltaic cells whether or not assembled in modules or made up into panels; light emitting diodes; mounted piezo-electric crystals.**
854140 (ex)	– Photosensitive semiconductor devices, including photovoltaic cells whether or not assembled in modules or made up into panels; light emitting diodes [Photovoltaic cells and modules.]
8402	**Steam or other vapour generating boilers (other than central hot water boilers capable also of producing low pressure steam); super-heated water boilers.**
840211	– Water-tube boilers with a steam production exceeding 45 tonnes per hour.
840212	– Water-tube boilers with a steam production not exceeding 45 tonnes per hour.
840219	– Other vapour-generating boilers, including hybrid boilers.
8413	**Pumps for liquids, whether or not fitted with a measuring device; liquid elevators.**
841350 (ex)	– Other reciprocating positive displacement pumps [DC-powered water pumps]
841370 (ex)	– Other centrifugal pumps [DC-powered submersible water pumps]
8416	**Furnace burners for liquid fuel, for pulverised solid fuel or gas; mechanical stokers, including their mechanical grates, mechanical ash dischargers and similar appliances.**
841630	– Mechanical stokers, including their mechanical grates, mechanical ash dischargers and similar appliances [Mechanical stokers and related appliances used for burning biomass.]
841690	– Parts [Parts for mechanical stokers and related appliances used for burning biomass.]

HS code	Product description [renewables component]
8501	**Electric motors and generators (excluding generating sets).**
850131	– Other DC motors; DC generators — Of an output not exceeding 750 W
850161	– AC generators (alternators) — Of an output not exceeding 75kVA
8504	**Electrical transformers, static converters (for example, rectifiers) and inductors.**
850440 (ex)	– Static converters [Inverters (for converting DC power to AC power)]
8507	**Electric accumulators, including separators therefor, or not rectangular (including square).**
850720 (ex)	– Other lead-acid accumulators [solar batteries]
8537	**Boards, panels, consoles, desks, cabinets and other bases, with two or more apparatus of**
853710 (ex)	– For a voltage not exceeding 1 000 V [Charge controllers (for storage batteries)]
8541	**Diodes, transistors and similar semiconductor devices; semiconductor devices, including photovoltaic cells whether or not assembled in modules or made up into panels; light emitting diodes; mounted piezo-electric crystals.**
854140 (ex)	– Photosensitive semiconductor devices, including photovoltaic cells whether or not assembled in modules or made up into panels; light emitting diodes [Photovoltaic cells and modules.]
9026	**Instruments and apparatus for measuring or checking the flow, level, pressure or other variables of liquids or gases (for example, flow meters, level gauges, manometers, heat meters), excluding instruments and apparatus of heading 90.14, 90.15, 90.28 or 90.32.**
902680 (ex)	Other instruments or apparatus [Anemometers]

Source: OECD (2005), *Liberalisation of Trade in Renewable-Energy and Associated Technologies: Charcoal, Solar Photovoltaic Systems, and Wind Pumps and Turbines.* OECD Trade and Environment Working Paper, COM/ENV/TD(2005)23/FINAL.

Table A- 6: Renewable energy products and technologies for harnessing renewable energy from OECD (2006), *Liberalisation of Trade in Renewable-Energy and Associated Technologies*

HS code	Product description [renewables component]
3824	**Products, preparations and residual products of the chemical or allied industries, incl. those consisting of mixtures of natural products.**
382490 (ex)	– Other. [Biodiesel and waste fats and oil suitable as a fuel.]
8406	**Steam turbines and other vapour turbines.**
840681 (ex)	– Other turbines, of an output exceeding 40 MW [Low-temperature and low-pressure steam turbines for use in a geothermal power plant.]
840682 (ex)	– Other turbines, of an output not exceeding 40 MW [Low-temperature and low-pressure steam turbines for use in a geothermal power plant.]
840690 (ex)	– Parts [Parts for low-temperature and low-pressure steam turbines for use in a geothermal power plant.]
8418	**Refrigerators, freezers and other refrigerating or freezing equipment, electric or other; heat pumps other than air conditioning machines of heading 84.15.**
841861	– Other refrigerating or freezing equipment; heat pumps : compression type units whose condensers are heat exchangers [Geothermal heat-pump systems]
841869	– Other refrigerating or freezing equipment; heat pumps : other [Geothermal heat-pump systems]
8419	**Machinery, plant or laboratory equipment, whether or not heated (excluding furnaces, ovens and other equipment of heading 85.14), for the treatment of materials by a process involving a change of temperature such as heating, cooking, roasting, distilling, rectifying, sterilising, pasteurising, steaming, drying, evaporating, vaporising, condensing or cooling, other than machinery or plant of a kind used for domestic purposes; instantaneous or storage water heaters, non-electric.**
841919 (ex)	– Instantaneous or storage water heaters, non-electric : other [Solar water heaters.]
841950 (ex)	– Heat exchange units [Heat-exchange units for solar-thermal or geothermal applications.]
8479	**Machines and mechanical appliances having individual functions, not specified or included elsewhere in this Chapter.**
847920 (ex)	– Machinery for the extraction or preparation of animal or fixed vegetable fats or oils. [Biodiesel refineries.]
847982	Mixing, kneading, crushing, grinding, screening, sifting, homogenising, emulsifying or stirring machines [Machines for crushing and filtering oil seeds.]
9032	**Automatic regulating or controlling instruments and apparatus.**
903289	– Other instruments and apparatus : Other [Heliostats.]

Source: OECD (2006), *Liberalisation of Trade in Renewable-Energy and Associated Technologies: Biodiesel, Solar Thermal and Geothermal Energy . OECD Trade and Environment Working Paper, COM/ENV/TD(2005)78/FINAL.*

Table A- 7: Renewable energy technologies

GP 2002	Product description
2911 22 000	Hydraulic turbines and water wheels
2911 32 000	Hydraulical linear drive system (with hydro cylinder)
2912 12 370	Concrete pumps
2912 41 300	Parts of Compressed Air Motors, water and steam turbines
3210 52 370	Parts of semiconductor devices (eg. solar cells)
3110 32 501	Electricty Generating Sets, Wind-Powered
2972 14 009	Instantaneous water heater, non-electric
2923 13 750	Absorption heat pupms

Source: Legler, Harald et al. (2006), *Wirtschaftsfaktor Umweltschutz: Leistungsfähigkeit der deutschen Umwelt- und Klimaschutzwirtschaft im internationalen Vergleich.* Hannover.

Table A- 8: Applied tariff rates on selected climate-friendly technologies

HS no.	HTS 6 digit description
392010	PVC or polyethylene plastic membrane systems to provide an impermeable base for landfill sites and protect soil under gas stations, oil refineries, etc. from infiltration by pollutants and for reinforcement of soil.
560314	Nonwovens, whether or not impregnated, coated, covered or laminated, n.e.s., of man-made filaments, weighing > 150 g
701931	Thin sheets (voiles), webs, mats, mattresses, boards and similar nonwoven products
730820	Towers and lattice masts for wind turbine
730900	Containers of any material, of any form, for liquid or solid waste, including for municipal or dangerous waste.
732111	Solar driven stoves, ranges, grates, cookers (including those with subsidiary boilers for central heating), barbecues, braziers, gas-rings, plate warmers and similar non-electric domestic appliances, and parts thereof, of iron or steel.
732190	Stoves, ranges, grates, cookers (including those with subsidiary boilers for central
732490	Water saving shower.
761100	Aluminium reservoirs, tanks, vats and similar containers for any material (specifically tanks or vats for anaerobic digesters for biomass gasification)
761290	Containers of any material, of any form, for liquid or solid waste, including for municipal or dangerous waste.
840219	Vapor generating boilers, not elsewhere specified or included hybrid
840290	Super-heated water boilers and parts of steam generating boilers
840410	Auxiliary plant for steam, water and central boiler
840490	Parts for auxiliary plant for boilers, condensers for steam, vapour power unit
840510	Producer gas or water gas generators, with or without purifiers
840681	Turbines, steam and other vapour, over 40 MW, not elsewhere specified or included
841011	Hydraulic turbines and water wheels of a power not exceeding 1,000 kW
841090	Hydraulic turbines and water wheels; parts, including regulators
841181	Gas turbines of a power not exceeding 5,000 kW
841182	Gas turbines of a power exceeding 5,000 kW
841581	Compression type refrigerating, freezing equipment incorporating a valve for reversal of cooling/heating cycles (reverse heat pumps)
841861	Compression type refrigerating, freezing equipment incorporating a valve for reversal of cooling/heating cycles (reverse heat pumps)
841869	Compression type refrigerating, freezing equipment incorporating a valve for reversal of cooling/heating cycles (reverse heat pumps)
841919	Solar boiler (water heater).
841940	Distilling or rectifying plant
841950	Solar collector and solar system controller, heat exchanger
841989	Machinery, plant or laboratory equipment whether or not electrically heated (excluding furnaces, ovens etc.) for treatment of materials by a process involving a change of temprature such a heating, cooking, roasting, distilling, rectifying, sterlizing, steaming, drying, evaporating, vaporizing, condensing or cooling.
841990	Medical, surgical or laboratory stabilizers
848340	Gears and gearing and other speed changers (specifically for wind turbines)
848360	Clutches and universal joints (specifically For wind turbines)

HS no.	HTS 6 digit description
850161	energy plants)
850162	generating renewable energy plants)
850163	AC generators not exceeding 375 kVA but not 750 kVA (specifically for all electricity generating renewable energy plants)
850164	AC generators exceeding 750 kVA (specifically for all electricity generating renewable energy plants)
850231	Electric generating sets and rotary converters; wind-powered
850680	Fuel cells use hydrogen or hydrogen-containing fuels such as methane to produce an electric current, through a electrochemical process rather than combustion.
850720	Other lead acid accumulators
853710	Photovoltaic system controller
854140	Photosensitive semiconductor devices, including photovoltaic cells whether or not assembled in modules or made up into panels; light emitting diodes
900190	Mirrors of other than glass (specifically for solar concentrator systems)
900290	Mirrors of glass (specifically for solar concentrator systems)
903210	Thermostats
903220	Manostats

Source: World Bank (2008), *International trade and climate change: economic, legal and institutional perspectives* . Washington, DC.

Table A- 9: Comparison of different lists of renewable energy technology goods

HS no.	Renewable Energy Application	ECOTEC (2002)	USITC (2005)	OECD (2005/06)	World Bank (2008)
392010	PVC or polyethylene plastic membrane systems to provide an impermeable base for landfill sites and protect soil under gas stations, oil refineries, etc. from infiltration by pollutants and for reinforcement of soil.				x
440110	Fuel wood, in logs, in billets, in twigs, in faggots or in similar forms.			x	
440200	Wood charcoal (including shell or nut charcoal), whether or not agglomerated.			x	
560314	Nonwovens, whether or not impregnated, coated, covered or laminated, n.e.s., of man-made filaments, weighing > 150 g				x
701931	Thin sheets (voiles), webs, mats, mattresses, boards and similar nonwoven products				x
730820	Towers and lattice masts		x		x
730900	Containers of any material, of any form, for liquid or solid waste, incl. for municipal or dangerous waste.				x
732111	Solar driven stoves, ranges, grates, cookers (including those with subsidiary boilers for central heating), barbecues, braziers, gas-rings, plate warmers and similar non-electric domestic appliances, and parts thereof, of iron or steel.				x
732190	Stoves, ranges, grates, cookers (including those with subsidiary boilers for central heating), barbecues, braziers, gas-rings, plate warmers and similar non-electric domestic appliances, and parts thereof, of iron or steel. - Parts.				x
732490	Water saving shower.				x
761100	Aluminium reservoirs, tanks, vats and similar containers for any material (specifically tanks or vats for anaerobic digesters for biomass gasification)				x
761290	Containers of any material, of any form, for liquid or solid waste, incl. for municipal or dangerous waste.				x
840211	Water-tube boilers with a steam production exceeding 45 tonnes per hour.		x	x	
840212	Water-tube boilers with a steam production not exceeding 45 tonnes per hour.		x	x	
840219	Vapor generating boilers, not elsewhere specified or included hybrid		x	x	x
840220	Super-heated water boilers for biomass plants		x		
840290	Super-heated water boilers and parts of steam generating boilers		x		x
840410	Auxiliary plant for steam, water and central boiler		x		x
840420	Condensers for steam or other vapor power units		x		
840490	Parts for auxiliary plant for boilers, condensers for steam, vapour power unit		x		x

HS no.	Renewable Energy Application	ECOTEC (2002)	USITC (2005)	OECD (2005/06)	World Bank (2008)
840510	Producer gas or water gas generators, with or without purifiers				x
840681	Steam turbines and other vapour turbines, other turbines, of an output exceeding 40 MW		x		x
840682	Steam turbines and other vapour turbines, other turbines, of an output not exceeding 40 MW		x		
840690	Parts of steam turbines		x		
841011	Hydraulic turbines and water wheels of a power not exceeding 1000 KW	x		x	x
841012	Hyd turbines and water wheels of a power exc 1000 KW but not excedg 1000	x		x	
841013	Hydraulic turbines and water wheels of a power exceeding 10000 KW	x		x	
841090	Parts of hydraulic turbines & water wheels including regulators	x		x	x
841181	Other gas turbines, not exceeding 5,000 kW		x		x
841182	Other gas turbines exceeding 5,000 kW		x		x
841191	Parts of other gas turbines		x		
841280	Other engines and motors				
841290	Parts of other engines and motors				
841350	Other reciprocating positive displacement pumps		x		
841360	Pumps for liquids, whether or not fitted with a measuring device; other rotary positive displacement pumps		x		
841381	Pumps for liquids, whether or not fitted with a meauring device, other pumps				
841581	Incorporating a refrigerating unit and a valve for reversal of the cooling/heat cycle (reversible heat pumps)				x
841630	Mechanical stokers, including their mechanical grates, mechanical ash dischargers and similar appliances [Mechanical stokers and related appliances used for burning biomass.]			x	
841690	Parts [Parts for mechanical stokers and related appliances used for burning biomass.]			x	
841861	Compression type refrigeratg/freez equip			x	x
841869	Other refrigerating or freezing equipment			x	x
841911	Instantaneous gas water heaters (excluding boilers or water heaters for central heating)	x			
841919	Solar boiler (water heater).	x	x		x
841940	Distilling or rectifying plant		x		x
841950	Heat exchange units		x		x
841989	Machinery, plant or laboratory equipment whether or not electrically heated (excluding furnaces, ovens etc.) for treatment of materials by a process involving a change of temprature				x
841990	Medical, surgical or laboratory stabilizers				x
847982	Mixing, kneading, crushing, grinding, screening, sifting, homogenising, emulsifying or stirring machines			x	
848340	Gears, ball or roller screws, gear boxes		x		x

HS no.	Renewable Energy Application	ECOTEC (2002)	USITC (2005)	OECD (2005/06)	World Bank (2008)
848360	Clutches and shaft couplings (incl. universal joints)		x		x
850131	Other DC motors; DC generators - Of an output not exceeding 750 W			x	
850161	AC generators not exceeding 75 kVA (specifically for all electricity generating renewable energy plants)		x	x	x
850162	AC generators exceeding 75 kVA but not 375 kVA (specifically for all electricity generating renewable energy plants)		x		x
850163	AC generators not exceeding 375 kVA but not 750 kVA (specifically for all electricity generating renewable energy plants)		x		x
850164	AC generators exceeding 750 kVA (specifically for all electricity generating renewable energy plants)		x		x
850231	Generating Sets, Wind-Powered		x	x	x
850239	Other power generation sets		x		
850300	Parts for equipment classified under 8501 and 8502		x		
850440	Other static converters		x		
850680	Fuel cells use hydrogen or hydrogen-containing fuels such as methane to produce an electric current, through a electrochemical process rather than combustion.				x
850720	Other lead acid accumulators				x
853710	Photovoltaic system controller				x
854140	Photosensitive semiconductor devices, incl. photovoltaic cells, light emitting diodes (excluding photovoltaic generators)	x	x		x
900190	Mirrors of other than glass (specifically for solar concentrator systems)		x		x
900290	Mirrors of glass (specifically for solar concentrator systems)		x		x
902680	Heat meters incorporating liquid supply meters, and anemometers		x		
903210	Thermostats				x
903220	Manostats				x
903289	Other instruments and apparatus [Heliostats]			x	

Table A- 10: Germany: Sources of imports and destination of exports of primary renewable energy technologies, 2007, in mio.

	Solar technology			Wind technology		
	Exports	**Imports**	**Net exports**	**Exports**	**Imports**	**Net exports**
Spain	1351.2	45.0	1306.2	19.3	0.0	19.3
USA	151.0	454.0	-303.0	266.7	1.9	264.7
Italy	295.0	19.4	275.6	54.3	0.0	54.3
France	153.9	67.5	86.4	133.7	0.0	133.7
Czech Rep.	176.4	231.1	-54.6	0.0	0.0	0.0
China	105.9	1666.4	-1560.5	5.9	0.4	5.5
Austria	123.6	38.6	85.0	0.0	0.1	0.0
Japan	31.7	766.0	-734.3	116.0	0.1	115.9
Switzerland	73.6	22.0	51.7	0.0	0.0	0.0
Netherlands	84.5	127.3	-42.9	2.6	0.0	2.6
UK	59.5	275.4	-215.9	38.7	0.3	38.4
Canada	26.5	16.6	9.8	91.4	0.0	91.4
Poland	16.7	3.2	13.5	72.9	0.0	72.9
Sweden	75.5	111.1	-35.6	0.0	0.0	0.0
Denmark	8.2	133.1	-124.9	0.0	449.7	-449.7

	Hydro technology			Geoth. and biomass technology		
	Exports	**Imports**	**Net exports**	**Exports**	**Imports**	**Net exports**
Spain	1.1	6.6	-5.5	4.0	0.0	4.0
USA	3.2	0.4	2.8	102.0	6.4	95.6
Italy	3.4	2.0	1.4	18.6	32.3	-13.7
France	0.4	0.2	0.2	27.7	19.7	8.0
Czech Rep.	4.2	0.1	4.1	23.5	40.5	-17.0
China	6.5	0.1	6.5	83.6	0.3	83.3
Austria	4.2	2.8	1.4	30.1	54.0	-24.0
Japan	0.0	0.0	0.0	7.9	7.3	0.6
Switzerland	20.3	6.7	13.6	56.7	51.5	5.3
Netherlands	0.0	0.0	0.0	51.9	5.8	46.1
UK	0.8	0.5	0.3	37.8	4.0	33.8
Canada	2.8	0.0	2.8	13.3	0.0	13.3
Poland	0.8	0.4	0.5	12.7	35.6	-22.9
Sweden	0.0	0.0	0.0	16.4	1.6	14.8
Denmark	0.0	0.0	0.0	2.3	0.0	2.3

Table A- 11: United States: Sources of imports and destination of exports of primary renewable energy technologies, 2007, in mio.

	Solar technology			Wind technology		
	Exports	**Imports**	**Net exports**	**Exports**	**Imports**	**Net exports**
Germany	404.8	151.9	252.8	0.0	212.4	-212.4
Mexico	226.7	133.5	93.3	0.0	0.0	0.0
Canada	112.5	36.2	76.3	0.0	1.4	-1.4
Japan	130.7	673.7	-542.9	0.6	315.1	-314.4
China	87.6	396.0	-308.4	12.8	85.8	-72.9
Hongkong	98.9	5.5	93.4	0.0	0.0	0.0
Spain	73.2	4.9	68.3	0.0	428.0	-428.0
UK	66.4	31.2	35.2	0.0	130.5	-130.5
France	58.6	17.6	41.0	0.0	0.0	0.0
Italy	43.7	6.7	37.1	0.0	0.0	0.0
Belgium	49.9	3.9	45.9	0.0	0.0	0.0
Netherlands	22.4	3.7	18.7	0.0	0.1	-0.1
Australia	13.2	7.7	5.5	0.0	0.0	0.0
Denmark	15.2	2.7	12.5	0.0	927.8	-927.8
Sweden	12.9	7.2	5.7	0.0	0.0	0.0
	Hydro technology			**Geoth. and biomass technology**		
	Exports	**Imports**	**Net exports**	**Exports**	**Imports**	**Net exports**
Germany	0.7	1.9	-1.2	16.3	104.3	-87.9
Mexico	6.6	0.3	6.3	34.4	33.5	1.0
Canada	1.7	25.0	-23.3	19.2	22.6	-3.4
Japan	2.9	0.1	2.8	19.4	94.6	-75.2
China	0.4	0.4	0.0	1.4	1.9	-0.5
Hongkong	0.5	0.0	0.5	19.5	0.0	19.5
Spain	2.1	0.0	2.1	12.8	0.0	12.7
UK	2.0	0.9	1.0	13.9	12.2	1.6
France	0.6	0.8	-0.1	13.5	15.4	-1.9
Italy	0.1	0.1	0.0	1.7	10.1	-8.4
Belgium	0.4	0.0	0.4	5.0	0.0	5.0
Netherlands	1.2	0.0	1.1	4.9	0.7	4.2
Australia	0.0	1.6	-1.6	0.1	11.4	-11.3
Denmark	0.0	0.0	0.0	1.0	1.2	-0.2
Sweden	0.0	0.1	-0.1	0.0	6.3	-6.3

Table A- 12: Japan: Sources of imports and destination of exports of primary renewable energy technologies, 2007, in mio.

	Solar technology			Wind technology		
	Exports	**Imports**	**Net exports**	**Exports**	**Imports**	**Net exports**
China	1244.8	378.2	866.6	0.0	1.5	-1.4
USA	1004.7	174.1	830.6	335.6	0.2	335.4
Hongkong	898.3	25.8	872.5	0.0	0.0	0.0
Germany	535.3	75.8	459.5	0.0	48.5	-48.5
UK	353.9	3.5	350.4	0.3	0.1	0.1
Hungary	213.4	2.1	211.4	0.0	0.0	0.0
Italy	121.1	1.0	120.2	0.0	0.0	0.0
Spain	107.9	9.5	98.4	0.0	9.2	-9.2
Mexico	95.0	5.6	89.4	0.0	0.0	0.0
Belgium	92.2	0.7	91.5	0.0	0.0	0.0
Czech Rep.	64.7	0.6	64.1	0.0	0.0	0.0
France	38.6	2.3	36.3	0.0	0.0	0.0
Netherlands	32.6	2.0	30.6	0.0	0.0	0.0
Australia	25.2	0.0	25.2	0.0	0.0	0.0
Austria	16.0	3.9	12.2	0.0	0.2	-0.2
	Hydro technology			**Geoth. and biomass technology**		
	Exports	**Imports**	**Net exports**	**Exports**	**Imports**	**Net exports**
China	9.8	4.3	5.6	309.4	47.3	262.0
USA	0.9	0.0	0.9	166.8	38.8	128.0
Hongkong	0.1	0.0	0.1	0.5	0.0	0.5
Germany	0.0	0.0	0.0	5.7	6.4	-0.7
UK	0.0	0.0	0.0	4.1	1.5	2.6
Hungary	0.0	0.0	0.0	0.0	0.2	-0.2
Italy	0.0	0.0	0.0	40.8	0.7	40.2
Spain	0.0	0.0	0.0	9.8	0.0	9.8
Mexico	0.0	0.0	0.0	1.1	4.9	-3.8
Belgium	0.0	0.0	0.0	4.6	0.2	4.4
Czech Rep.	0.0	0.3	-0.3	0.0	0.0	0.0
France	0.0	0.0	0.0	0.1	0.4	-0.3
Netherlands	0.0	0.0	0.0	2.8	0.5	2.3
Australia	2.3	0.0	2.3	3.5	0.0	3.5
Austria	0.0	0.0	0.0	0.4	3.6	-3.2

Table A- 13: RCA_1 values for different renewable energy technologies, Germany, the United States and Japan, 1996-2007

Germany	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Total RE	1.09	1.05	0.98	0.92	0.89	0.96	0.90	0.89	0.85	1.12	1.26	1.35
Solar	0.87	0.94	0.87	0.79	0.82	0.96	0.80	0.82	0.72	0.85	1.00	1.25
Wind	0.32	5.79	0.43	0.35	0.77	0.30	0.16	0.55	0.69	2.56	2.33	2.17
Hydro	1.77	0.99	0.73	1.00	0.72	0.86	0.79	1.08	1.44	1.14	1.47	1.07
Geoth. + biomass	1.28	1.11	1.23	1.31	1.12	1.23	1.37	1.25	1.24	1.31	1.63	1.28

United States	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Total RE	1.31	1.69	1.44	1.28	1.26	1.19	0.98	0.95	1.08	1.03	0.82	0.71
Solar	1.18	1.54	1.75	1.54	1.44	1.54	1.24	1.15	1.19	1.13	0.88	0.77
Wind	0.01	0.88	0.37	0.06	0.02	0.01	0.01	0.01	0.20	0.02	0.28	0.04
Hydro	0.66	0.65	0.64	0.67	0.51	0.55	0.48	0.43	0.43	0.50	0.51	0.38
Geoth. + biomass	1.76	2.09	1.39	1.38	1.29	1.10	0.94	0.85	1.13	1.31	0.98	0.97

Japan	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Total RE	2.55	2.92	3.47	3.17	3.55	3.62	4.12	4.55	4.74	4.23	3.92	3.37
Solar	3.50	4.01	4.26	4.22	4.34	4.57	5.50	5.79	5.71	5.07	4.50	3.61
Wind	0.00	0.80	0.65	0.00	0.31	0.00	0.01	0.01	0.00	0.06	0.76	1.47
Hydro	0.80	1.12	0.50	1.64	0.80	0.82	0.75	0.19	0.23	0.72	0.63	0.68
Geoth. + biomass	2.27	1.99	3.51	2.75	3.04	3.67	3.55	3.62	3.85	4.10	4.26	4.16

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