GSI Global Subsidies Initiative

iisd International Institute for Sustainable Development
Institut international du développement durable

RESEARCH REPORT

Germany's Green Industrial Policy

Stable Policies – Turbulent Markets: The costs and benefits of promoting solar PV and wind energy

Wilfried Lütkenhorst
Anna Pegels
German Development Institute

January 2014

d·i·e
Deutsches Institut für
Entwicklungspolitik

50 Years | 1964–2014
German Development
Institute

www.iisd.org/gsi

Published by the International Institute for Sustainable Development.

About IISD

The International Institute for Sustainable Development (IISD) contributes to sustainable development by advancing policy recommendations on international trade and investment, economic policy, climate change and energy, and management of natural and social capital, as well as the enabling role of communication technologies in these areas. We report on international negotiations and disseminate knowledge gained through collaborative projects, resulting in more rigorous research, capacity building in developing countries, better networks spanning the North and the South, and better global connections among researchers, practitioners, citizens and policy-makers.

IISD's vision is better living for all—sustainably; its mission is to champion innovation, enabling societies to live sustainably. IISD is registered as a charitable organization in Canada and has 501(c)(3) status in the United States. IISD receives core operating support from the Government of Canada, provided through the International Development Research Centre (IDRC), from the Danish Ministry of Foreign Affairs and from the Province of Manitoba. The Institute receives project funding from numerous governments inside and outside Canada, United Nations agencies, foundations and the private sector.

Head Office
161 Portage Avenue East, 6th Floor, Winnipeg, Manitoba, Canada R3B 0Y4
Tel: +1 (204) 958-7700 | Fax: +1 (204) 958-7710 | Website: www.iisd.org

---

About GSI

GSI is an initiative of the International Institute for Sustainable Development (IISD). GSI is headquartered in Geneva, Switzerland and works with partners located around the world. Its principal funders have included the governments of Denmark, the Netherlands, New Zealand, Norway, Sweden and the United Kingdom. The William and Flora Hewlett Foundation have also contributed to funding GSI research and communications activities.

International Institute for Sustainable Development
Global Subsidies Initiative
International Environment House 2, 9 chemin de Balexert, 1219 Châtelaine, Geneva, Switzerland
Tel: +41 22 917-8373 | Fax: +41 22 917-8054

Germany's Green Industrial Policy
Stable Policies – Turbulent Markets: The costs and benefits of promoting solar PV and wind energy
Written by Wilfried Lütkenhorst & Anna Pegels
German Development Institute

January 2014

Acknowledgements

The research project leading to the present report was funded by the International Institute for Sustainable Development (IISD). The authors are grateful to Tilman Altenburg and Aaron Cosbey for overall direction and guidance, as well as to Morgan Bazilian, Michele Clara, Lucy Kitson and Hubert Schmitz for their review of an earlier version of the report. Ruth Pollak has provided valuable research support in connection with competitiveness and innovation indicators. The responsibility for any remaining shortcomings of the report is obviously entirely ours.

Table of Contents

List of Tables

List of Figures

List of Boxes

List of Acronyms

AEE	Agentur für Erneuerbare Energien
AGEE-Stat	Arbeitsgruppe Erneuerbare Energie – Statistik (Working Group Renewable Energies – Statistics)
BDEW	Bundesverband der Energie- und Wasserwirtschaft (Federal Association of Energy and Water Business)
BMBF	Bundesministerium für Bildung und Forschung (Federal Ministry for Education and Research)
BMELV	Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz (Federal Ministry for Food, Agriculture and Consumer Protection)
BMWi	Bundesministerium für Wirtschaft und Technologie (Federal Ministry for the Economy and Technology)
BMU	Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (Federal Ministry for Environment, Nature Conservation and Nuclear Safety)
BMVBS	Bundesministerium für Verkehr, Bau und Stadtentwicklung (Federal Ministry for Transport, Construction and Urban Development)
BNA	Bundesnetzagentur (Federal Grid Agency)
BoS	Balance of System
BSW	Bundesverband Solarwirtschaft (German Solar Energy Association)
BWE	Bundesverband Windenergie (German Wind Energy Association)
CSP	Center for Silicon Photovoltaics
CO_2	carbon dioxide
ct	€ cent
DENA	Deutsche Energie-Agentur (German Energy Agency)
DERA	Deutsche Rohstoffagentur (German Raw Materials Agency)
DIHK	Deutsche Industrie- und Handelskammer
UCO	(German Chamber of Industry and Commerce)
DW	Deutsche Welle
EC	European Commission
EEG	Erneuerbare Energien Gesetz (Renewable Energy Sources Act)
EPIA	European Photovoltaic Industry Association
EPO	European Patent Office
ETS	Emissions Trading System
EU	European Union
FiT	feed-in tariff
GATT	General Agreement on Tariffs and Trade

GDP	gross domestic product
GHG	greenhouse gas
GWh	gigawatt hour
GWS	Gesellschaft für wirtschaftliche Strukturforschung (Institute of Economic Structures Research)
HS	Harmonized System
IAEE	International Association for Energy Economics
IDS	Institute of Development Studies
IEA	International Energy Agency
ISE	Institute for Solar Energy Systems
ISI	Institute for Systems and Innovation Research
IWES	Institute for Wind Energy and Energy System Technology
JPO	Japan Patent Office
KfW	Kreditanstalt für Wiederaufbau (Federal Bank for Reconstruction)
kWp	kilowatt peak
LCOE	levelized costs of electricity
MAP	Marktanreizprogramm (Market Incentives Programme)
MWp	megawatt peak
NIMBY	not in my backyard
NGO	non-governmental organization
OECD	Organization for Economic Cooperation and Development
OPV	organic photovoltaics
PV	photovoltaics
PWC	PriceWaterhouseCoopers
RAVE	Research at Alpha Ventus
RCA	revealed comparative advantage
REN21	Renewable Energy Policy Network for the 21st Century
R&D	research and development
RPS	relative patent share
RWE	Rheinisch-Westfälisches Elektrizitätswerk
RWI	Rheinisch-Westfälisches Institut für Wirtschaftsforschung
UNCOMTRADE	United Nations Commodity Trade Statistics Database
USPTO	U.S. Patent and Trademark Office
WIPO	World Intellectual Property Organization
Wp	watt peak
WTO	World Trade Organization
WWF	World Wide Fund for Nature

Summary

The Report in Brief: In this report, we address the fiercely debated challenge of Germany's energy transition *(Energiewende)* and review the policy measures taken in support of increasing the share of renewables in the country's energy mix. We place special emphasis on solar photovoltaic (PV) and wind energy, analyze the evolution of both sectors in Germany, assess the costs and benefits associated with support policies and draw some conclusions and lessons concerning the need to reform the feed-in tariff approach and to consider the broader issues of green industrial policy. We find mixed evidence that Germany reaches its green industrial policy aims at reasonable costs. Wind energy seems to perform better against all policy objectives, while the solar PV sector has come under intense pressure from international competition. However, this is only a snapshot of current performance, and a dynamic and systemic perspective may nonetheless make the support of various renewable energy sources advisable.

Industrial policy today must be placed within the broader perspective of sustainable development goals. Economic competitiveness, social inclusiveness and environmental footprints need to be considered simultaneously in a scenario characterized by planetary boundaries, resource scarcities and climate change. Various concepts of green industrial policy are being implemented by both industrialized and emerging economies with the overall aim to move towards a low-carbon and low-emission development trajectory. In this context, energy policy takes centre stage. A radical rethinking of the manner in which energy is being generated, distributed and consumed is necessary as a key element of a global industrial transformation.

Against this backdrop, we review Germany's experience with implementing an ambitious energy transition as a national "project" that involves a complete phase-out of nuclear energy and a gradually increasing reliance on renewable energy sources (Chapter 1). In 2012 renewable energy already accounted for 23 per cent of Germany's gross electricity generation, a share that, according to government targets, is to increase to 50 per cent by 2030 and 80 per cent by 2050. In addition to creating a sustainable foundation for the country's energy supply and contributing to global climate change objectives, the *Energiewende* is also intended to create a leading position for German industry in renewable energy technologies, boost innovative capabilities and create employment opportunities in future growth markets.

Specifically, we focus on assessing the costs and benefits of policies promoting the solar PV and wind energy sectors. We analyze the evolution and structure of these two sectors in Germany both from an aggregate perspective as well as by providing key company profiles (Chapter 2). In Chapter 3, we take stock of the various policy measures applied—ranging from the feed-in tariff pioneered through the Renewable Energy Sources Act (EEG) to dedicated loan programmes, extensive research and development support facilities and public-private partnerships aimed at boosting technological innovation. The feed-in tariff receives special attention, as it is the central policy tool replicated in a large number of countries worldwide.

Despite a generally stable policy environment, both the wind energy and the solar PV markets have become highly turbulent in recent years. We demonstrate that a spectacular rise in the production of equipment, deployment of new installations and generation of electricity (largely policy-induced) is being gradually replaced by an economic crisis in significant segments of both sectors. Most dramatically, the intense competitive pressure from Chinese suppliers of solar PV cells and modules has caused many German companies to go bankrupt, sell or reduce their solar operations or be taken over by competing companies.

The costs of support policies have been substantial yet are easily overstated depending on the methodology applied. In assessing the subsidy costs (Chapter 4), we draw on different approaches and methodologies, including "differential costs" (comparing feed-in tariffs with market prices), "net real costs" (calculating anticipated total support costs over the lifetime of subsidized installations) as well as more comprehensive cost-benefit analyses that factor in environmental benefits as well. We point out that quantitative assessments of the subsidy costs associated with the promotion of renewable energies have remained controversial, are fraught with methodological intricacies (such as the need to separate macroeconomic costs from distributional effects) and are often linked to vested political interests. However, in comparison, the subsidies granted to renewable energy sources are lower than those provided to conventional energy sources. Even within the renewables sector itself, subsidies for solar PV have been significantly higher than those for wind energy.

In terms of economic and social benefits, wind energy seems to perform better than solar PV. We derive this conclusion from a detailed quantitative assessment of the impact of support policies in various dimensions (Chapter 5). This ranges from economic competitiveness (based on market share, relative export advantage and revealed competitive advantage indicators) to technological innovation (based on relative patent share indicators as well as qualitative analyses of innovation paths), employment creation, evolution of market positions, environmental benefits from avoided emissions as well as various elements of energy security. We consolidate the evidence in these impact dimensions into a stylized comparison of solar PV and wind energy with the unequivocal result that the wind energy sector is leading in performance. Whether or not this should result in future policy preference to be given to wind energy is a broader industrial policy issue that we address in the final chapter.

Regarding policy implications, we suggest reforming the feed-in tariff to make it more efficient while maintaining technological diversity and to address equity and distribution effects (Chapter 6). While the feed-in tariff has triggered an early deployment and upscaling of a wide spectrum of renewable energies, it has not allowed for a focus on the most cost-efficient decarbonization technology. A premium was placed on creating a diversified renewables industry. At the same time, this approach has led to sharp increases in the electricity bill for end consumers and has been unable to avoid political capture (on account of proliferating exemptions for industrial companies) as well as the current turmoil in particular in the German solar PV market. Against this background, we present reform proposals such as more flexible feed-in tariff adjustments, the introduction of more competitive elements (for instance through "reverse auctioning schemes") and enhanced attention to income distribution effects.

Furthermore, we emphasize the need to adopt a systemic perspective of green industrial policy, which includes addressing the challenges of institutional fragmentation, interacting policy schemes and transformative alliances. This systemic view implies building up not just a market but an entire competitive and viable industry for renewable energy technologies— a challenge that so far has received a more effective response in wind energy compared to solar PV. Also, with renewable energy having grown out of a niche existence, issues related to transmission grid planning, grid stability and energy storage capacities must receive immediate priority attention. Looking ahead, we highlight the importance of overcoming the presently high level of institutional fragmentation in energy policy management; the need to address interacting policy schemes, in particular the national feed-in tariff and the European Emissions Trading Scheme; and the need to build transformative alliances involving public policy actors, major business players and civil society to put the German *Energiewende* on a sustainable path.

Introduction

Energy literally powers economic development. Hence, energy policy must be considered as a cornerstone of any industrial policy, regardless of the latter's specific objectives, approach and implementation. Through its impact on energy availability in general, and through more specific measures targeting the promotion of different energy sources and their relative prices, energy policy has a strong influence on an economy's competitiveness, employment, sectoral diversification patterns, trade position and long-term technological trajectory.

This has always been the case. However, it applies even more powerfully in a scenario of planetary boundaries, global material resource scarcity and climate change that together call for a radical rethinking of the manner in which energy has been generated, distributed and consumed so far. While notions and concepts of a Third, or New, or Next Industrial Revolution are currently proliferating in various manifestations (Rifkin, 2011; Dosi & Galambos, 2013; *The Economist*, 2012; Marsh, 2012; Andersen, 2012), it is evident that a long-term transition to a decarbonized energy scenario has to be part and parcel of building a sustainable future.

At the same time, energy policy is invariably designed and applied within a veritable minefield of stakeholders, interests, conflicts and alliances. It requires a long-term planning perspective and a holistic look at political, social, economic and technological challenges and scenarios. Above all, energy policy fundamentally determines a country's future basic infrastructure for decades ahead and thus creates strong lock-in effects and path dependency. It is a field of economic policy that does not lend itself to frequent shifts and reorientations unless huge investments are to be turned into stranded and wasted assets.

The above applies in particular in the context of the German case. The country is in the midst of a fundamental energy transition *(Energiewende)*, which involves a complete phase-out of nuclear energy and a deliberate policy of reliance on renewable energy sources. This necessitates a basic consensus on societal preferences, resulting energy policy aims and the way forward. In a somewhat stylized perspective, German society has generally been characterized by a strong technological risk aversion; more specifically, the nuclear exit policy commands broad political and popular support and such technological options as carbon capture and storage or hydraulic fracturing meet with strong public opposition. Also, climate change considerations figure high on the agenda of societal concerns. At the same time, energy availability and access have not really been an issue in the last 50 years, and even questions of energy security are of only secondary importance in the public discourse. What dominates the debate around energy policy is the issue of energy prices, both for industrial and household consumption, and this has become one of the essential yardsticks for assessing the progress and prospects of the ongoing energy transition towards renewables.

Against this backdrop, the present report reviews the German policy in support of raising the share of renewables in the energy mix within the context of multiple social, economic and technological objectives. Special sectoral emphasis is placed on solar photovoltaic (PV) and wind energy.

Chapter 1 presents the political and social contexts for green industrial policies in Germany, which is followed in Chapter 2 by a survey of the main characteristics, evolution and current status of the German solar PV and wind energy industries.

While Chapter 3 takes stock of the various cross-cutting and sectoral policies applied, Chapters 4 and 5 seek to measure the costs and benefits, respectively, of these policies. This is a complex undertaking fraught with diverse methodological challenges. Often, political positions and lobbying guide seemingly technical calculations. An attempt is thus made to rely to the extent possible on quantitative assessments and clearly spell out their underlying assumptions.

Chapter 6 provides a summary assessment of the Renewable Energies Sources Act and its FiT scheme as the central policy tool and reviews the current debate on its necessary reform. The chapter concludes with some broader issues to be considered in Germany's green industrial policy.

Overall, the report attempts to put the German energy transition into the broader perspective of economic, social, environmental and technological objectives and to provide an objective, up-to-date and balanced assessment of what has become a fierce controversy.

Chapter 1: Green Industrial Policy and the German Energy Transition

1.1 From Industrial Policy to Green Industrial Policy

As much as the concept of industrial policy has seen "business cycles" of acceptance, skepticism, denial and renaissance, the basic idea has remained the same (Altenburg, 2011; United Nations Industrial Development Organisation [UNIDO], 2011). At the national level, the application of industrial policy by governments reflects deliberate efforts to steer the sectoral composition of a country's economic output and growth (as normally measured by GDP) in a desired direction. This may imply lower or higher degrees of sectoral diversification depending on the specific case. Also, it can rely on a variety of different policy measures, including state-owned enterprises, strict controls (e.g., intervening in capital markets); tariffs and non-tariff barriers to trade; laws and regulations; targeted creation of infrastructure; priority supply of financing; sector-, region- or technology-specific research and development initiatives; incentives schemes; and outright subsidization, as well as various forms of public-private stakeholder consultations and moral suasion.

The strongest case for justifying industrial policy is normally derived from the identification of market failures in the form of public goods, coordination and information deficiencies or externalities, which may lead to suboptimal investment levels due to societal costs and benefits not accounted for in the market calculus. In addition—quite distinct from the market failure argument—industrial policy can be justified in cases where the market does not deliver socially acceptable outcomes, as is, for example, often the case with regard to asset and income inequalities.

Any industrial policy in action is faced with the twin challenges of taking place under conditions of limited information and risk-prone anticipation of future scenarios (it is literally macro-management under uncertainty), as well as having to respond to a complex set of economic and social objectives. Typically, in the context of a developed economy like Germany, the latter encompass employment creation, competitiveness, growth, income equality (functional and regional), technological innovation, low inflation, manageable levels of public debt and a positive trade balance.

In many ways, green industrial policy involves an even more ambitious and complex set of objectives, as well as additional technology assessment and risk dimensions (Pegels, in press; Morris, Nivola & Schultze, 2012; Lütkenhorst, 2010). Planetary boundaries in terms of both limited absorptive capacities for emissions and pollution (related to biodiversity, ozone layer and climate) and resource scarcities (related to raw materials, water and energy) need to be factored in. Essentially, this extends the necessary time horizons in which actions and their consequences must be considered. It also heightens the risk profile of policy decisions that involve massive investment commitments from public and private sources, define a development trajectory and create lock-in effects for generations to come. Hence, there is a compelling case for achieving a societal consensus on the desired long-term vision and direction of development (Altenburg & Pegels, 2012).

Importantly, any green industrial policy creates winners and losers. The industries of the future tend to be at the centre of the public debate and policy discourse. However, the industries of the past, the sunk costs and stranded assets, can and will mobilize resistance to any policy perceived to negatively affect their acquired status. Where significant employment levels are involved, coalitions between industry associations and trade unions can easily delay or even completely derail forward-looking environmental policies.

In the case of Germany, green industrial policy has a long track record and commands a particularly high level of support in the population at large. The first initiatives of fighting industrial pollution through emission-control regulations date back to the early 1960s. The rise of a politically powerful and effective green party started in the early 1980s, which was initially heavily based on an anti-nuclear platform. The relative weight of the environmental and energy agendas have shifted over time: the former was dominant in much of the 1980s and early 1990s while subsequently the theme of a necessary transformation or transition of the country's energy system became paramount.[1] Interestingly, today both agendas are partly in conflict as evidenced in mounting environmentally motivated resistance to large-scale wind and solar installations and their massive grid expansion requirements.

1.2 The Energy Transition *(Energiewende)*

Any discussion of Germany's renewables policy in general—and solar PV and wind energy promotion policy in particular—must take place within the overall political scenario established by the announcement in mid-2011 of a fundamental energy transition. This is true even in light of the much earlier adoption of the Renewable Energy Sources Act (*Erneuerbare-Energien-Gesetz* [EEG]) in 2000, which has to date (with various amendments) remained the cornerstone of German energy policy.

The energy transition has seen a number of twists and turns, which will not be documented here. Importantly, following the Fukushima nuclear disaster in March 2011, Chancellor Merkel and her coalition government adopted a long-term energy concept combining the earlier energy efficiency targets and a rising level of renewables in the energy mix with a complete phase-out of nuclear energy.

Germany is thus aiming at achieving, in the long run, a largely decarbonized energy generation scenario under highly ambitious conditions. The share of nuclear energy in electricity generation—in earlier years hovering around 30 per cent—currently stands at roughly 16 per cent. Its complete phase-out is now targeted for completion by 2022, in less than a decade, compared to earlier plans to prolong the lifespans of nuclear plants by an average of 12 years and have them run well beyond 2030. This puts Germany in the singular position of being the only major industrial economy abandoning the nuclear option altogether. As a consequence, the pressure of achieving renewable energy expansion targets has increased massively. With its 2012 amendment, the EEG envisages a share of renewables in the total electricity supply of 50 per cent by 2030 and 80 per cent by 2050. A fierce debate on the feasibility and costs of reaching these targets and on the relative role of coal and gas as bridging technologies has been triggered. For reference, the composition of electricity generation in 2012 is provided in Figure 1.[2]

---

[1] It is intriguing to note that the German language terms *Waldsterben* (forest dieback) and more recently, *Energiewende* (energy transition) have both made it into English language use.

[2] Unless explicitly stated otherwise, all tables and figures refer to the case of Germany.

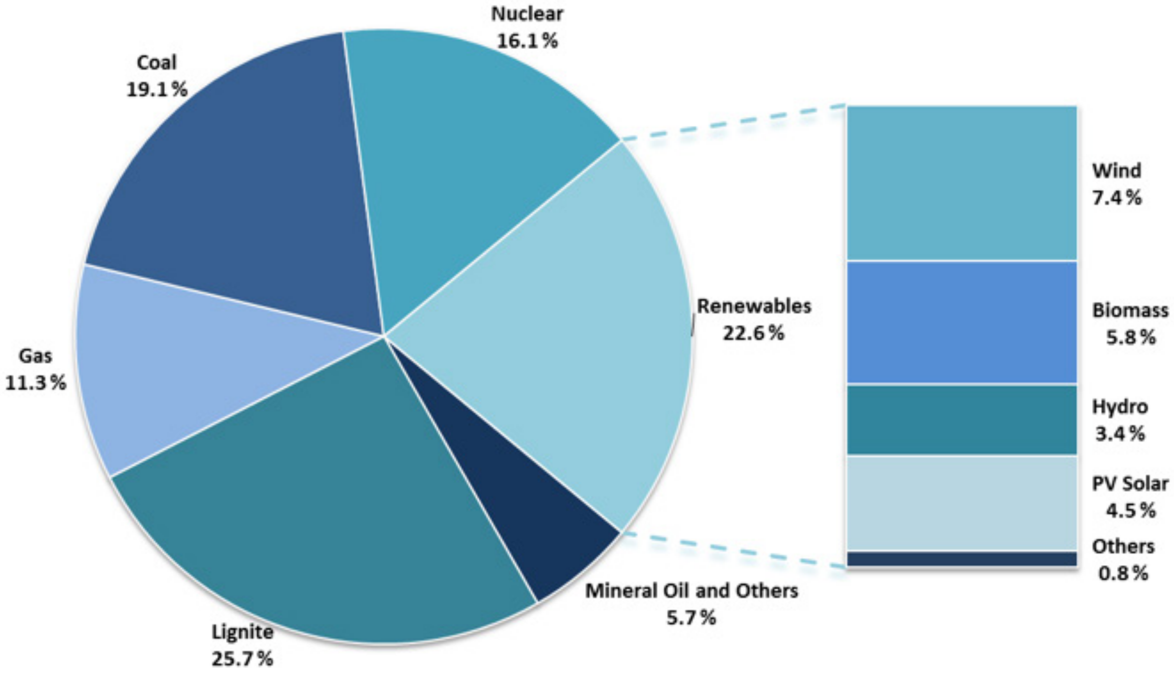

FIGURE 1: GROSS ELECTRICITY GENERATION IN GERMANY 2012

Source: Bundesministerium für Wirtshaft und Technologie (2013).

Obviously, the energy transition plans are much wider in scope than just covering electricity generation. In fact, only about one fifth of Germany's final energy demand is met by electricity, with the bulk related to heat and transportation accounting for some 40 per cent, respectively. Hence, the energy transition will also have to address the need for energy efficiency in buildings, as well as innovative, sustainable public and private transport systems (e.g., "e-mobility") as integral components—aspects that are not covered in this report.

The energy transition in Germany is not proceeding without intense debate—indeed controversy—and powerful resistance from both the suppliers of conventional, carbon-based energy (the big utilities) and highly energy-intensive industrial production companies. However, it is noteworthy that overall it can rely on an exceedingly broad political foundation and even a gradual buy-in from some significant business players. Specifically, on the latter aspect, two of the four large utilities (RWE and Eon), as well as one of the country's largest industrial conglomerates (Siemens) have announced their intention of moving out of building nuclear plants even outside Germany—a powerful example indeed of business strategies reflecting clearly expressed policy directions. However, there are growing signs of backlash as well: conservative parties (including the German conservatives) have blocked the necessary reform of the European Emissions Trading System (ETS); the German government recently opposed the European Commission (EC) proposal for lower automotive fleet emissions standards; and there is growing opposition to the EEG within Germany itself.

Generally, however, the energy transition can count on broad popular support. This is reflected in particular in the ownership structure of renewable energy generation: in 2010, more than 50 per cent of renewable energy was generated under private ownership, with private individuals (often organized in the form of energy cooperatives) accounting for as much as 40 per cent and farmers for another 11 per cent (Buchan, 2012, p.11). The vast majority of the German population considers the expansion of renewable energy sources as important, or even very important (94 per cent). While there has been local evidence of the "not in my backyard" (NIMBY) phenomenon, the general acceptance levels of solar parks and wind farms in the neighbourhood are reported to be as high as 84 per cent and 73 per cent, respectively—compared to only 54 per cent for biomass plants (Agentur für Erneuerbare Energien, 2012).

In terms of geographical preconditions, the Northern regions of Germany—which feature generally higher wind intensity and speed—are conducive to attracting both onshore and offshore wind installations, whereas the Southern regions are more favourable for solar energy. At the same time, because solar installations are most often emplaced on rooftops, they tend to be concentrated in areas of high population density, such as the urban agglomerations in the country's traditional industrial heartland in North Rhine-Westphalia.

Accordingly, plans to speed up the deployment of solar PV and wind energy installations call for an expansion of the transmission grid and increasingly need to be balanced with spatial planning and related regulations. Also, trade-offs between pushing renewable energy expansion on the one hand and protecting natural habitats on the other hand are becoming more frequent—leading to protracted legal proceedings and concomitant delays. This applies in particular to onshore wind installations and to new high-voltage transmission lines. As a result, conflictive scenarios at the local level are clearly on the rise.

1.3 Key Policy Objectives

A national priority project of the highest order, such as the energy transition, is invariably governed by a complex set of objectives. To some extent, these have been officially pronounced and codified in legal documents. In addition, they can be derived from ministerial policy statements and publications.

With the EEG being the most important green energy policy law, its expressed policy objectives deserve prime consideration (Renewable Energy Sources Act – EEG 2012). In its Article 1 on the purpose of the law, the following objectives are listed:

- "Sustainable development of energy supply."
- "Protecting our climate and the environment."
- "Reducing the costs of energy supply to the national economy."
- "Further development of technologies for the generation of electricity from renewable energy sources."

In various publications, statements and speeches by the relevant government entities (Ministry of Environment, Nature and Nuclear Safety; Ministry of the Economy and Technology, as well as the Chancellor herself), the energy transition is portrayed as contributing to:

- Strengthening Germany's leading global market position for climate-friendly technologies.
- Ensuring reliable and affordable energy supply to maintain competitiveness.
- Boosting innovative capabilities of industry.
- Creating employment opportunities from renewable energy development.
- Saving scarce resources and reducing import dependency from fossil fuels.

It is further noteworthy that quite a number of quantified policy targets have been set, which, however, relate exclusively to the direct domains of environment and energy. More specifically (and as summarized in Table 1), they cover planned reductions in greenhouse gas (GHG) emissions and in energy consumption as well as the rising share of renewables in gross electricity consumption. However, no such targets exist for the level of additional employment expected from the development and deployment of renewable sources of energy, or for any other of the objectives listed above.

It is worth mentioning that the long-term German GHG emissions targets and renewables targets are identical to those stipulated at the European Union level through the Energy Roadmap 2050 (EC, 2011). Hence, the uniqueness so often claimed with regard to Germany's energy transition is not related to the targets' time horizon and level of ambition but only to foregoing the nuclear option.

TABLE 1: QUANTIFIED ENERGY POLICY TARGETS, 2020–2050 (PERCENTAGES)

YEAR	2012 CURRENT STATUS	2020	2030	2040	2050
GHG emissions (base year 1990)	-26	-40	-55	-70	-80-95
Gross electricity consumption (base year 2008)	-3	-10			-25
Primary energy consumption (base year 2008)	-6	-20			-50
Share of renewable energy sources in gross electricity consumption	23	35	50	65	80

Source: Adapted from BMWi (2013, p. 5). Targets are based on the 2010 energy concept of the German government.

Based on the available policy declarations, it would thus seem that the main objectives driving the German energy transition can be summarized as presented in Figure 2. Compared to the mix of policy objectives prevailing in other countries, the German policy matrix is characterized by:

- A high priority placed on achieving the wider benefits of reducing GHG emissions and thus contributing to global climate change goals going beyond the realm of purely national policy.
- A deliberate effort to harness the energy transition as a driver of economic dynamism aimed at creating the technologies and industries of the future, as well as a lasting source of competitiveness and employment going forward.
- A relatively lower priority attached to objectives related to energy security.

---

[2] Unless explicitly stated otherwise, all tables and figures refer to the case of Germany.

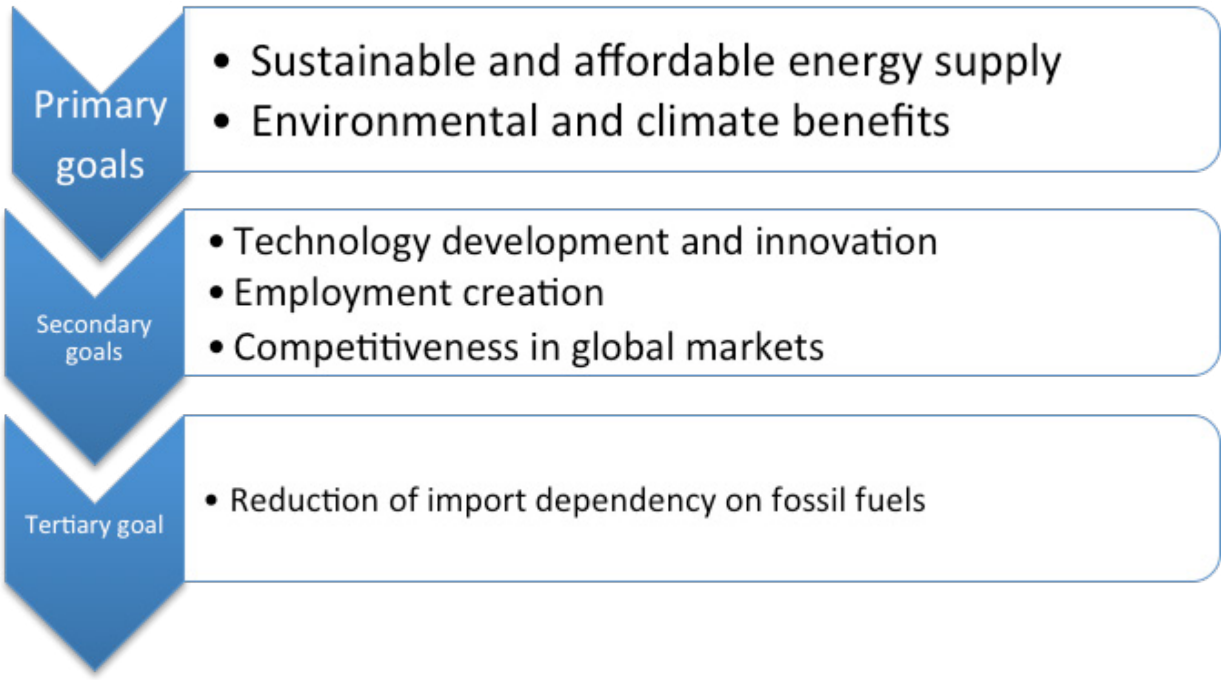

FIGURE 2: HIERARCHY OF ENERGY POLICY OBJECTIVES

The swift transition to various renewable energy sources primarily for electricity generation (but also increasingly for heat generation and fuels) constitutes the centrepiece of German energy policy. For the purpose of this report, an exclusive focus on electricity generation is adopted.[3]

---

[3] The role of renewables in fuel production is confined to biodiesel, vegetable oil and bioethanol. The share of solar energy (in the form of thermal solar, not solar PV) in total heat generation is negligible and accounted for just 0.4 per cent in 2011.

Chapter 2: The Evolution and Status of the Solar PV and Wind Energy Industry

2.1 The Solar PV Industry

This section—just as the following one on the wind energy sector—will take stock of the sector's development and current status. The approach is factual, with a closer analysis of policy impact and key challenges ahead being addressed in the following chapters.

The story of the solar PV industry in Germany has been one of a spectacular rise—followed by a crash in parts of the sector—within just one decade. From negligible capacity and production levels in 2000 (newly installed physical capacity of 45 megawatt peak [MWp] and solar PV power generation of 64 million kilowatt hours [kWh]) and initially modest growth rates, the industry recorded two-digit and at times even three-digit growth rates between 2004 and 2010, when installed capacity growth started to stagnate and reached a plateau of approximately 7,500 MWp annually (BSW-Solar, 2013)[4] —which, up to 2012, made Germany the largest solar PV producer in the world. Within the broader EU context, Germany currently accounts for about half of the entire solar PV capacity and exhibits a PV/per capita ratio of 400 (measured in terms of Wp per inhabitant)—four times higher than Spain and three times higher than the EU average (EurObserv'ER, 2013; figures for 2012).

Over time, the average size of installed PV solar systems has increased significantly. Back in 2000, more than 60 per cent of PV systems installed were operating at a capacity below 10 kilowatt peak (kWp) and only slightly more than 10 per cent at more than 100 kWp. A decade later, the situation had reversed: only 10 per cent of systems installed in 2011 were below 10 kWp, yet more than 50 per cent above 100 kWp (Quitzow, 2012).

It is widely recognized that the German solar boom was largely caused by the investment stability and strong incentives provided by the EEG (essentially through guaranteed, generous feed-in tariffs (FiTs) combined with priority grid connection for supplied electricity). This was coupled with unexpectedly strong price decreases for PV systems: between 2006 and 2012, prices fell by roughly two thirds, from €5,100 to €1,750 per kWp. In 2012 alone, solar module prices tumbled by 45 per cent (BSW-Solar, 2013).

The 2012 profile of the sector is summarized in Table 2.

---

[4] Between 2010 and 2012, around 7,500 MWp of installed capacity were added annually, resulting in an increase of PV power generation from 11,700 kWh in 2010 to 28,060 kWh in 2012.

TABLE 2: KEY INDICATORS OF THE PV SOLAR INDUSTRY IN GERMANY (2012)

New capacity installed Share of world total	7,600 MWp 31 per cent
Total cumulative capacity Share of world total	32,400 MWp 47 per cent
Power generated	28,060 gigawatt hours (GWh)
Total cumulative number of installed PV systems	1,280,000
Share of gross electricity generation	4.7 per cent
Share of gross electricity generation from renewables	20 per cent
Number of PV companies (incl. installers and suppliers) *Thereof: Number of companies producing cells, modules and components*	5,000 *200*
Export share of production	60 per cent
Investment	€11.2 billion
Employment	87,800

Sources: Compiled from BSW-Solar (2013); O'Sullivan, Edler, Bickel, Lehr, Peter & Sakowski (2013); AGEE-Stat (2013); Germany Trade & Invest (2013a).

The rapid rise of the German solar PV industry under favourable market conditions has created a highly diversified sector with significant industrial capabilities and capacities in practically all segments of the value chain (PriceWaterhouseCoopers, 2010; Grau, Huo, & Neuhoff, 2011), as presented in Table 3.

In general, the German solar PV industry is facing tough conditions with fierce competition from low-cost Asian (mainly Chinese) suppliers. Market turbulence has increased, and already a large number of companies (among them Q-Cells—once the global leader in solar cell production—Solon, Solar Millennium, Solar, Solarhybrid, and Odersun) have gone bankrupt. At the same time, several industrial players with core expertise outside the solar industry are abandoning their solar PV operations: in March 2013 Bosch announced the discontinuation of its PV ingot, wafer and cell production and the sale of all its solar business units; Siemens is closing down its solar division after having entered the solar business only in 2009 with great expectations; WürthSolar, after a thorough evaluation, completely exited from its solar PV production in May 2013.

In 2012 alone, 19 German companies in the solar PV sector left the market, either due to genuine insolvency, strategic decisions or takeover by competitors. Specifically, this included two companies in wafer production, three cell manufacturers and one module manufacturer, six producers of silicon thin film, five producers of CIS modules and two companies producing inverters (Photon, 2013).

Only a few companies (Wacker Chemie AG, Joint Solar Silicon, PV Crystalox—the latter in serious economic turmoil) are engaged in the capital-intensive upstream production and processing of silicon. Wacker AG is the dominant player and has in recent years expanded its production capacity significantly.

Most German solar companies are active in solar cell production, a market segment that has in recent years come under intense pressure from imported cells, above all from Chinese companies entering the high-volume German market. Competition is fierce, profit margins have become exceedingly low and a mature technology leaves only limited space for quality as a selling proposition. Furthermore, in this segment there are no distinct advantages of proximity to end users.

A number of companies (e.g., Bosch Solar Energy, Schott Solar, Conergy, SolarWorld, Sovello) are/were fully vertically integrated across the manufacture of wafers, cells and modules. In principle, this allows both for internal cross-subsidization of different lines of production and for a positioning as a supplier of system solutions with a high advisory and service content. However, survival has become difficult in this market segment as well: Sovello is being closed down; SolarWorld is heavily in debt and faces an uncertain future; and Schott Solar (with glass manufacturing as a core business) is withdrawing from crystalline silicon manufacturing while staying in the thin film business. As recently as July 2013, Conergy had to file for bankruptcy and is looking for new investors.

With regard to solar PV equipment manufacturers (e.g., cell coating, module stringers or automation), many companies originate from, and still serve, other industrial sectors such as automotive or medical and are applying their core expertise now also to solar PV production.

Finally, there is increasing potential for German firms in the field of installation systems and services. This is an area with significant customer proximity advantages. However, with module prices coming down fast, the relative share of installation costs is bound to rise and will be subject to intense price reduction pressure in the future.

Table 3 provides an overview of the German solar PV industry, which covers the whole value chain and can be considered as one of the most comprehensive and sophisticated solar PV clusters globally.

TABLE 3: SOLAR PV INDUSTRY VALUE CHAIN: NUMBER OF LEADING BUSINESS AND RESEARCH AND DEVELOPMENT (R&D) PLAYERS IN GERMANY (2013)*

PV manufacturers (silicon, wafer, cells modules)	46
PV module materials (glass, frames, junction boxes etc.)	61
PV system components (inverters, cables, connectors)	53
PV equipment suppliers (silicon equipment, thermal equipment, wet chemistry, coating, stringers, thin film, automation, laser processing etc.)	94
PV mounting & tracking systems	63
Sub-total: Business players	317
Specialized R&D institutions	73
Total value chain	390

** While this overview contains the main business players, it is not exhaustive. Also, it does not fully reflect some very recent cases of company bankruptcies. There are also minor inconsistencies in the classification as some vertically integrated companies are active in several value chain segments.*

Source: Compiled from GTAI (2013b) and various fact sheets on: http://www.gtai.de/GTAI/Navigation/DE/Invest/Industrien/Energie-umwelt-technologien/Solar-industrie/solar-industrie-downloads-medien.html

Company Profile: SolarWorld[5]

SolarWorld was founded in 1988 and was listed on the Frankfurt stock exchange in 1998. Though the company received the German Sustainability Award as recently as 2008 and was among the top three nominees for Germany's "Most Sustainable Brand," it has meanwhile come to epitomize the crisis in the German solar PV industry. Severe price-based competition from China (considered as a case of unfair dumping by SolarWorld itself) triggered massive losses amounting to €144 million by mid-2012 and €69 million more by mid-2013, a reduction of employees by 14 per cent and a drop in sales in the German market of 61 per cent. A drastic capital reduction, coupled with a restructuring plan and the prospect of a major loan from a Qatar-based investor was agreed in August 2013 and has created new breathing space for the company.

SolarWorld has a diversified product portfolio covering the entire value chain, from producing polysilicon as a raw material down to manufacturing solar panels and supplying turnkey solar installations. The company plans to maintain this broad coverage with enhanced emphasis placed on small- to medium-sized comprehensive solutions (solar PV, solar thermal, storage and control systems) for customers. The introduction of an innovative manufacturing process is supposed to deliver a more cost-effective wafer production. Furthermore, SolarWorld is reported to be interested in taking over at least part of the operations on sale by Bosch Solar.

Company Profile: Wacker[6]

The chemical company Wacker (founded in 1914 and currently having more than 16,000 employees globally) operates five main divisions, one of which is Wacker Polysilicon, which accounts for more than one quarter of total company business. In polysilicon—a major input for solar wafer and panel production—the company is among the global market leaders with a market share of 18 per cent in 2012, second only to the Chinese company GCL. With polysilicon sales of more than €1.1 billion in 2012, this division alone generated more than twice the entire business turnover of SolarWorld. Wacker has deliberately pursued a strategy of global presence, with early emphasis on the Asian market (accounting for approximately 40 per cent of sales) and the U.S. market. Even so, it could not escape the solar PV market downturn. In the first quarter of 2013 (on a year-to-year basis) its polysilicon sales volume decreased by 10 per cent and profits by almost 90 per cent.

Not surprisingly in view of its global delivery profile, Wacker has been a fervent opponent of the punitive EU tariffs against Chinese solar PV imports. Its global market orientation has also led the company to announce its withdrawal from the German Solar Industry Association (BSW) while maintaining its membership in the European Photovoltaic Industry Association (EPIA).

---

[5] Based on www.solarworld.de; PV Magazine (2013d); PV Magazine (2013^{e}).

[6] Based on www.wacker.com as well as coverage of Wacker company developments on www.bizzenergytoday.com, www.boerse-online.de and www.handelsblatt.com.

Company Profile: SMA Solar[7]

SMA Solar is the global market leader (market share of 23 per cent in 2012) among manufacturers of inverters and control and monitoring devices for solar PV installations across all size segments. Increasing emphasis is placed on delivering hybrid energy management solutions (diesel plus PV) and flexibility services for grid integration. The company has been squarely hit by the recent solar PV market crisis. During the first half of 2013, its global sales volume suffered a 45 per cent decline while operating profits (still positive in 2012) turned into significant losses. More than 10 per cent of its 5,600 employees will be laid off. The export share of production is rapidly rising from 54 per cent in the first half of 2012 to close to 70 per cent in mid-2013.

SMA's business strategy relies on further expansion in the fast-growing Asian and U.S. markets. This includes the 2013 acquisition of Zeversolar, a leading Chinese inverter company, where SMA Solar has acquired majority ownership of 72.5 per cent. Access to the Chinese market combined with preparation for an anticipated entry of Chinese inverter manufacturers into the German market have driven this strategic investment.

These brief profiles of leading companies positioned in different segments of the solar PV industry clearly demonstrate that the crisis caused by overcapacities and rapidly decreasing prices indeed permeates the entire solar PV value chain in Germany.

2.2 The Wind Energy Industry

Just as in the case of solar PV, the real takeoff of the German wind industry was triggered by a favourable policy environment embedded in the EEG in 2000 and its predecessor law back in 1991. Building on earlier developments in the 1980s, the sector has recorded a phenomenal growth since the mid-1990s. Globally, in terms of cumulative installed wind energy capacity, the German market currently ranks third (after the United States and China) thus representing the largest market in the EU. Its share of global installed capacity stood at 11.1 per cent at the end of 2012. However, the German share of new installed capacity in 2012 decreased to 5.4 per cent (Global Wind Energy Council, 2013).

The 2012 profile of the sector is as summarized in Table 4.

---

[7] Based on www.smasolar.de.

TABLE 4: KEY INDICATORS FOR THE WIND ENERGY INDUSTRY IN GERMANY (2012)

New capacity installed	2,415 MW
offshore	*80 MW*
Share of world total	5.4 per cent
Total cumulative capacity	31,308 MW
offshore	*280 MW*
Share of world total	11.1 per cent
Total cumulative number of turbines	23,030
offshore	*68*
Power generated	46 GWh
Share of gross electricity generation	7.4 per cent
Share of gross electricity generation from renewables	32.7 per cent
Employment	117,900
offshore	*18,000*
Investment	€3.8 billion

Sources: Compiled from AGEE-Stat (2013); Deutsche WindGuard (2012); O'Sullivan, Edler, Bickel, Lehr, Peter, & Sakowski (2013); Bundesverband WindEnergie (2012).

The offshore wind sector is still relatively small, accounting in 2012 for 0.9 per cent of total installed capacity and 3.3 per cent of the capacity added in that year. Interestingly, its share in total employment generated by the wind energy sector is significantly higher (largely due to a higher export share) and stood at 15.3 per cent. Currently, six large-scale projects are under development in the North Sea with a total capacity of 1,800 MW—that is more than six times the current offshore capacity in Germany. A total of 29 projects (with an overall capacity of around 10,000 MW) have been licensed, mostly at a distance of 20 to 60 kilometres from the coast.

The offshore wind sector has huge development potential and is forecast to be on par with onshore wind electricity generation by 2040. According to a recent study (PriceWaterhouseCoopers, 2012), by 2021 the sector is expected to generate a turnover of close to €22 billion, with a 60 per cent share of manufacturing operations. Employment is expected to increase to 33,000 jobs, of which 85 per cent will be in small- and medium-sized enterprises. Importantly, when considering the entire value chain, the onshore wind industry is regionally well dispersed. In particular, the component supplier companies are largely located in traditional Central and Southern industrial centres.

Currently, two major issues dominate the debate around offshore wind. Firstly, the challenge of grid connections linking generation in the country's North with electricity consumption centres in the country's South has given rise to questions of financial burden sharing, realistic time horizons and environmental damage. Secondly, the issue of relative priorities for offshore versus onshore wind generation has been reignited by a recent study (Umweltbundesamt, 2013) that identifies a huge potential for onshore expansion and calls for a discontinuation of FiTs for offshore wind farms.

It is particularly noteworthy that the share of repowering of existing wind installations is rising steadily.[8] Of total capacity installed in 2012, almost 18 per cent originated from repowering, leading to higher energy yields due to technological progress in turbine efficiency.

---

[8] It is to be noted that data on repowering are imprecise due to a number of reasons. These include changing manufacturers, changing locations across municipal borders as well as a general lack of a central turbine registry at national level.

For the wind energy sector as a whole, there has been a clear trend towards an upscaling of installations over time. The average capacity of 2,420 kW for new turbines coming on stream in 2012 is almost 80 per cent higher than the average capacity in the total stock of turbines. Regarding regional distribution, the trend has been towards a more even spread across the country. While 20 years ago close to 90 per cent of installed capacity was to be found in the Northern region, in 2012 this share was down to 42 per cent, with 46 per cent located in the Central region and the remainder in the Southern region. This trend is accompanied by the deployment of larger turbines (in terms of hub height) in the Southern region, which generally has lower wind speed conditions. This has led to the somewhat paradoxical result that energy yields per turbine are now even higher in the climatically less favourable region: 1.5 MW in the South as compared to 1.3 MW in the North (calculated from data in Deutsche WindGuard, 2012). Irrespective of this regional dispersion trend, and above all stemming from expected future offshore capacities, the critical issue for Germany's future wind energy development will be the buildup of North-South transmission lines.

In terms of a value chain perspective, the sector is divided into a manufacturing chain and a deployment services chain (Lema, Berger, & Schmitz, 2012). The former typically covers the production of towers, blades, gearboxes, power converters and myriad small components; overall, a wind turbine is made of more than 8,000 components, with cast iron, forgings and reinforcement fibres being among the main materials used. The deployment services segment encompasses utilities, wind park construction, operation and maintenance as well as various forms of technical and managerial consultancy. A 2013 overview shows a total of almost 200 companies active in the sector (see Table 5).

TABLE 5: WIND INDUSTRY VALUE CHAIN: NUMBER OF LEADING BUSINESS AND R&D PLAYERS IN GERMANY (2013)*

Wind energy converters	12
Towers, tubes, foundations	6
Blades	4
Mechanical components (hydraulic equipment, generators, gearboxes, bearings, brakes, etc.)	24
Electronic components (automation, controls, power converters, transmission systems, etc.)	16
Sub-total: Manufacturing value chain	62
Project developers for onshore wind parks	43
Technical and commercial operator management	37
Service, maintenance and repair services	54
Sub-total: Deployment services value chain	134
Specialized research institutions	17
Total value chain	213

** While this overview contains the main business players, it is not exhaustive. There are also minor inconsistencies in the classification as some vertically integrated companies are active in several value chain segments.*

Source: Compiled from GTAI (2013a) and various fact sheets available at http://www.gtai.de/GTAI/Navigation/EN/Invest/Industries/Energy-environmental-technologies/wind-industry.html#247560.

In terms of market structure, the wind energy sector in Germany is highly concentrated and characterized by a close connection to the central transmission grid. In terms of wind converter production, just three companies account for more than 90 per cent of the onshore wind market, with Enercon being the undisputed market leader (almost 60 per cent of newly installed capacity in 2012) followed by Vestas (25 per cent), REpower (11 per cent) and Nordex. Whereas Enercon is a wholly German-owned company, Vestas is Danish and REpower is under majority ownership from Indian Suzlon.

The difference in leading companies in the onshore and offshore market segments is striking. The cumulative offshore capacity installed up to 2012 in Germany is strongly dominated by just two German companies: BARD[9] (59 per cent) and Siemens Wind Power (17 per cent).

In the global wind turbine market, Siemens Wind Power is the leading German company, with a market share of 9.5 per cent in 2012, which is surpassed among European companies only by Vestas, with 14 per cent (see Table 13 in Chapter 5). Here again, the pronounced concentration on the offshore market stands out: Siemens Wind Power is the undisputed global leader for offshore turbines with a cumulative market share of 56 per cent—and even a 78 per cent share in new capacity installed in 2012 worldwide (Fraunhofer IWES, 2013).

Market turbulence is currently increasing, yet less pronounced than in the solar market, primarily due to longer gestation periods and higher levels of technological sophistication. While business representatives expect a slowdown of the global wind turbine market, the German market (in particular its onshore segment) is expected to further expand. German industry is well positioned and among the technological leaders worldwide. For instance, Enercon expects a profit increase of some 30 per cent for this year. However, there are also signs of a slowdown, and REpower, with a relatively high offshore business share, is suffering from delays occurring in new North Sea wind projects. The company expects a 20 per cent turnover reduction this year and has plans to lay off more than 20 per cent of its employees.

The following section provides a brief account of some of the main business players[10] in Germany's wind industry (primarily based on Urban, Nordensvärd, Lema & Moller Andersen, 2013; "Windräder," 2012; "Windkraftbranche," 2012, "Nordex und Vestas," 2012; annual reports and press releases of companies concerned).

Company Profile: Enercon[11]

With Enercon accounting for more than half of the entire German market, it is worth taking a closer look at the company's prevailing business model and strategy. Enercon employs about 18,000 people worldwide (about 3,000 at the German headquarters in Aurich) and has produced some 20,000 wind turbines with a total capacity of 30 GW worldwide. The company has remained family owned, is not listed on the stock market and does not publish turnover and profit data. While reports by independent analysts are lacking, it is widely considered as financially solid and healthy.

As technologically less sophisticated and mature market segments are increasingly taken over by Asian companies competing primarily on price, a premium is placed on offering system solutions or, as in the case of Enercon, selling the availability of energy. Distinguishing itself from foreign companies selling wind turbines, Enercon provides an entire package of planning, equipping, operating and maintaining wind parks for its customers. Around 90 per cent of customers actually sign a so-called partner concept, which—over a contract period of 10 to 15 years—guarantees

---

[9] In 2013, some subsidiaries of BARD became insolvent.

[10] Institutional players will be addressed in the following policy chapters. Apart from sector-specific industry associations and research entities, most of them are cross-cutting with a broader mandate for renewable energy.

[11] The Enercon company profile is based on an interview conducted on August 29, 2013 with Dr. Brand-Schock, Enercon Berlin Office, and on Enercon 2010.

the timely provision of comprehensive technical and managerial services. Interestingly, the payment terms are split into fixed and variable components—with the latter depending on the annual amount of wind energy actually generated. In general, Enercon does not engage in direct sales of turbines without complementary services. Customer satisfaction ratings are extremely high—so much so that wind park owners working with Enercon can benefit from lower insurance fees.

Enercon so far is exclusively operating onshore and intends to maintain this focus. Also, the company has deliberately stayed away from both the Chinese market and withdrew from both the U.S. and the Indian markets following protracted intellectual property lawsuits. The German home market currently accounts for one third of all business operations and is expected to increase up to 40 per cent. Beyond Germany, regional diversification emphasizes European markets (France, Austria, Eastern Europe), as well as Turkey and Canada. The strategic orientation is towards a multitude of small markets with potential for expansion, often initially building on relationships with existing company clients.

In terms of technology, Enercon relies on its homemade Direct Drive technology (no gear box) with a smaller number of rotating components, and lower operating and maintenance costs compared to other technologies. Also, the Direct Drive technology allows for better performance and additional system benefits in terms of grid stability. The company produces the highest-capacity turbine (7.6 MW) currently available on the world market and is conducting research and development efforts into producing turbines with capacities in excess of 10 MW.[12]

While thus sharply focused geographically and technologically, the company's operations are characterized by an exceedingly high degree of vertical integration. Enercon not only combines production with planning, operation and maintenance services (essentially covering the whole wind park life cycle) but also manufactures the majority of components in-house so as to ensure synergies and strict quality assurance. Recently, Enercon launched its own foundry as an additional step towards even deeper integration.

Company Profile: Nordex

Nordex is a medium-sized, Hamburg-based company producing turbines only for onshore deployment. Its German market share was around 4 per cent in 2012. With 2,500 employees (down slightly from 2011), the company managed to increase its sales by 17 per cent and its order intake by 15 per cent. However, it is generating significant losses: the return on sales ratio (still positive at 4.1 per cent in 2010) dropped to -5.7 per cent in 2012. Nordex has announced a major cost cutting program not only targeting production costs, but also including a reduction in the number of board members.

The company strategy places great emphasis on growing the service business (which in 2012 increased by 25 per cent) and expanding in particular maintenance services for its own turbines worldwide. In addition to Asia, key growth markets targeted are South Africa (with three major contracts awarded recently, including a 10-year service agreement) and South America.

---

[12] This is in stark contrast to the technology option chosen by Vestas, which relies on gear-driven turbines and has outsourced the gear manufacturing to a specialized German supplier, namely Bosch-Rexroth.

Company Profile: REpower

While India's Suzlon has gradually taken full ownership of REpower, the company has maintained independence in terms of intellectual property rights and profit retention. REpower currently employs around 3,300 people worldwide, with the majority of its production sites located in Germany. Both onshore and offshore turbines are being manufactured; technological leadership is most pronounced in the offshore segment where REpower offers the most powerful available turbine (6 MW) for installation in the high seas. The market focus lies in Europe, and the company has recently reduced its engagement with the Chinese market.

The business strategy is built upon high-quality, gear-driven turbine manufacturing coupled with maintenance and other services. Unlike Enercon, vertical integration is low. While rotor blades are produced in-house, most other components have been outsourced to a diversified range of German, other European and Asian suppliers.

Recently, also REpower has faced challenging business conditions. An April 2013 company communication announced a €100 million cost-cutting programme coupled with the layoffs of 750 staff—almost one quarter of total employees.

Company Profile: Vensys

Vensys represents the interesting case of a small company that has developed out of a dedicated research centre (*Forschungsgruppe Windenergie*) at the University of Applied Sciences of the Saarland, one of Germany's smaller federal states.[13] While this research centre was set up in 1990, it was in 2000 that Vensys started a commercial spin-off operation. The company employs 180 people in Germany and had deployed 8,700 wind turbines (with a total capacity of 13,000 MW) by the end of 2012. Production takes place mainly in Germany, with licensed production sites also operating in Brazil, China, Egypt, India and Spain. In 2008, China's Goldwind company bought 70 per cent of the shares of Vensys.

The turbine technology offered by Vensys is based on a direct gearless drive yet with a solution (permanent magnet) different from the one promoted by Enercon. Also, the degree of vertical integration in production is comparatively lower; however, nacelles, generators, converter systems and electrical switchgear systems are produced in-house. Again, emphasis on offering full maintenance and repair service agreements to clients is a strong element of the business model.

Generally, the German wind energy industry is among the technological leaders worldwide and has played a pioneering role in innovation, particularly with regard to the gearless direct drive option, which experts expect to gain future market shares. The German market itself is dominated by one company (Enercon), which is unique in having maintained 100 per cent German ownership and a fully integrated production strategy without any component outsourcing. Most other companies are increasingly characterized by cross-country ownership patterns. The highest growth potential is seen in new offshore wind park development, yet this cannot be taken for granted given grid connection challenges and an emerging renewed emphasis on less costly onshore potential. In terms of business strategies, the development of comprehensive production-cum-services models is widely pursued to capitalize on sophisticated design and maintenance capabilities and expand the value proposition.

---

[13] In 2011 Vensys established an endowed chair for wind energy at the same university with a view to reciprocating for its earlier incubation.

2.3 Summary

In summary, the rise of the renewable energy sector in Germany has been spectacular in recent years and is predominantly a story of solar PV and wind industries driving the change. Renewables as a whole managed to increase their share in total gross electricity generation from an extremely low base of just 3 per cent in 1990, to 7 per cent in 2000, 10 per cent in 2005 and 23 per cent in 2012. In that year, wind and solar PV alone accounted for 12 per cent of the country's gross electricity generation and more than half (54 per cent) of electricity generated by renewables.

In recent years both wind and solar industries (the latter more than the former) have come under intense competitive pressure from Asian suppliers able to provide products based on mature technologies at a lower cost. The most dramatic example has been in the manufacture of solar PV cells and modules—a market segment with bleak prospects for German companies. In this context, the current debate around possible EU-imposed anti-dumping tariff measures is beset with immense overall risks of an escalating trade dispute and is unlikely to offer more than a temporary breathing space for German producers. Positive long-term prospects for both wind and solar will have to build on high-tech capabilities, innovation power and integrated manufacturing-cum-services solutions.

Without any doubt, the economic dynamics of renewables in general, and of wind and solar in particular, have been policy-induced. The various incarnations of the Renewable Energy Sources Act, as well as policy incentives related to R&D efforts, investment and financing have all played an important supportive role. The next chapter will take stock of these policy measures in greater detail.

Chapter 3: Policies in Support of Renewable Energy Promotion

3.1 General Renewable Energy Policies

In general, renewable energy promotion policies in Germany are built around the core concept of FiTs, complemented by dedicated renewables loan programs, as well as various types of support to R&D activities (direct funding, demonstration projects, innovation alliances etc.) as part of science and innovation policies. Neither local content policies nor government procurement or renewables purchase obligations (outside the EEG-FiT, which constitutes a de facto unlimited purchasing commitment) are in place at either the federal or the state level. The German renewables policy scenario can thus best be characterized as being a combination of a robust legal and policy framework, sustained funding of a diversified set of research institutions and an emphasis on price-based rather than quota-based investment incentives.

Accordingly, the policy schemes considered in this report include:

- The FiTs embedded in the Renewable Energy Sources Act (EEG).
- Various loan programs for renewable energy in general and specifically for solar PV and wind energy.
- R&D support through the Federal Energy Research Programme.
- Sector-specific innovation and cluster support programs.

Notwithstanding diverging opinions and assessments of German energy policy as such, there is a broad consensus on the pivotal role that federal government policies have played in triggering the growth of a renewables industry in the country. The main institutional players have been the Ministry for the Environment (BMU) and the Ministry for the Economy and Technology (BMWi). While the former is in charge of policies and regulations specifically geared at renewables, the latter has a cross-cutting mandate of promoting economic growth and innovation. As has become evident in the ongoing debates around the energy transition, at least two further ministries come into play: the Ministry for Infrastructure (BMVBS) with regard to issues of grid modernization and expansion, as well as the Ministry for Consumer Protection (BMELV) when it comes to the impact on consumers of changes in electricity tariffs.[14] This scenario of fragmented responsibilities has given rise to institutional rivalries and frequent calls for establishing a genuine Energy Ministry fully in charge of all dimensions of the energy transition. Another important institutional player is the Federal Grid Agency (BNA). Established in its current form in 2005, the BNA reports to the BMWi and, among other things, is in charge of grid planning and extension, ensuring competitive and non-discriminatory grid access, and certifying electricity fed into the grid.

As mentioned before, the Renewable Energy Sources Act of 2000 must be considered as crucially important, and its significance and impact cannot be overestimated. This is true both for the buildup and expansion of a German renewables industry in the last two decades and for its future development trajectory. Thus, this policy chapter will foreground the law's key building blocks and implementation arrangements.

---

[14] For the sake of simplicity, the names of Federal Ministries are used in abbreviated English versions coupled with the official German acronyms.

In terms of overall laws and strategic policy concepts (which will not be reviewed here in detail), reference should be made to:

- National Energy Concept 2010 (with subsequent post-Fukushima amendments of 2011). Concerning renewables, the concept calls for the rapid expansion of a wide range of renewables, a concomitant expansion of electricity grids and the development of storage technologies. Special emphasis is placed on both onshore and offshore wind energy expansion with total investment requirements estimated at €75 billion to boost national offshore capacity to 25 GW by 2030 (BMWi & BMU, 2010).
- Law on Energy and Climate Fund 2010. This fund is meant to finance a broad range of environmentally friendly technologies, as well as investments into energy efficiency and renewables. However, its endowment from two sources (profits from nuclear power operators and revenues from the ETS) has become highly insecure due to the nuclear exit and the fall in CO_2 prices.
- Integrated Climate Change and Energy Programme (2007/2008). This program encompasses a broad range of initiatives covering buildings, power plants, car emissions, combined heat and power generation, energy efficiency and renewables promotion.
- Energy Industry Act (2005, amended 2012). This federal law regulates grid management and expansion with special provisions for integrating renewable energy sources, including electricity labelling. The 2012 amendment addresses primarily grid planning issues for offshore wind management.

In addition to the Renewable Energy Sources Act, this chapter will cover other policy support schemes covering the entire renewables sector, as well as specific policy measures targeting either wind energy or solar PV for electricity generation.

Renewable Energy Sources Act (*Erneuerbare Energien Gesetz* [EEG])

In 1991, the first Electricity Feed-in Act (*Stromeinspeisungsgesetz*) was passed, which established the principle of FiTs.[15] However, the law provided for FiTs to be directly linked to retail electricity prices (so-called “premium FiTs”) thus subjecting them to market fluctuations. This caused a high level of uncertainty and made it difficult for business players to anticipate, and rely upon, long-term scenarios of commercial viability.

In 2000 the EEG addressed this shortcoming and became the central milestone of Germany’s new energy policy landscape. The EEG document is close to 100 pages and represents a comprehensive, complex and detailed legal instrument establishing not only financial entitlements, but also outlining intricate organizational and procedural arrangements. The law has been amended several times—in 2004, 2009, 2010 and 2011 and twice in 2012 (including a 2012 special amendment concerning solar PV). The following summary refers to the 2012 version.[16]

The EEG has the stated objectives “to facilitate a sustainable development of energy supply, particularly for the sake of protecting our climate and the environment, to reduce the costs of energy supply to the national economy . . . and to promote the further development of technologies for the generation of electricity from renewable energy sources.” It explicitly sets targets for a rapidly rising share over time of renewables in electricity supply (identical with those listed in Table 1). The EEG establishes three fundamental principles:

---

[15] The German word *Einspeisung* literally means “feeding in” and has been the origin of the term FiT, which since has become widely used internationally.

[16] Available at http://www.erneuerbare-energien.de/fileadmin/ee-import/files/english/pdf/application/pdf/eeg_2012_en_bf.pdf

- Guaranteed FiT levels covering a 20-year time horizon, which are energy source-specific (in some cases even further subdivided according to types of technologies or deployment conditions) and constitute a purchasing guarantee for unlimited volumes.
- Grid connection, transmission and distribution priority for electricity supplied from decentralized renewable energy sources.
- Burden sharing of additional costs by all electricity consumers through an electricity price surcharge (with exceptions in particular for energy-intensive manufacturing enterprises[17]).

More specifically, the FiT for onshore wind energy is currently set at a basic tariff of 4.87 €ct/kWh with 8.93 €ct/kWh for the first five years after commissioning an installation. Thereafter, the annual FiT reduction amounts to 1.5 per cent. Particularly favourable provisions apply for repowering and offshore installations:

- If the capacity of an existing wind installation is at least doubled through repowering, the FiT rate increases by roughly 10 per cent.
- While the basic rate for offshore installations is 3.5 €ct/kWh, the initial tariff for the first 12 years amounts to 15 €ct/kWh (or alternatively, 19 €ct/kWh for eight years). Also, more favourable FiTs are guaranteed for installations far off the coastline and in greater water depth.

The FiT for solar PV currently has a basic amount of 21.11 €ct/kWh on a degressive scale stipulating an annual reduction of 9 per cent and even higher annual reductions depending on the size of installations. Special, more favourable provisions apply to solar installations attached to buildings or noise protection/reduction walls.

It is worth mentioning that as a result of EEG amendments between 2010 and 2012, the FiT rates for rooftop installations came down from 47 €ct/kWh in 2008 to 24 €ct/kWh at the beginning of 2012. A similar FiT reduction (by approximately 50 per cent) took place for ground-mounted installations; however, in all cases it was not applied retroactively, but only for new installations.

Following intense political debate triggered by the unexpectedly sharp price decreases for new PV systems, a special PV solar amendment to the EEG took effect in April 2012. Its main features include:

- A one-off FiT reduction of 15 per cent coupled with future FiT rates ranging between 19.5 €ct/kWh for small roof top installations and 13.5 €ct/kWh for greenfield installations.
- A basic annual FiT reduction rate of 11.4 per cent (one per cent per month).
- The introduction of a corridor for the planned annual expansion capacity (2.5–3.5 GW) and a link between actual expansion and future FiT reduction rates (so-called “flexible ceiling”) with a maximum annual FiT reduction of 29 per cent.
- A maximum target capacity of 52 GW beyond which FiT for solar PV would cease to be paid.
- Transitional arrangements applying the previously applicable FiT regime for installations in advanced stages of planning.

---

[17] Defined as enterprises with a ratio of at least 14 per cent of electricity costs in gross value added. For such enterprises, a degressive pricing scale applies whereby only 10 per cent of the surcharge is levied for electricity consumption above 1 GW/h, 1 per cent above 10 GW/h and 0.05 per cent above 100 GWh.

The electricity surcharge amounts to €5.3 ct/kWh in 2013. The privileges granted to energy-intensive industries (exemption from electricity surcharge) effectively applied to approximately 20 per cent of total electricity consumption in 2012, with a growing tendency in 2013. At the same time, the 2012 EEG amendment introduced a requirement for enterprises consuming more than 10 GWh to undergo a certified energy audit (assessment of consumption and savings potentials) as a precondition for eligibility—without, however, introducing mandatory energy-efficiency targets to be met.

With a view to better integrating renewable energy into the electricity market, the 2012 EEG also introduced a so-called market premium. Under this provision, owners of renewables installations can sell electricity directly at market prices either to large users or to the national electricity exchange, and get the difference between the (lower) market price and the (higher) FiT reimbursed. They can also claim a management premium as compensation for any additional costs caused by direct marketing efforts. It is expected that, due to the commercial attractiveness of this option, in the medium term (2015 to 2017) more than 50 per cent of onshore wind energy and 10 to 15 per cent of solar PV will be marketed directly (*Bundesverband der Energie- und Wasserwirtschaft* [BDEW], 2013, p. 62).

In mid-2013, a fierce debate was raging in Germany on the impact and further adjustment needs of the EEG (Diekmann, Kemfert, & Neuhoff, 2012a). The trigger was the massive and unanticipated expansion of solar PV installations under EEG provisions. With PV panel prices down by more than 60 per cent over the last six years, the expansion of capacity exceeded government targets by a factor of two. As a result, solar PV alone was then responsible for more than 40 per cent of the electricity surcharge under the EEG, while it only accounted for 20 per cent (2012) of total renewable electricity generation. Against this backdrop, political negotiations are ongoing in the two parliamentary chambers (Bundestag and Bundesrat) on a federal government proposal to rein in future capacity expansion. Specifically, the proposal envisages the introduction of ceilings for future capacity growth, strong reductions of future FiT rates and an ambitious degression scale that, unlike in all previous amendments, would even allow for discretionary adjustments. The latter element has given rise to legal concerns in view of its possible retroactive impact.

BOX 1: DOES AN FIT CONSTITUTE A SUBSIDY?

The question of whether or not an FiT can be considered a government subsidy has been controversial so far and defies a simple yes/no answer (Wilke, 2011; European Court reports, 2001; EurActiv, 2012). Departing from the subsidy definition embedded in the WTO Agreement on Subsidies and Countervailing Measures leads to legal intricacies not to be dealt with here. The answer depends significantly on how an FiT system is being designed and implemented. Interestingly, two cases (Japan in 2010 and the EU in 2011) directed against the FiT system introduced by the Canadian province of Ontario, were taken to the WTO dispute settlement body—yet the issue at hand here was not the FiT itself, but the fact that its implementation is linked to local content provisions, which is not the case in Germany. However, even if legally considered a subsidy, an FiT would qualify as an actionable (as opposed to prohibited) subsidy, meaning it is allowed as long as it does not adversely affect the market share of foreign electricity producers.

In 2001, shortly after entering into force, the German EEG was challenged and its FiT system brought to the European Court of Justice. The Court ruled that the system did not constitute "state aid" and explicitly referred to its important contribution to protecting the environment and reducing the emission of greenhouse gases. The 2012 EEG amendment has also triggered a complaint on legal grounds. The EC is currently investigating possible competitive distortions caused by the generous exemptions for energy-intensive enterprises.

Apart from such ongoing debates about the legality of an FiT system, from an economic policy logic any FiT system interferes with a purely market-based price determination. It deliberately supports the development and deployment of renewable energy sources with the effect of mandating temporarily higher electricity prices. In this sense, for the purpose of the present study, it will be considered as an economic subsidy.

The EEG as the central policy measure in support of renewables has been complemented by a variety of loan programs operated by the Federal Bank for Reconstruction (Kreditanstalt für Wiederaufbau [KfW]), which in 2009 were consolidated into the current Renewable Energies Loan Programme summarized below. Typically, interest rates are set at 1 per cent to 2 per cent below prevailing market rates and credits are extended for a 20–year period. It is estimated that from 1990 to 2005, loan programmes for renewables totalled close to €11 billion with the majority (more than 80 per cent) supporting wind energy (Jordan-Korte, 2011, p. 79).

BOX 2: RENEWABLE ENERGIES LOAN PROGRAMME (KFW)

1. Background

The program started in 2009 when KfW consolidated various support programs for renewable energy investments into one single program, which consists of two parts: standard and premium. The standard program comprises loans for electricity from solar energy (PV), biomass, biogas, wind energy, hydropower and geothermal energy, as well as electricity and heat from combined heat and power stations. (The premium program offers loans and repayment bonuses for heat from renewable energies and is not covered here.)

Funding is provided in the form of long-term (up to 20 years), interest-reduced loans financing up to 100 per cent of investment costs, with a ceiling of €25 million (for the standard program)

1. Policy objective:

To ease funding constraints for all types of renewable energy investment

2. Recipients:

Private individuals, non-governmental organizations (NGOs), enterprises, municipalities, energy service providers, investment funds

Annual estimates (for the standard program):

2008: €2.8 billion
2009: €4.6 billion
2010: €8.9 billion
2011: €6.5 billion (2011 interest subsidy approx. € 0.3 billion)

Source: Lehr et al. (2012); KfW (n.d.).

Regarding R&D for renewable energy development, Germany possesses one of the most sophisticated networks of specialized research institutions worldwide. The national energy research program summarized below relies in particular on the Helmholtz institutes and centres. In addition, there are specialized Fraunhofer institutes,[18] such as the Institute for Wind Energy and Energy System Technology (IWES), the Centre for Silicon Photovoltaics (CSP) and the Institute for Solar Energy Systems (ISE), as well as dozens of dedicated university institutes.

With respect to R&D funding for wind and solar PV, it is not possible within the scope of this study to derive a complete and accurate quantitative picture of the volumes involved. Relevant funding is provided through a variety of channels with partly overlapping facilities and institutional arrangements. While the Federal Energy Research Programme (currently in its sixth version) plays a central role, it is complemented by core institutional budgets of a vast array of research institutions (partly within, partly outside the university system), as well as additional funding for dedicated research consortia and alliances—with often intersecting research budgets. Even within the Federal Research Programme itself there are special allocations for wind and solar PV-related research, yet also cross-cutting renewables programs that by their very nature cannot be disaggregated by technology. In addition, R&D funding is provided to a lesser amount by federal and state governments and foundations.

---

[18] The Helmholtz institutes and the Fraunhofer institutes receive roughly two thirds and one third, respectively, of their funding from public sources.

BOX 3: SIXTH FEDERAL ENERGY RESEARCH PROGRAMME

1. Background

The program was adopted in 2011. Entitled "Research for an Environmentally Sound, Reliable and Affordable Energy Supply," it represents the research backbone supporting the 2010 National Energy Concept. It is a joint program of four federal ministries coordinated by BMWi and aligned with relevant EU and International Energy Agency (IEA) programs. Research support is provided as limited project funding and/or long-term institutional funding. Total funding is €3.5 billion for 2011 to 2014, up 75 per cent compared to 2006 to 2009. The share of renewable energy research is planned to increase from 36 per cent (2011) to 43 per cent (2014). Within the renewables part, wind (both onshore and offshore) and solar PV remain top priorities. No data are available on specific funding amounts for wind and solar PV.

1. Policy objective

Generally, to contribute to achieving national energy and climate targets, enhance the leading position of German companies and widen technological options.

Specifically for renewables, to lower technology costs, strengthen German companies and optimize the energy system so as to cope with an increasing share of renewables.

2. Recipients:

Research institutes, universities, companies

Annual estimates (million €; renewable energy share in parentheses):

2011: 733 (266)
2012: 754 (285)
2013: 964 (402)
2014: 1,007 (431)

Source: BMWi (2011).

With a view to supporting medium-sized companies in particular, a renewable energy export initiative was established in 2002. Managed by the German Energy Agency (DENA) under the authority of BMWi as the lead ministry, it offers a wide range of services to renewable energy firms at the threshold of entering into export markets. These services comprise market information, partnership brokering, participation in fairs and exhibitions, and marketing efforts, etc.

3.2 Solar PV Policies

Solar PV energy has traditionally benefited from a variety of special support programs starting as early as 1991 with the five-year "1,000 roofs" initiative for solar panels, which was upscaled into a "100,000 roofs" program providing low-interest loans (with a subsidy element of roughly 25 per cent) from 1999 to 2003. Currently, loans for solar PV investments are part of KfW's general renewables loan program.[19]

In May 2013, a potentially very significant new program (described below in Box 4) was launched in support of fixed battery storage systems. While it is too early to gauge the ultimate impact of this program, it does send a clear signal of policy support to both households seeking enhanced grid independence and companies investing in new storage technologies.

BOX 4: SOLAR PV STORAGE LOAN PROGRAMME (KFW)

1. Background

This new loan scheme called "Storage" became operational in May 2013 and was launched jointly by KfW and BMU. It provides low-interest loans and repayment subsidies to new PV systems up to 30 kWp incorporating a fixed battery storage system and for retrofitting of batteries to PV installations commissioned after December 31, 2012. Up to 100 per cent of eligible net investment costs can be financed, with a maximum subsidy element of 30 per cent and cash incentive of up to €660 per kWp. Only technologically advanced, high-quality storage systems can qualify for support based on furnishing a conformity declaration. Loan periods are 5, 10 or 20 years with 1 to 3 years, respectively, of free redemption.

2. Policy objective:

To stimulate self-consumption of generated electricity and overall flexibility of integrating small-to-medium solar PV systems into the electricity grid

3. Recipients:

Companies and households using solar PV systems and feeding self-generated electricity into the grid

Annual estimates: €25 million for 2013

Source: "KfW and Federal Environment Ministry launch programme" (2013).

---

[19] The Market Incentives Programme (German acronym MAP)—initiated in 1999 and often cited in literature—is not aimed at solar PV. Within its remit, homeowners, small and medium-sized businesses and municipalities can seek upfront funding to reduce purchase prices for solar heat collectors, biomass-fired furnaces with automatic feed systems (such as wood pellets), firewood gasifiers and heat pumps.

BOX 5: INNOVATION ALLIANCE PV

1. Background

The Innovation Alliance PV was founded in 2010 as a joint initiative of the federal ministries for Environment and for Education and Research (BMU and BMBF). Through 26 innovation projects (at time of writing), it fosters alliances between various specialized research institutions and the solar business community. Innovation projects range from the reduction of material costs for PV systems to production process optimization and the development of new products. Emphasis is placed on broad issue-specific alliances in pre-competitive development stages and on bringing together all relevant players of the solar value chain. Project budgets range from €2.5 to €21.5 million with funding shares between 38 to 100 per cent. It is expected that this seed funding will trigger solar industry investments in innovative activities to the tune of approximately €500 million.

2. Policy objective:

To pool research and business expertise with a view to strengthening the long-term competitive position of the German solar PV industry

3. Recipients:

Project-based consortia of research institutions and business

Annual estimates: €100 million for 2010–2012; €50 million for 2013 (as part of the Federal Government Energy Research Programme)

Source: www.innovationsallianz-photovoltaik.de

BOX 6: SOLAR VALLEY *MITTELDEUTSCHLAND*

1. Background

Supported by the Federal Ministry for Education and Research (BMBF) since 2008, this initiative represents a cluster of solar energy stakeholders comprising more than 20 solar companies, 10 specialized research institutions, five universities, five colleges and three state-level ministries from the participating federal states of Saxony, Saxony-Anhalt and Thuringia. Cluster activities cover joint technology development efforts as well as solar-related education programmes. Three of the participating universities have formed a Solarvalley Graduate School for PV.

As of February 2013, the Solar Valley cluster employed 10,500 people in the solar PV industry and 2,500 people in related supplier industries.

2. Policy objective

To contribute to making solar power competitive as a source of electricity generation

3. Recipients

This is an open-ended, multi-stakeholder platform for collaboration

Annual estimates: Not available. In total: 98 projects with a combined budget of €120 million over five years.

Information source: www.solarvalley.org

3.3 Wind Energy Policies

The development of the German wind energy industry has benefitted from a variety of government support programs, in particular related to focused R&D programs seeking to stimulate technological innovation and breakthroughs, as well as dedicated loan facilities. The most significant of these support programs are briefly summarized below.

BOX 7: OFFSHORE WIND ENERGY LOAN PROGRAMME (KFW)

1. Background

The program started in 2011. It targets large-scale offshore wind projects within the Exclusive Economic Zone (EEZ) in the North and Baltic Seas. The interest rate is fixed for 10 years with co-funding of up to 70 per cent of total capital requirements; however, this is not to exceed €700 million per project.

1. Policy objective:

To speed up expansion of offshore wind energy capacity

2. Recipients:

All companies operating in the EEZ

Annual estimates: €0.54 billion for 2011

Source: Lehr et al., 2012; KfW, n.d.

BOX 8: RAVE – RESEARCH AT ALPHA VENTUS

1. Background

Supported by the Federal Ministry for the Environment (BMU), RAVE consists of a variety of research projects (geology, platform foundations, efficiency, remote sensing etc.) in connection with the installation and operation of the first German offshore wind farm Alpha Ventus. It is located 45 kilometres north of the island of Borkum next to the research platform FINO 1 and comprises 12 offshore wind turbines. With 267 GW of power generated in 2011, expectations were exceeded by 15 per cent. Fraunhofer IWES coordinates 33 individual research projects in a consortium involving 45 institutes and companies. The test site is equipped with extensive measurement instrumentation in order to provide all participating research projects with detailed data.

1. Policy objective:

To reduce the costs of offshore wind energy deployment in deep water

2. Recipients:

Participating research institutes and companies

Annual estimates: €50 million over several years

Source: Research at Alpha Ventus, 2010.

BOX 9: GERMAN OFFSHORE WIND ENERGY FOUNDATION

1. Background

Established in 2005 by Federal Ministry for the Environment (BMU), the foundation is engaged in research funding and coordination, knowledge sharing and advocacy. It also owns the licensing rights for the Alpha Ventus offshore test site. Ongoing research looks into new demands on harbours and shipyards relating to offshore wind energy.

2. Policy objective:

To expand the role of offshore wind energy and serve environmental and climate goals

3. Recipients:

A diverse range of public and private stakeholders

Annual estimates: not available

Source: Die Stiftung Offshore-Windenergie, n.d.

BOX 10: 250 MW WIND PROGRAMME

1. Background

The 250 MW Wind Programme of 1991 was an extension and upscaling of the earlier 100 MW Wind Programme initiated in 1989. It was operational until 2006 and from the outset was accompanied by an elaborate monitoring and evaluation component. The program was directly aimed at fostering piloting and demonstration projects for new wind turbine technologies (design and manufacturing). As such, it complemented basic and applied R&D with a view to promoting the commercial deployment of viable technologies. The program offered investment grants of up to 60 per cent of the total project amount. While open to foreign companies as well, about two thirds of funded projects originated from German wind companies. In total, the program supported close to 1,500 wind turbines with a combined capacity of slightly more than 350 MW.

2. Policy objective:

To foster the commercialization of new wind turbine technologies

3. Recipients:

German and foreign wind turbine manufacturers

Annual estimates: not available; total grants (1991 to 2005): €161 million

Source: Langniss, 2006.

Chapter 4: The Costs of Policies: The FiT and beyond

4.1 Introduction

The German FiT approach has become an "export success story" in itself, and, to date, has been replicated in essence (with variations in detail) in some 40 countries worldwide, including most EU countries, but also China and Japan. It continues to be widely recognized as a benchmark for effective policy design in support of renewable energy expansion. Therefore—and also in view of limited annualized data availability for the volume and terms of renewable energy loans, as well as R&D expenditures—this chapter will focus entirely on seeking to assess the cost-effectiveness of this policy instrument.

Particularly with regard to wind energy and solar PV, there is a perfect nexus between capacity expansion and electricity generation on the one hand and the provision of FiT on the other. While in 2011 (the latest year for which data are available) 85 per cent of all renewable electricity generation actually benefitted from FiT support (in the case of hydro power, the ratio is as low as 28 per cent due to the non-eligibility of large-scale installations), the ratios for both onshore and offshore wind, as well as solar PV, are indeed 100 per cent (BDEW, 2013, p. 20). As Table 6 clearly shows, before the first Electricity Feed-in Act of 1991, hydropower dominated the renewables scene, while wind and solar PV were virtually non-existent. In stark contrast, by 2000 wind energy already accounted for almost one quarter of renewable electricity—a share that is now up to around 40 per cent—whereas solar PV picked up only much later. It is thus plausible to assume a strong causality running from the availability of FiT to solar and wind capacity expansion, with the latter being an intended consequence of a policy-induced diversification strategy towards renewable sources of energy.

While there has been a host of other policy measures and support schemes, most notably in terms of dedicated R&D facilities and publicly funded innovation programs, these would not have been sufficient to trigger the high-risk investments into new installations. These investments did require stable investment conditions with reliable revenue forecasts as provided by the FiT; meanwhile the commercial scaling up of wind and solar capacities has driven prices down.

TABLE 6: COMPOSITION OF ELECTRICITY GENERATION FROM RENEWABLE SOURCES (1990, 2000, 2005, 2011) (%)

	1990	2000	2005	2011
Hydro	91.1	63.4	31.5	14.7
Wind	0.4	24.3	43.8	39.7
Solar PV	-	0.2	2.1	15.7
Others	8.5	12.1	22.6	29.9
Total	100	100	100	100

Source: Author calculations based on AGEE-Stat (2012).

In this chapter, various methodologies will be applied to measure the additional macroeconomic cost of wind and solar PV energy production induced by the FiT, and the cost of the EEG surcharge, which additionally includes distributional effects. This differentiation is essential, although it is not always made explicit in the literature. The additional macroeconomic costs arise from the fact that electricity production from most renewable sources is still more expensive than from conventional sources. These costs can be measured as the difference between the levelized cost of electricity (LCoE) generated from renewable sources and the LCoE of non-renewable sources.[20] If an FiT is to induce investments in renewable energy, it needs to cover these costs and a reasonable markup as compensation for the added risks of such investments. The markup, however, does not add to macroeconomic costs. It is rather a redistribution of funds from electricity consumers to producers of renewable energy. The EEG surcharge thus includes an additional component, which cannot be counted as a macroeconomic cost. It may, however, have strong distributive effects. In the case of Germany, these are reinforced by the exemptions granted to energy-intensive enterprises, which raise the burden on the remaining consumer groups.

We will start with presenting approaches to calculating the annual FiT-related costs,   proceed to the aggregation of these costs over the entire 20-year FiT period and,, finally contrast these numbers with actual macroeconomic costs. We will furthermore place the subsidy costing issue in the broader context of energy markets, which are massively distorted and subject to environmental and security externalities that need to be factored in.

4.2 Annual FiT-Related Differential Costs

Table 7 presents the shares of the FiT-related differential costs attributable to wind and solar PV, respectively. They are calculated in accordance with the following methodology (BDEW, 2013):

- Based on the average annual FiT paid (in € ct/kWh) for each energy source and the volume of electricity fed into the grid, the total amount of paid-out FiT is calculated and compared with the prevailing electricity market prices, thus arriving at the differential costs.
- A weighting scheme for individual energy sources is applied with a view to addressing fluctuating market prices and temporal feed-in patterns (e.g., peak feed-in of solar PV electricity around midday, corresponding with peak demand patterns and thus high electricity spot market prices, in contrast to more irregular wind feed-in times).[21]
- The "market premium" option introduced in the 2012 EEG amendment is reflected in the calculation.

---

[20] LCoE is calculated on the basis of the total expenses (investment, operation, maintenance, replacement, insurance, etc.) of a project over its entire life span. These are discounted to the same reference point and divided by the present values of the electricity output. For a critique of various concepts of LCOE and grid parity see Bazilian, et al. (2013).

[21] The weighting factors applied have changed over time. In 2013, the factor for solar PV was 98 per cent while for wind energy it was 89 per cent.

TABLE 7: ANNUAL DIFFERENTIAL COSTS FOR WIND AND SOLAR PV UNDER EEG-FIT (2005–2013)

	ONSHORE WIND	OFFSHORE WIND	SOLAR PV
2005 - differential costs €ct/kWh - differential costs € million	5.24 1,428	- -	49.21 631
2006 - differential costs €ct/kWh - differential costs € million	4.49 1,379	- -	48.60 1,079
2007 - differential costs €ct/kWh - differential costs € million	3.95 1,569	- -	47.07 1,447
2008 - differential costs €ct/kWh - differential costs € million	3.29 1,337	- -	44.71 1,976
2009 - differential costs €ct/kWh - differential costs € million	1.92 739	8.00 3	41.10 2,704
2010 - differential cost €ct/kWh - differential costs € million	5.24 1,965	11.39 20	38.26 4,472
2011 - differential costs €ct/kWh - differential costs € million	5.19 2,338	11.01 63	34.22 6,618
2012* - differential costs €ct/kWh - differential costs € million	4.14 2,010	10.46 142	31.06 7,478
2013* - differential costs €ct/kWh - differential costs € million	5.21 2,864	13.81 344	25.06 8,690

**Projection*

Source: BDEW (2013, pp. 37–38).

From Table 7, it can be seen that the combined projected differential costs for wind energy and solar PV promotion amount to close to €12 billion in 2013—almost double the amount of 2010. Moreover, Table 7 clearly shows a pattern of a relative increase in the weight of solar PV within the total differential cost scenario: between 2005 and 2013, the ratio of total solar PV subsidies to total onshore wind subsidies (in € million) rose from 0.4 to 3.0—from less than half to three times as much. This increase coincided with a narrowing of the same ratio in terms of ct/kWh: in 2005, the average feed-in differential tariff for solar PV was 9.4 times higher than for onshore wind; in 2013 this factor was down to 4.8—the obvious explanation being the FiT reductions triggered by the phenomenal cost decreases and subsequent growth of solar PV electricity generation. While the latter grew by a factor of 27, wind-generated electricity just doubled in volume from 2005 to 2013.

Table 8 delivers the same message by presenting the shares of solar PV and wind energy, respectively, in total differential costs. It demonstrates that the relative importance of wind energy as a subsidy recipient has decreased over time whereas solar PV experienced a rapid increase, peaking at 58 per cent in 2012.

TABLE 8: PERCENTAGE SHARE OF SOLAR PV AND WIND ENERGY IN TOTAL DIFFERENTIAL COSTS UNDER EEG-FIT (2005-2013)

	2005	2006	2007	2008	2009	2010	2011	2012	2013
Share of solar PV	22.9	32.4	33.4	41.0	51.0	47.4	54.8	58.1	54.3
Share of wind	51.7	41.4	36.2	27.8	14.0	21.0	19.9	16.7	20.1

Source: Own calculations based on BDEW (2013, pp. 37–38).

The absolute amounts of EEG surcharge per MWh generated from different sources are summarized in Figure 3.

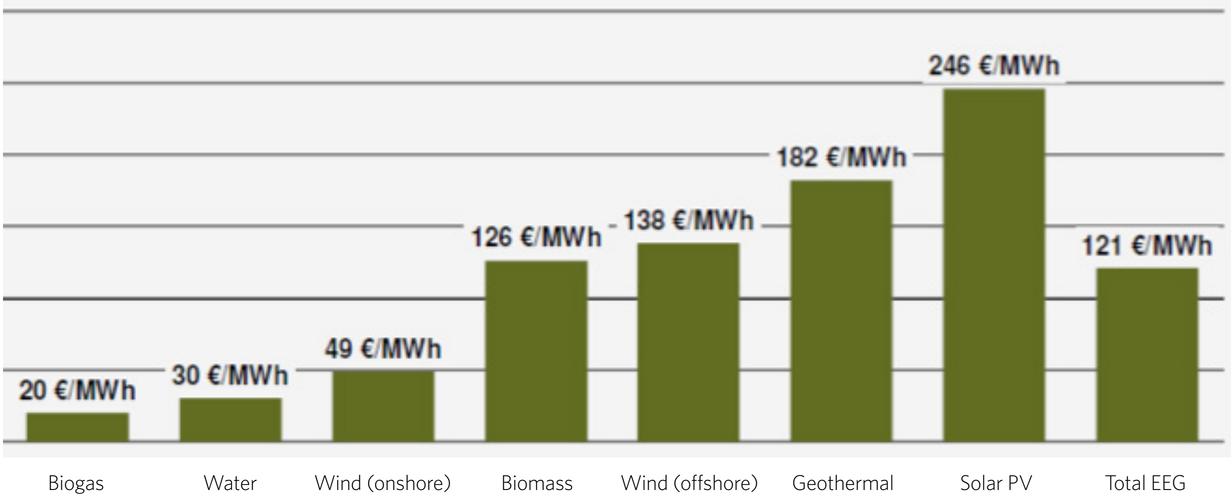

FIGURE 3 EEG-ELECTRICITY SURCHARGE BY ENERGY SOURCE (2013)

Source: BDEW (2013, p. 55). Note: Differences in numbers as compared to Table 8 are explained by the inclusion of avoided grid charges.

However, a holistic look at the composition of electricity prices is necessary with a view to putting the EEG-surcharge in perspective. Electricity prices basically result from the costs of generation, transmission and distribution; various state taxes and levies; and finally the EEG-surcharge. In 2013 the latter accounted for 22 per cent of electricity prices for households and 35 per cent for industrial consumers. In 2005 the shares were 5 per cent and 7 per cent, respectively. Thus, while contributing between one fifth and one third to total prices, the EEG surcharge has increased rapidly in recent years to become a pronounced cost factor.

In the context of this growing relative weight, the distributional impact of the EEG-surcharge has recently become a controversial subject. In 2013 the EEG apportionment for electricity consumers—that is to say, the rise in their electricity price attributable to the FiT—amounts to 5.3 ct/kWh. Private households (with an electricity consumption share of roughly one quarter) have to bear 35 per cent of the surcharge while the industrial sector (with a consumption share of almost 50 per cent) accounts for only 30 per cent of the surcharge—largely a result of exemptions for energy-intensive industries. However, the financial burden to be borne by households is easily overestimated. A recent study concludes that in a scenario of a further 1.3 ct/kWh increase of the electricity surcharge by 2015, additional expenditures would amount to just 0.1 per cent of the average disposable household income, although with a slightly regressive effect (Lehr & Drosdowski, 2013).

4.3 "Net Real Cost" of Solar PV and Wind Energy Promotion

Building upon the differential cost analysis presented above, attempts have been made to calculate the "net present cost" of renewable energy promotion through the EEG-FiT system. The method employed is based on anticipating the total support volume of eligible capacities over the 20-year period of their subsidization.[22] The ensuing controversy in the scientific community has involved two leading German research institutes, the Rheinisch-Westfälisches Institut für Wirtschaftsforschung (RWI) and the Wuppertal Institute for Climate, Environment and Energy. This ongoing methodological debate has brought to light fundamental differences in the framing and measurement of the cost-effectiveness and distributional effects of renewable energy promotion policies, which will be addressed below. Before doing so, the results of the RWI study will be summarily presented.

The RWI study was conducted in 2009 and presented in various publications (the summary here is based on Frondel, Ritter, Schmidt, & Vance, 2009). The study uses technology-specific electricity generation and technology-specific differential costs (difference between FiT and market prices at the power exchange). It assumes a high-price scenario for the electricity price. However, as the study rightly points out, the uncertain development of future electricity prices is not a critically sensitive assumption for estimating the subsidy element given that in particular for solar PV, the FiTs are far above market prices. Table 9 provides a consolidated presentation of the results.

TABLE 9: NET REAL COST OF EEG-FIT PROMOTION FOR SOLAR PV AND WIND ENERGY (€ BILLION AT 2007 PRICES)

	SOLAR PV	WIND ENERGY	
		SCENARIO 1*	SCENARIO 2*
2000	0.559	5.884	3.320
2001	0.442	2.100	1.171
2002	0.563	3.281	1.808
2003	0.897	1.645	0.899
2004	1.913	2.906	1.540
2005	6.027	0.603	0.328
2006	7.164	0.990	0.585
2007	8.969	1.982	1.276
2008	8.409	0.389	0.274
2009	9.032	0.450	0.275
2010	9.296	0.299	0.196
Total	53.272	20.529	11.672

** Assuming that higher FiTs granted for initial five-year period are extended over 20 years.*
*** Assuming that higher FiTs end after initial five-year period.*

Source: Compiled from Frondel, Ritter, Schmidt, & Vance (2009, Tables 4–6).

---

[22] For each annual cohort of installed capacity, the expected electricity market prices are subtracted from the FiT and the resulting net cost is multiplied by the anticipated amount of electricity produced. This is done for the entire subsidy period of 20 years.

The overall result of net total costs in the range of €65 billion (Wind Energy Scenario 2) and €74 billion (Wind Energy Scenario 1) has given rise to serious criticism, in particular from the Wuppertal Institute (Lechtenböhmer & Samadi 2011). Specifically, the following counter arguments were put forward:

- Technical errors regarding solar PV power generation over the 20-year period and concerning the size composition of installed capacities. Adjusting for these alleged errors would reduce the costs by 6 per cent.
- More fundamental flaws in terms of insufficient consideration of the "merit order" effect[23] and non-inclusion of continued electricity generation benefits after expiry of the 20-year support period.
- In addition, a total lack of discounting future costs, which would be required to derive a reasonable estimate of the net present cost of subsidies.

Additional adjustments for these factors would lead to a total cost reduction by as much as 30 per cent (assuming Wind Energy Scenario 2) or put differently: the RWI calculations would imply an overestimation by as much as 42 per cent.

The above controversy alone vividly demonstrates the extent to which renewable energy subsidy assessments are fraught with intricate methodological challenges. Moreover, the debate is often influenced by ideology or special interests, and distributional effects are frequently confused with actual macroeconomic costs. As BDEW (2013, p. 45) rightly points out, the distributional effects have no (or, at most, indirect) effects on macroeconomic costs. A sober assessment of macroeconomic costs, however, is vital for the assessment of the efficiency of the support system in place. Moreover, some studies represent an unacceptably narrow framing of the subsidy issue itself—they completely disregarding broader systemic dimensions, as well as externalities. In what follows, we will thus summarize findings on both macroeconomic costs and systemic effects.

4.4 Macroeconomic Costs and Systemic Effects

Several recent studies have attempted to do justice to the broader systemic costs and benefits of renewable energy sources and to factor in their multidimensional impact on energy, environmental and economic objectives. One significant exercise was undertaken jointly by researchers from four German institutes: Gesellschaft für Wirtschaftliche Strukturforschung (GWS), Fraunhofer Institute for Systems and Innovation Research (ISI), Deutsches Institut für Wirtschaftsforschung (DIW) and Institut für ZukunftsEnergieSysteme (IZES). The results are briefly summarized below (Lehr et al., 2012).

The study adopts a comprehensive approach and seeks to measure the costs and benefits of renewable energy in three broad dimensions: system-related effects (all costs and benefits caused by the consumption and protection/saving of resources), distributional effects (e.g., the redistributed burden sharing through the EEG electricity surcharge) and broader macroeconomic effects (e.g., investments, employment). As the EEG-FiT surcharge and its distributional effects were already covered above (see in particular Table 7) and employment effects will be addressed in Chapter 5, we focus here on the system-related effects. These include the additional macroeconomic cost of electricity generation from renewables, which arise from the fact that most renewables still feature a higher LCoE than conventional energies (direct costs) and that they require additional activities such as balancing fluctuations in supply (indirect costs). The costs are typically lower than the FiT surcharge, since the latter includes

---

[23] While the specific level of the "merit order" effect is subject to debate, in general this effect takes into account the impact on market price levels caused by electricity generated and fed into the grid by renewable energy sources. By virtue of their low marginal costs and availability at peak times (in particular solar PV), renewable electricity sources can tangibly push down high peak electricity prices.

an additional subsidy element to cover technology risks and thus incentivize renewable energy investments. The subsidy element is not part of macroeconomic costs since it constitutes a redistribution from electricity consumers to producers of renewable electricity. While this can lead to a high financial burden on consumers, it is cost-neutral from a macroeconomic perspective.

The system-related effects (Lehr et al., 2012) have been calculated separately for electricity and heat without, however, providing a further disaggregation by energy sources. More specifically, the following system-related costs and benefits have been identified for electricity generation from renewables (based on preliminary data for 2011):

- Additional costs composed of:
  - Direct additional costs based on the difference between levelized cost of renewable electricity and applicable market prices[24] (€9.3 billion).
  - Balancing costs in terms of detailed forecasting of renewables power supply and adapting to forecast errors (€0.16 billion).
  - Grid costs related to necessary transmission grid extensions and offshore grid connections, pro-rated for renewables and with annuities for investments assuming a 6.5 per cent interest rate and a life span of 40 years (€0.13 billion).
  - Transaction costs attributable to additional staff in various relevant institutions (€0.03 billion).
- Additional environmental benefits encompass costs for avoided damages from GHG emissions and other airborne pollutants and are calculated on the basis of source-specific emission and substitution factors as well as estimates for damage costs (€8.0 billion).[25]

Hence, in effect, for 2011 additional system-related costs (i.e., not reflecting the FiT subsidy as a distributional effect) in the order of €9.6 billion are juxtaposed with additional benefits in terms of avoided environmental costs amounting to €8.0 billion.

4.5 Subsidies for Renewable and Conventional Energy Sources: A Comparison

Having addressed the environmental benefits of renewable energy promotion, the next logical step is a comparative analysis and costing of subsidies granted to renewable energy on the one hand and conventional energy on the other.

An attempt was made in a 2012 study to arrive at a comprehensive account of all subsidies provided over time to the different sources of energy (Greenpeace & BWE 2012). The results are aggregated in Table 10 and are largely self-explanatory. According to this study, in absolute amounts renewables have received fewer subsidies than all other energy sources with the exception of natural gas. When it comes to subsidies per unit of electricity generated, [26]renewables are roughly at the same level as coal. It is only since 2007 that the subsidies per unit of electricity generated have been higher for renewables than for coal.

---

[24] Lehr et al. (2012, p. 9) claim a lack of data necessary for the calculation of fossil fuel LCoE. They thus develop an alternative calculation scheme in which they replace the fossil fuel LCoE with an "applicable price," which reflects the market price of electricity at different voltage levels and from different fossil fuels.

[25] Avoided damages are multidimensional (health, biodiversity, yield losses, etc.). Their calculation has to rely on complex models and cannot be determined with certainty. The aggregate figure of €8 billion assumes damage costs of €80/tonne for CO_2, while for airborne pollutants it relies on the damage cost assessment of the EU NEEDS project.

[26] The approach used here differs from the EEG surcharge, which has the total amount of electricity as a basis while the figures here relate specifically to the amounts of electricity generated from the respective energy sources.

TABLE 10: SUBSIDIES PROVIDED TO VARIOUS ENERGY SOURCES, 1970–2012

	TOTAL STATE SUBSIDIES (€ BILLION)*	SUBSIDIES FOR ELECTRICITY GENERATION (€ BILLION)*	(€ CT/KWH)*
Hard coal	331	177	3.3
Lignite	87	65	1.3
Nuclear	213	187	4.0
Natural gas	8	1	0.3
Renewables	67	54	3.4

**In 2012 prices.*

Source: Compiled from various tables in Greenpeace & BWE, 2012.

4.6 Summary

The various quantitative assessments presented above of the costs and distributional effects associated with the promotion of renewable energy sources in Germany demonstrate the extent to which the debate has remained controversial, is fraught with methodological intricacies and is directly linked to (and at times abused by) vested political interests.

In general, there is a myth prevalent in much of the public discourse that renewable energies are massively subsidized and given preferential treatment over conventional energy sources. While this may well be justified as part of low-carbon technology development policies (a question that will be discussed in chapter 6), the notion itself is misconstrued and needs to be dispelled.

In essence, a fundamental visibility bias is at work here. While the subsidies for renewables are highly transparent and, in the case of the EEG-FiT, ultimately appear as electricity surcharge on the power bill of end consumers, subsidies for conventional energy sources are embedded and de facto hidden in state budgets. This applies not only to tax incentives, but more importantly, to the direct provision of infrastructure (grid construction and expansion) and even the costly search and management process of nuclear waste disposal sites.

Chapter 5: The Impact of Policies

The preceding chapter presented various approaches to measure the costs of policies in support of promoting renewable energy sources. These costs have proven to be considerable as evidenced by the rising share of the FiT-induced electricity surcharge in total electricity prices (although not higher than the subsidies paid per unit of electricity generated from coal and nuclear power). We now proceed to identifying the positive impact of support policies. What have been the benefits generated in terms of building up new competitive industries, creating employment, fostering innovation, enhancing energy security and contributing to fighting climate change? Only after having assessed both the costs and benefits of policy interventions in favour of renewables will it be possible to meaningfully assess the question of cost-effectiveness.

Again, in counterfactual terms, the underlying assumption is that without the policy push through the EEG and its generous technology-specific FiT provisions, the foundation for creating a sizable and dynamic renewables industry in general, and wind and solar PV energy in particular, would not have existed—that is to say, we are looking at a case of directly policy-induced market creation and growth (Haas, Panzer, Resch, Ragwitz, Reece, & Held, 2011).

In its general approach, Chapter 5 will be factual and, to the extent possible, quantitative in nature. It aims at a sober stock taking of policy impact. Broader issues of the rationale and conceptualization of green industrial policies will come to the fore in Chapter 6.

5.1 Competitiveness

The notion of competitiveness is one of the most fundamental concepts in economics. However, exactly how to define and measure competitiveness and how to delineate its meaningful remit has remained highly controversial, in particular when moving up from competing firms to competing locations, sectors or entire economies and, for that matter, nations. Famously, Krugman (1994) went as far as branding competitiveness as a "dangerous obsession" of policy-makers. This may indeed apply to much of the popular debate and its oversimplifications, yet it does remain a valid concern—economically and politically—to ascertain how goods produced in a country can stand the test of international market acceptance and how they fare in relation to the same goods produced elsewhere.

This section reviews the competitiveness of the German wind energy and solar PV industry. It does so by relying on commonly used competitiveness indicators. In view of some conceptual deviations in the literature, it is necessary to specify the exact definition of the terms used here. We will present three indicators:

- World market share: Defined as the share a country has in world exports for a given product.
- Revealed export advantage (relative world trade shares): This indicator compares the world export share of one product to that of all products for a given country. A positive value indicates that the product (or technology) has a superior competitive position compared to the entire export portfolio of a country.[27]
- Revealed competitive advantage (RCA)[28]: This indicator also factors in imports and compares the export-import ratio of one product to that of all products for the same country. A positive value is associated with a competitive advantage.

---

[27] The values of revealed export advantage and of revealed competitive advantage can vary hugely and theoretically reach infinity. In order to be able to present the values better in graphs, we "normalize" the values, using the *tanh* function (tangens hyperbolicus), multiplying the number by 100, and using the *ln* (logarithmic) function. In this approach, positive numbers indicate a competitive advantage. See also Eichhammer & Walz (2009) for with data coverage up to 2008.

[28] This differs from Balassa's original concept of revealed comparative advantage, which is solely based on export performance.

In terms of data sources, we rely on the UNCOMTRADE database.[29] The product nomenclature used originates from the Harmonized System (HS 1996), which is available at the 6-digit level. Specifically, for wind energy and solar PV, it offers the following two product groups:

- 850231: "Other generating sets—wind powered" (referred to below as wind converters).
- 854140: "Photosensitive semiconductor devices, including photovoltaic cells whether or not assembled in modules or made up into panels; light emitting diodes" (referred to below as solar PV).

Two caveats are in order:

First, it needs to be understood that the RCA approach of measuring competitiveness cannot discriminate between specialization patterns rooted in structural economic determinants (factor endowments, productivity, etc.) and those caused by trade policy interventions. For instance, a country's temporary recourse to import restrictions or export dumping practices would translate immediately into an improved RCA value.

Second, in a few cases annual fluctuations of country-specific export and import data are of such an immense magnitude that doubts arise as to their accuracy. However, UNCOMTRADE data cannot be verified here and must be assumed as being correct.

With these reservations in mind, the figures presented below lead to the following broad results.

Wind Converter Competitiveness

Figures 4 to 6 send the resounding message of the buildup over time of a highly competitive German wind converter industry. Between 2004 and 2012, its export share in the global market surged from just 10 to almost 50 per cent, thus assuming the position of leading export country. Background data point to a staggering export growth of 65 per cent from 2011 to 2012. The low world market share before 2005 is explained by the fact that in those years Germany represented a lead market for wind energy—accounting for 45 per cent of wind converter installations worldwide in 2002 (down to 7 per cent in 2005). The pioneering FiT introduction had created such a strong domestic market pull that early export efforts were effectively stifled. A similar pattern can be observed for both the relative export advantage and the revealed competitive advantage: for both indicators, values increased sharply in 2005 and kept growing in the period up to 2012.

In terms of comparator countries, the recent sharp growth in China's market share is to be noted, as is the rapid and consistent loss of market shares by Denmark.

---

[29] Available at: www.wits.worldbank.org/WITS/WITS/Restricted/Login.aspx

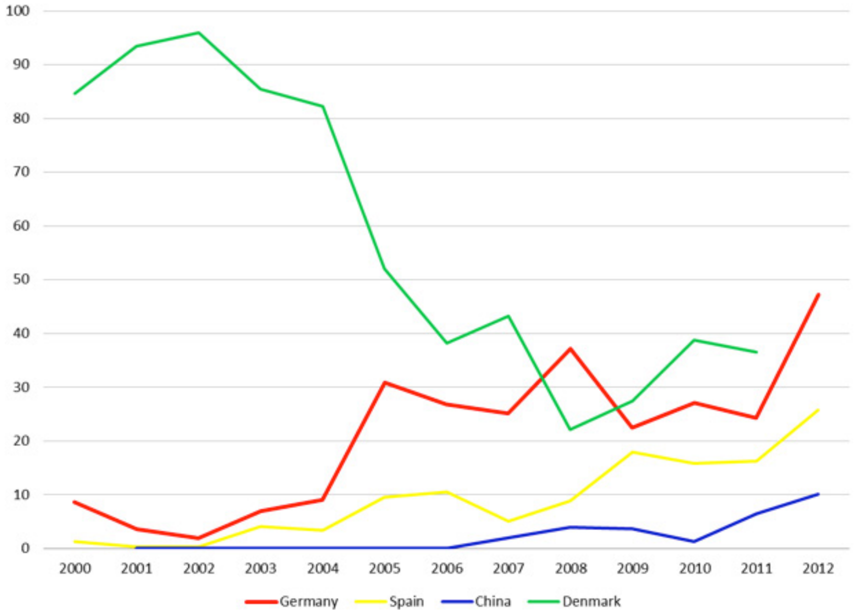

FIGURE 4: WIND CONVERTERS: WORLD MARKET SHARES BY COUNTRY, 2000–2012 (PERCENTAGE)

Source: Author calculations based on UNCOMTRADE.

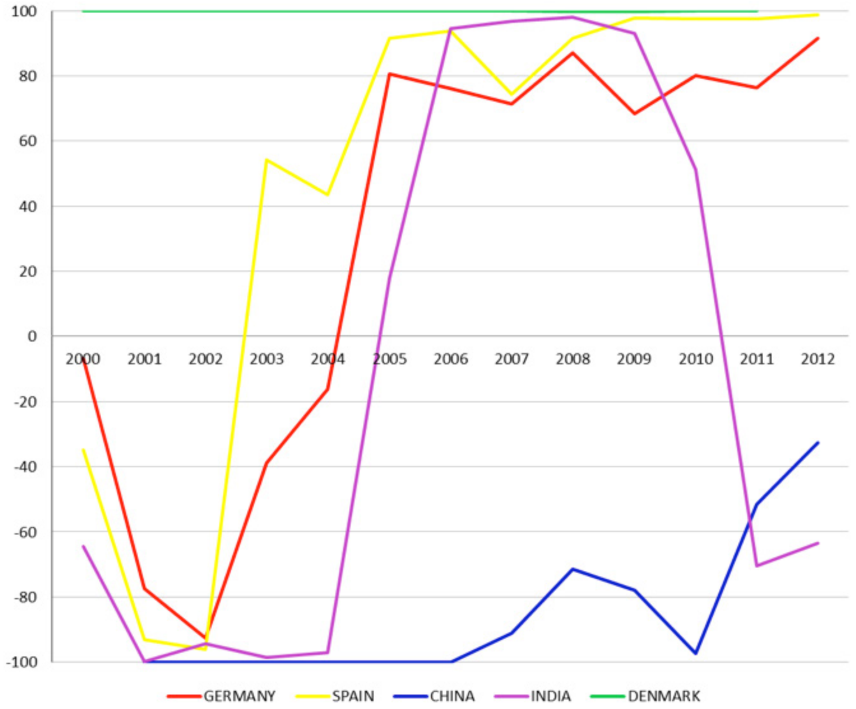

FIGURE 5: WIND CONVERTERS: RELATIVE EXPORT ADVANTAGE BY COUNTRY, 2000–2012

Source: Author calculations based on UNCOMTRADE.

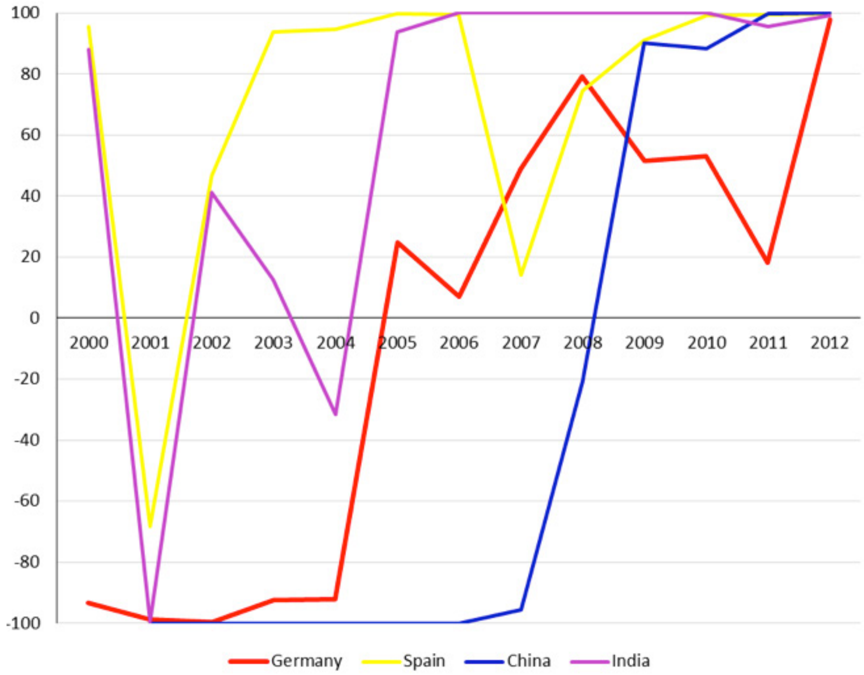

FIGURE 6: WIND CONVERTERS: REVEALED COMPETITIVE ADVANTAGE BY COUNTRY, 2000–2012

Source: Author calculations based on UNCOMTRADE.

Beyond the aggregate data presented in the charts, industry analysts underline the particularly strong competitive position of German companies when it comes to offshore turbines (and offshore wind parks in general), as well as large-scale onshore turbines above 5 MW capacity. A particular driver of competitive strength originates from a classical technology cluster constellation in the four Northern states of Lower Saxony, Schleswig-Holstein, Bremen and Hamburg. This so-called North Western Region Wind Power Cluster has grown into a densely interconnected web of more than 300 partners—comprising globally leading turbine manufacturers, specialized component suppliers, wind park operators, local governments and cutting-edge research institutions.[30] The cluster boasts some of the industry's major innovations (e.g., the development of the 5 MW offshore turbine and the offshore test site Alpha Ventus). At the same time, the wind cluster also owes some of its success to the long-standing track record of Germany's engineering, machinery and power sectors in general. Without the foundation of highly advanced manufacturing capabilities and skills across a whole range of industries, the German wind energy sector would not have been able to achieve global technological leadership. Arguably, the North Western wind cluster represents an internationally unique level of sophistication and comprehensiveness, with business players along the entire value chain exhibiting a high intensity of interactions based on shared ambitions and quality standards. The cluster represents a genuine public-private partnership and is co-funded by state resources and business membership fees.

---

[30] For details see www.windpowercluster.com and the case study by Boeckle, Dua, Henriques, Simon, & Tronci, 2010.

Solar PV Competitiveness

The global solar PV market, even more so than other renewable energy markets, is a highly political market shaped by trade patterns that are subject to significant government interventions. The recent EU-China trade dispute around subsidized solar panel exports and alleged dumping practices bears testimony to this feature. Hence, analysis revealed competitive advantages must be seen with this caveat in mind.

Figures 7 to 9 clearly demonstrate the relatively lower international competitiveness of the German solar PV industry compared to the German wind energy industry. A temporary increase in the world market share up to 2008 (15 per cent) could not be sustained: in 2012, this share fell back to its pre-2005 level of below 10 per cent. Background data show that German exports of solar PV were almost cut in half between 2010 (US$8.1 million) and 2012 (US$4.5 million). However, despite a growing gap between domestic demand and supply capacity, the export share of Germany's solar PV products has been rapidly growing (Barua, Tawney, & Weischer, 2012).

Similarly, a relative export advantage built up between 2005 and 2008 turned into a disadvantage again in 2012. At the same time, we can witness a consistently revealed competitive disadvantage over the entire period from 2000 to 2012.

In terms of comparator countries, the spectacular rise of China stands out. By 2012, the country was in the leading position for all three indicators presented here.

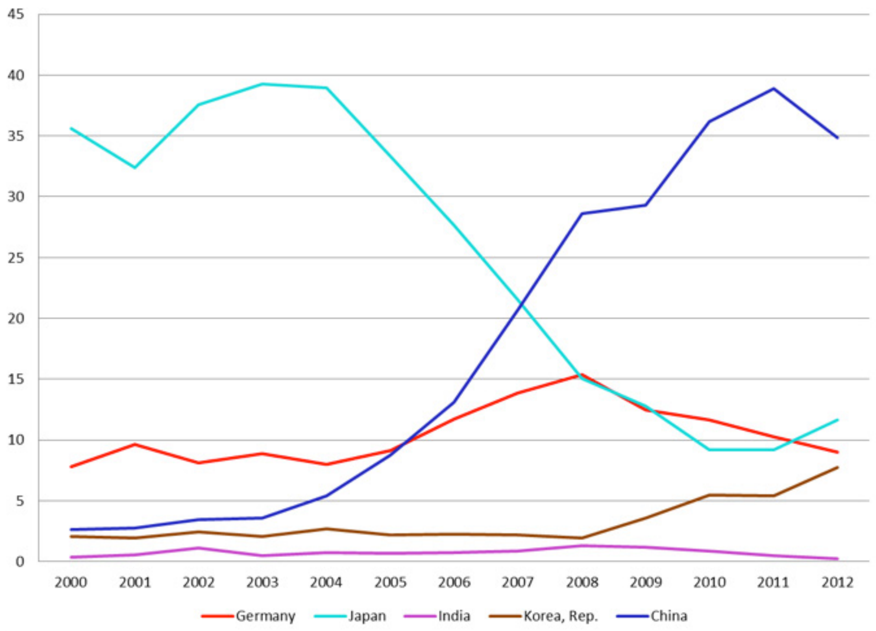

FIGURE 7: SOLAR PV: WORLD MARKET SHARE BY COUNTRY, 2000–2012 (PERCENTAGE)

Source: Author calculations based on UNCOMTRADE.

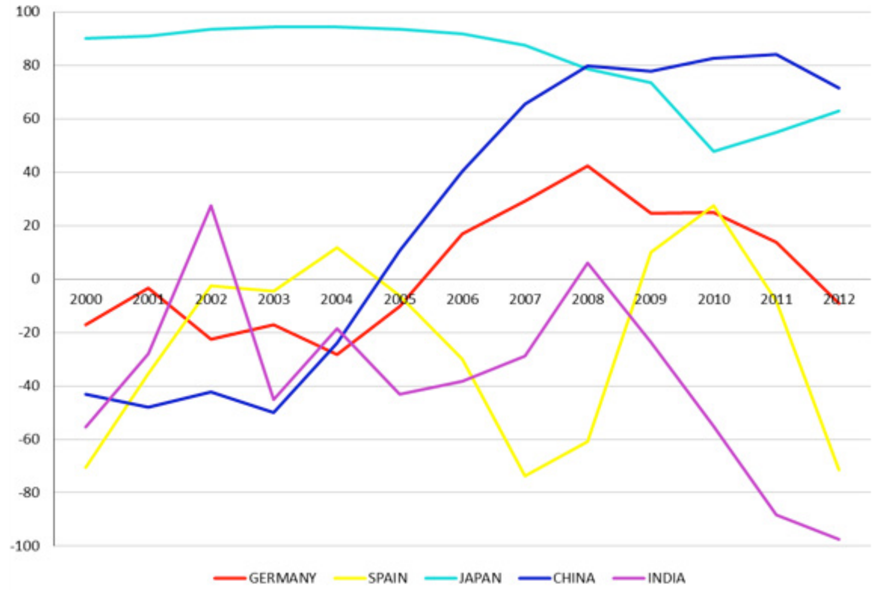

FIGURE 8: SOLAR PV: RELATIVE EXPORT ADVANTAGE BY COUNTRY, 2000–2012

Source: Author calculations based on UNCOMTRADE.

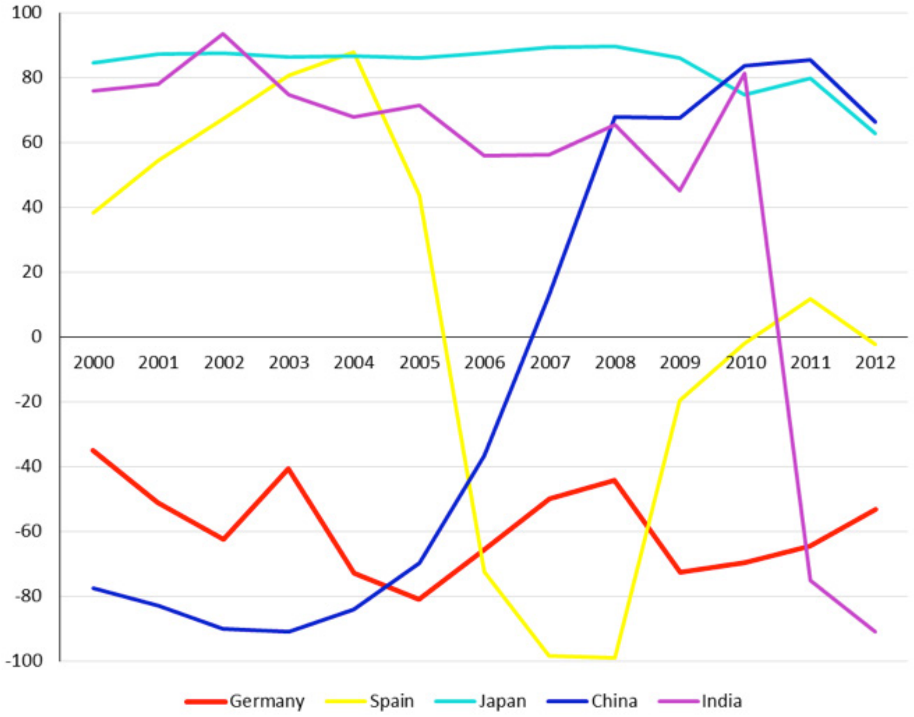

FIGURE 9: SOLAR PV: REVEALED COMPETITIVE ADVANTAGE BY COUNTRY, 2000–2012

Source: Author calculations based on UNCOMTRADE.

Beyond the aggregate data presented in the charts, the strong competitive position of German PV system component manufacturers and equipment suppliers must be emphasized. Data for 2011 show that the share held by German firms in the global market for specialized PV equipment was as high as 50 per cent, while the market share of PV inverters (converting the direct PV cell current into alternating grid current) stood at 35 per cent (GTAI, 2013a, fact sheets). With a share of approximately 25 per cent, the German company SMA Solar is the world market leader for inverters. However, the company has recently been suffering from overcapacity and had to announce significant job cuts in the first quarter of 2013 (see also the company profile in section 2.1).

In general, the solar PV industry is characterized by a rising share of non-module components in the value chain. For European producers, the relative importance of modules has decreased from around 70 per cent of the entire PV system value in 2007, to less than 50 per cent in 2012. The value of downstream value chain segments such as Balance of System (BoS) components (inverters, mounting structures, cabling) and installation-related services is now estimated at around 45 per cent (EPIA, 2012).

The future of a competitive German solar PV industry can only lie in a long-term strategy capitalizing on quality-sensitive segments of the value chain, high innovation power and the supply of integrated system solutions to customers. Specifically, this could involve:

- Solar park planning and development coupled with reliance on cheaper, imported modules as a potentially viable business model.
- Investments into battery-based solar storage systems, which will be of increasing importance in view of the trend towards more residential, decentralized electricity generation.
- Relying more on specialized machinery and facilities to serve emerging markets (Asia, South Africa, Brazil) and offering German expertise in building solar factories.
- A focus on innovative solar panel integration into buildings based on architectural design know-how.
- Enhanced inter-industry cooperation drawing on the relevant expertise of equipment suppliers in related sectors such as the semiconductor, medical and automotive industries (Grau, Huo, & Neuhoff, 2011).

It has become evident that German solar cell manufacturers cannot successfully compete with Chinese imports. Solar cell production is based on a mature technology resulting in largely price-driven competition. Also, there are no significant advantages of proximity to customers. Increasingly, even German module producers depend on imported Chinese solar cells.

Finally, many companies appear to have relied too much on extrapolating past successes. As recently as in 2010, industry surveys revealed a high level of business confidence and optimistic expectations; less than two years later, a full-blown crisis had arrived. In the assessment of the German Center for Solar Market Research, needed investments into R&D were neglected for too long (DW, 2012).

5.2 Technological Innovation

The measurement of innovation dynamics is notoriously difficult. In the absence of sufficient company-level data on R&D investments, international patent data can be a useful proxy indicator. However, evidence needs to be treated with care. Results will differ in accordance with the database applied, the country in which a patent has been filed, the reliance on either patent applications or patents granted as well as the inventor's or applicant's home country. Also, the significant time required for processing a patent registration and the incidence of cross-sectoral patent use (e.g., electronics patents applied in solar PV; machinery and automotive patents applied for wind turbine gearboxes) would ideally need to be considered.

The results presented in Figures 10 and 11 are based on the OECD Patent Database (as updated in January 2013 with data up to 2010).[31] The database covers patent applications (not patents granted), which are generally considered to be a better indicator for innovation dynamics. The relative patent shares (RPS) have been calculated using the same methodology as applied earlier for calculating relative world trade shares. RPS thus compares, for a given country, the world share for a patent of one specific technology with the world patent share across all technologies. A positive value indicates that the technology under consideration has a superior patent (innovation) position compared to the entire technology portfolio of a country.

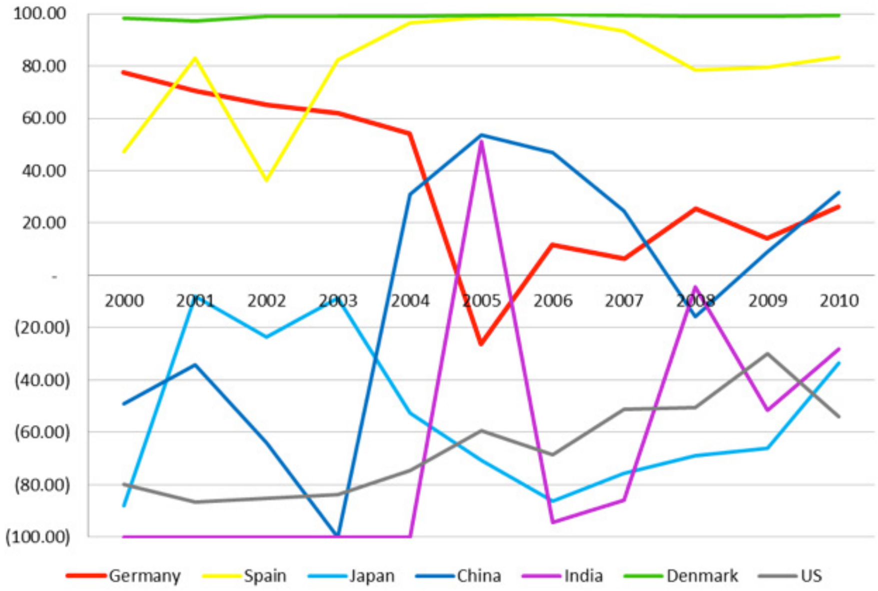

FIGURE 10: WIND ENERGY: RELATIVE PATENT SHARES BY COUNTRY, 2000–2010 (PERCENTAGE)

Source: Author calculations based on OECD Patent Database.

---

[31] The OECD database covers patent applications to the European Patent Office (EPO) (from 1978 onwards); patents granted by the EPO (from 1978 onwards); patents granted by the U.S. Patent and Trademark Office (USPTO) (from 1976 onwards); patents filed under the Patent Co-operation Treaty, at international phase, that designate the EPO (from 1978 onwards); and patents that belong to Triadic Patent Families (OECD definition): i.e., subset of patents all filed together at the EPO, at the Japan Patent Office (JPO) and granted by the USPTO, protecting the same set of inventions.

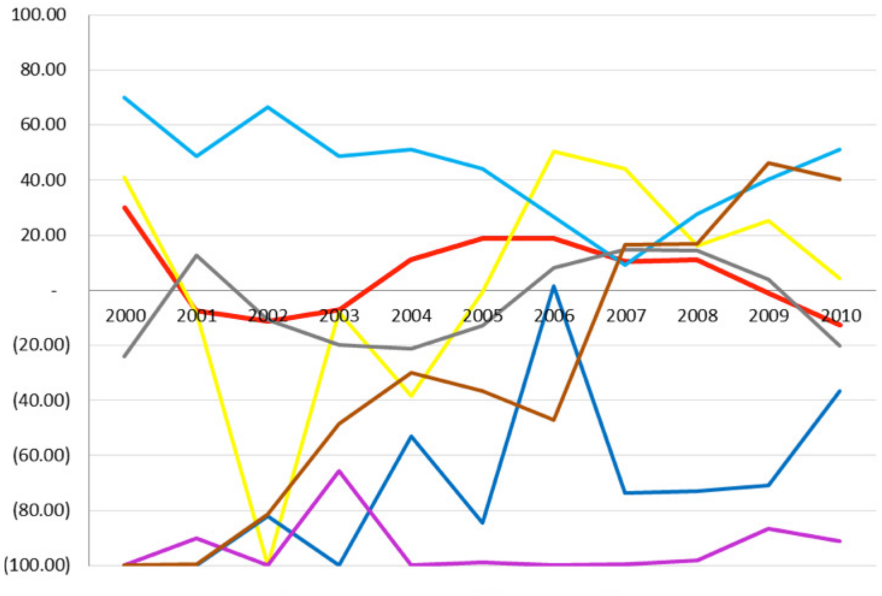

FIGURE 11: SOLAR PV: RELATIVE PATENT SHARES BY COUNTRY, 2000–2010 (PERCENTAGE)

Source: Author calculations based on OECD Patent Database.

It emerges that in the case of Germany, wind energy—after a trend reversal in 2005—has consistently achieved a positive RPS (value of +26 in 2010), while the opposite applies for solar PV. From a moderately positive RPS up to 2006, the trend has been downwards resulting in negative RPS as of 2009 (with a value of -13 in 2010). Background data show that between 2005 and 2010, the absolute number of German wind energy patents more than tripled; the number of solar PV patents increased by one quarter.

These results are corroborated by a similar analysis undertaken for 2009 based on European Patent Office (EPO) data (Bointner, 2012) in which the gap between a positive RPS value for wind technology and a negative RPS value for solar PV technology is even more pronounced. They are further substantiated by a recent broader cross-country analysis of green technology patents based on WIPO's classification (Bierenbaum, Frank, Lenox, & Maheshwari, 2012), which led to the following results (for the 1990–2010 period):

- While trailing behind the U.S. and Japan in terms of the absolute number of "green" patents granted, Germany exhibits the highest per capita green patent[32] intensity of all countries worldwide.
- In wind energy technology, Germany is comparatively stronger as an innovator (measured as share of cumulative global wind patents) than as an adopter (share of installed global wind power capacity) although the difference, with 21 per cent and 14 per cent respectively, is relatively small.
- In solar PV technology, Germany is comparatively stronger as an adopter than as an innovator, with a 44 per cent share of installed global capacity and only 12 per cent share of global cumulative patents.

---

[32] According to WIPO's Green Inventory, "green patents" cover alternative energy production patents in 13 sectors: solar, wind, geothermal, biofuel, biomass, fuel cell, hydro, synthetic gas, integrated gasification combined cycle, man-made waste, mechanical power from muscle energy, natural heat and waste heat.

In general, there seems to be a closer alignment between innovation and deployment trends in the case of wind energy, while for solar PV, innovation and deployment hubs may be decoupled as PV technology is more easily transposable to countries with the most conducive incentives structure for large-scale deployment (Lee, Iliev, & Preston, 2009). From the same study, it emerges that several German wind energy companies are among the top 20 patent holders (Enercon[33] indeed is number 1, followed by Siemens at number 7), whereas in the case of solar PV patents only Siemens figures at number 20.

Wind Energy: Main innovation paths in Germany

The German wind energy industry is currently among the leading global innovators and is poised to remain in the technological vanguard in the years ahead. Companies like Enercon, Siemens, Vensys, Nordex, REpower and others have contributed to technological breakthroughs in recent years. The following technology areas have been key for the technological trajectory in Germany and are likely to also dominate in future (for details see Urban, Nordensvärd, Lema, & Moller Andersen, 2013)[34]:

- *Massive upscaling of turbine (as well as rotor and blade) size:* All German wind turbine manufacturers have dedicated R&D programs aimed at building giant turbines that push the boundaries of conventional capacities. This is true for both onshore and offshore deployment. Already now, Enercon has developed the largest turbine worldwide with 7.6 MW capacity (E-126), which is operated exclusively onshore.
- *Direct drive turbines:* Direct drive turbines are a prototypical German invention pioneered and manufactured in-house by Enercon. This development is likely to continue as direct drive turbines are gradually gaining in market share. Siemens is also active in this field; however, it favours the permanent magnetic direct drive (PMDD) approach in its R&D activities. The same applies to Vensys with its 1.5 MW and 2.5 MW PMDD turbines, which has been the company's most significant innovation so far.[35] Recent innovation emphasis is on enhancing the adaptability of these turbines to extreme weather conditions and diverse grid characteristics (e.g., low-voltage grids) with a view to serving growing export markets in China, the U.S., Africa and South America.
- *Increasing focus on offshore deployment:* REpower leads in offshore deployment capacity with a 6 MW size turbine; Siemens is working on giant offshore turbines as well. Generally, the Alpha Ventus offshore test site has boosted innovation in this area through a strong consortium of companies, including Germany's major utilities and two federal ministries (BMU and BMWi) in a co-funding arrangement. In the opinion of the German Wind Energy Association (BWE), the current status of offshore wind energy can best be characterized as being an advanced development project, with R&D remaining critically important.
- *Grid stability:* In view of the rapidly rising share of wind energy in total electricity generation, special attention is given to technological innovations geared at contributing to grid stability (so-called *Systemdienstleistungen* or "system services"). More specifically, this relates to relative rotor-blade proportions in view of the fact that smaller rotors combined with larger blades can reduce the feed-in strain on the grid.

---

[33] Enercon patents are registered under the name of Aloys Wobben, who founded the company in 1984 and has remained its owner to date.

[34] This section is also based on an interview conducted on September 2, 2013, with Henning Dettmer, Managing Director, German Wind Energy Association (BWE).

[35] PMDD technology has the advantage of higher efficiency and reliability but does require the use of rare earths not locally available.

Solar PV: Main Innovation Paths in Germany

In recent years, Germany's solar industry has come under massive competitive pressure, yet its innovation dynamics should not be underestimated. The following innovation fields are currently emerging (Solarpraxis, 2012; PV Magazine, 2013a; Prognos, 2011)[36]:

- *Grid integration and storage:* Quite similar to the case of wind energy, priority attention is given to technological innovations geared at contributing to grid stability. This relates to such issues as controlling power range, peak shaving (which is a precondition for accessing the new KfW battery storage loan programme) and smart metering.
- *Thin-film technology:* Nano-scale thin film PV cells and panels are considered to be a technology with great promise in terms of achieving high technical efficiency with low raw-material cost. Germany's Berlin-based Helmholtz research centre is expecting significant technological breakthroughs in this area and is engaged in dedicated research partnerships (e.g., with Masdar PV) to develop the next generation of thin-film crystalline silicon-based PV. Future application areas for flexible, lightweight cells are likely to range from cars to textiles.
- *Organic PV cells:* In addition to the Innovation Alliance PV (see Box 5), the Federal Ministry of Education and Research (BMBF) has established an Innovation Alliance for Organic PV (OPV) aimed at promoting R&D and bridging the gap between science and industry in this field, which can benefit significantly from Germany's strong chemical industry base. Application-oriented, collaborative research between companies (BASF, Bosch, Heliatek, Merck, Schott) and research institutions is being supported. The focus is on improving the durability and stability, as well as scaling of OPV systems to make them commercially viable. Funding by both government and industry amounts to approximately €360 million.
- *PV module recycling:* The future importance of efficient recycling is underlined by the EU Waste Electrical and Electronic Equipment Directive, which prescribes recycling also of solar modules as of 2014. SolarWorld Germany and the Technical University Freiberg, following a pilot plant operation, are now collaborating on a large-scale recycling plant with a planned recycling rate of over 95 per cent. At the same time, it is anticipated that recycling operations will be largely outsourced to specialized companies and may thus in future constitute more of a logistical than a technological challenge.

An interesting crossover innovation path addresses the potential efficiency gains to be had from hybrid wind-solar parks. A new study (PV Magazine, 2013b) jointly undertaken by the Reiner Lemoine Institute and Solarpraxis emphasizes the much higher electricity generation intensity (related to the surface area covered) of combined systems and the minimal shading losses (1 to 2 per cent) caused by wind turbines. Advantages also include more grid feed-in stability due to the different electricity generation patterns of wind and solar. A hybrid pilot plant will go on stream in 2014 near Berlin, financially supported by the BMBF's new "Zwanzig20" Partnership for Innovation program. Both sectoral industry associations (BWE and BSW) are engaged in exploring the potential of such hybrid power plants.

---

[36] This section is also based on an interview conducted on September 2, 2013, with Rainer Brohm, Head of Department for Governmental Relations and International Affairs at the German Solar Industry Association (BSW).

5.3 Employment Creation

The solar and wind technology sectors have grown into significant providers of employment in the German economy. While no data are available on the number of net jobs created, there are reliable data on gross employment creation both directly through capacity investment and indirectly through maintenance, operation and other support activities. Of the almost 380,000 total jobs created by renewable energies in 2012 (for the first time, down from the previous year), more than half (54 per cent) were accounted for by solar PV and wind energy alone (Table 11). Based on the two sources below Table 11, the following structural features stand out:

- The share of new jobs attributable to the Renewable Energy Sources Act (EEG) has grown over time: from 61 per cent in 2004 to 71 per cent in 2012. More specifically, of the 268,000 jobs created through the EEG in 2012, wind energy accounted for 117,900 and solar PV for 87,800 with the remainder originating from biomass plants.
- While the majority of jobs stem from investments into solar and wind installations, the share of jobs related to maintenance and operation services is growing. This applies in particular to onshore wind, where the share of maintenance and operations jobs is as high as 16 per cent. For solar PV, the same share stands at 10 per cent. Despite the 2012 slump in new solar installations, maintenance and operation jobs kept growing.
- Export markets play an essential role in employment creation. For all renewables, in 2012 the domestic market generated 59 per cent of investment-related jobs, with export markets accounting for 41 per cent. In view of the above-average export ratio of electricity-generating technologies, export-driven employment must be even higher for wind energy and solar PV.
- The regional distribution of employment is more dispersed than often assumed. While there is a basic pattern of more wind installations in the northern and eastern coastal regions and a higher solar PV intensity in southern federal states, component-driven employment is often located in the traditional industrial centres. At the same time, an important inequality-reducing impact is noticeable: In those eastern federal states suffering from the highest unemployment ratios nationwide (with the exception of city states), the relative importance of solar and wind employment is most pronounced. Specifically, this applies to Mecklenburg-Western Pomerania, Saxony-Anhalt and Brandenburg with unemployment rates (June 2013) of 10.8 per cent, 10.7 per cent and 9.5 per cent, respectively.
- In terms of the skill profile of the labour force (see Table 12), employment in both the solar PV and wind energy industry is very much in line with the comparative advantage of a sophisticated labour market in a high-tech economy like Germany's. While there is a negligible share of unskilled labour, in both the wind and particularly the solar PV industry the share of university-degree staff is around three times as high as the national industry average.

TABLE 11: EMPLOYMENT CREATED BY WIND ENERGY AND SOLAR PV, 2010–2012

	INVESTMENT-RELATED JOBS		JOBS RELATED TO MAINTENANCE AND OPERATION		TOTAL JOBS	
	2011	2012	2011	2012	2011	2012
Wind - onshore - offshore	82,600	98,600 81,300 17,300	18,500	19,300 18,600 700	101,100	117,900 99,900 18,000
Solar PV	103,300	78,900	7,600	8,900	110,900	87,800
Total renewable energies	242,000	227,100	75,800	80,700	381,600*	377,800*
Total share of wind (per cent)	34	43	24	24	26	31
Total share of solar PV (per cent)	43	35	10	11	29	23

**Includes also jobs created by fuel supply activities (biogas, biomass, biofuel), as well as related jobs in public institutions (R&D, administration).*

Sources: Based on data in Federal Ministry for the Environment (2012); O'Sullivan, Edler, Bickel, Lehr, Peter, & Sakowski (2013).

TABLE 12: SKILL PROFILE OF EMPLOYMENT IN THE WIND ENERGY AND SOLAR PV SECTOR (SURVEY-BASED; PERCENTAGE SHARES)

	NO VOCATIONAL TRAINING	COMPLETED VOCATIONAL TRAINING	UNIVERSITY DEGREE
Wind energy	0.9	79.9	27.1
Solar PV	5.8	81.7	34.7
Total industry	15.0	69.5	9.9

Source: Federal Ministry for the Environment (BMU) (2012).

5.4 Global Market Competition

The question of whether the rise of the German wind and solar industries has increased global market competition is not easily answered. In the case of wind energy, German companies have gained a strong foothold in terms of their share in global exports, which moved up to almost 50 per cent in 2012 (see Figure 11 above). As shown in Table 13, the global market displays a high degree of concentration with 10 companies accounting for more than three quarters of the total (slightly down from 83 per cent in 2010 to 77 per cent in 2012). Enercon is consistently ranked between number 4 and number 5, with a 2012 market share of more than 8 per cent. Between 2009 and 2011, Siemens maintained its rank of number 9 with a market share of approximately 6 per cent before jumping up to become the third largest global player in 2012. Nordex and REpower both dropped out of the top 10 companies in 2010.

Overall, the composition of the top 10 global wind turbine manufacturers has remained fairly stable over recent years. Leading companies originate from just three European countries (Denmark, Germany, Spain) and from China, the United States and India.

TABLE 13: GLOBAL MARKET SHARES HELD BY LEADING WIND TURBINE MANUFACTURERS, 2008–2012 (RANKS AND PERCENTAGES)

2008	2009	2010	2011	2012
Vestas	Vestas	Vestas 14.8	Vestas 12.7	GE 15.5
GE	GE	Sinovel 11.1	Sinovel 9.0	Vestas 14.0
Gamesa	Sinovel	GE 9.6	Goldwind 8.7	Siemens 9.5
Enercon	Enercon	Goldwind 9.5	Gamesa 8.0	Enercon 8.2
Siemens	Goldwind	Enercon 7.2	Enercon 7.8	Suzlon 7.4
Suzlon	Gamesa	Suzlon 9.6	GE 7.7	Gamesa 6.1
Sinovel	Dongfang	Dongfang 6.7*	Suzlon 7.6	Goldwind 6.0
Goldwind	Suzlon	Gamesa 6.6	Guodian 7.4	United Power 4.7
Dongfang	Siemens	Siemens 5.9	Siemens 6.3	Sinovel 3.2
Nordex	REpower	Guodian 4.2	Mingyang 3.6	Mingyang 2.7
Top 10 market share (%)		82.5	78.8	77.3

** Exact share not available, yet known to be between 6.6 and 6.9 per cent.*

Source: Based on data in Cleantech, 2012; Navigant Research, 2013.

Compared to the wind energy market scenario, the global market for solar PV manufacturers (see Figure 12) is at the same time more and less diversified: more so in terms of leading companies (the top 10 and top 15 accounting for just 38 per cent and 49 per cent, respectively) and less so in terms of their countries of origin with heavy Chinese dominance. Moreover, it is striking to see that, despite the distinct lead market role of Germany in terms of solar PV deployment, not a single German solar module manufacturer surfaces among the top 15 globally.

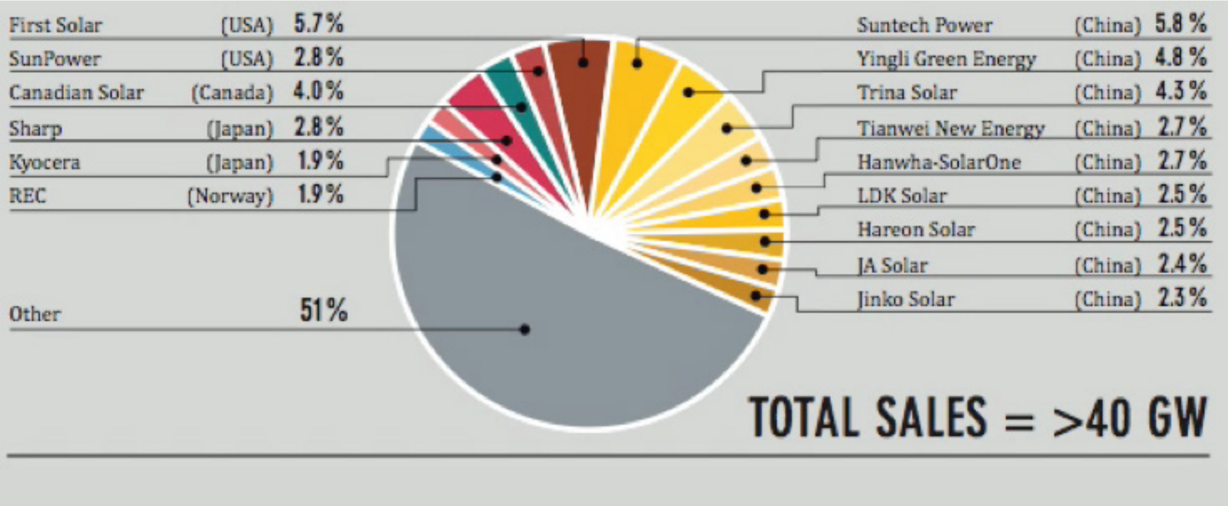

FIGURE 12: GLOBAL MARKET SHARES HELD BY THE 15 LEADING SOLAR PV MODULE MANUFACTURERS, 2011 (PERCENTAGES)

Source: REN21 (2012, p. 48).

However, Figure 12 covers only PV module manufacturers and again, a more granular perspective of the entire value chain is necessary to fully understand solar market dynamics. The picture changes dramatically when considering solar components such as inverters supplied by specialized companies. Here, in 2012 the global market leader was the German company SMA Solar, while German Kaco and RefuSol were ranked numbers 3 and 9, respectively. At the same time, there is a trend for the solar inverter industry to become more fragmented due to expanding markets in China and Japan with their own well-established supplier firms (PV Magazine 2013c).

5.5 Environmental Benefits From Avoided Emissions

As emphasized in Chapter 1, from the outset one of main drivers of renewable energy promotion in Germany has been the political commitment to achieving ambitious goals of reducing GHG emissions in the fight against climate change, as well as reaching environmental objectives in terms of reducing various pollutants. Hence, the question of exactly what level of avoided emissions can be attributed to the growing deployment of wind energy and solar PV is of particular importance.

In Table 14, we take a look at directly avoided CO_2 emissions for which consistent time series data are available. It emerges that between 2005 and 2012 the amount of avoided CO_2 emissions has more than doubled from 23.8 million tonnes to 56.5 million tonnes. The contribution of wind energy and solar PV to reducing Germany's carbon footprint thus is of significance at the broader national level: in 2012, both sectors combined avoided CO_2 emissions amounting to 6.9 per cent of total CO_2 emissions, or 17.8 per cent of CO_2 emissions caused by electricity generation. When considering the entire 2005 to 2012 period, more than one tenth (11.3 per cent) of electricity-related CO_2 emissions could be prevented.

TABLE 14: DIRECTLY AVOIDED CO_2 EMISSIONS FROM WIND ENERGY AND SOLAR PV, 2005–2012 (IN 1,000 TONNES)

	WIND ENERGY	SOLAR PV	WIND ENERGY PLUS SOLAR PV	SHARE OF TOTAL CO_2 EMISSIONS (PER CENT)	SHARE OF CO_2 EMISSIONS FROM ELECTRICITY GENERATION (PER CENT)
2005	23,227	616	23,843	3.3	7.4
2006	24,038	1,341	25,379	2.9	7.7
2007	30,367	1,818	32,185	3.8	9.5
2008	28,989	2,978	31,967	3.8	10.0
2009	28,211	4,435	32,646	4.2	11.2
2010	27,244	7,792	35,036	4.2	11.5
2011	35,239	12,848	48,087	6.0	15.8
2012*	35,489	20,998	56,487	6.9	17.8

** Total CO_2 emissions and CO_2 emissions from electricity generation are estimates.*

Sources: Compiled and calculated from AGEE-Stat (2012); Umweltbundesamt (2013a); Umweltbundesamt (2013b).

Tables 15 and 16 provide a more comprehensive and disaggregated picture for the year 2012. First, they cover a broader spectrum of emissions by incorporating the eight most important types of air pollutants—those with reporting obligations under the UN Framework Convention on Climate Change, the Kyoto Protocol and the Geneva Convention on Air Pollution. Second, they are based on the concept of net avoided emissions, which also factors in the emissions caused by the generation of wind energy and solar PV in upstream production stages.

Furthermore, in terms of the methodology used, data in both tables are based on applying specific substitution factors for wind energy and solar PV, respectively. This is relevant in view of the fact that the emission intensities of coal, lignite and natural gas differ substantially. More specifically, the following substitution patterns are assumed by BMU:

- For wind energy: coal 80 per cent, natural gas 17 per cent and lignite 3 per cent
- For solar PV: coal 75 per cent, natural gas 22 per cent and lignite 3 per cent

In addition to the high volume of avoided CO_2 emissions, it turns out that both energy sources combined have avoided gross emissions of 29,000 tonnes of sulphur dioxide (SO_2) and 41,000 tonnes of nitrogen oxides (NOx).

TABLE 15: TOTAL AVOIDED EMISSIONS FROM WIND ENERGY (INCLUDING EMISSIONS THROUGH UPSTREAM PRODUCTION ACTIVITIES) BY TYPE OF EMISSION, 2012 (IN TONNES)

	AVOIDED EMISSIONS (GROSS)	GENERATED EMISSIONS	AVOIDED EMISSIONS (NET)
Sulphur dioxide (SO_2)	18,288	1,558	16,730
Nitrogen oxides (NOx)	25,668	1,184	24,484
Particulate matter (PM)	1,781	1,641	140
Carbon monoxide (CO)	7,832	2,935	4,897
Non-methane volatile components (NMVOC)	1,565	262	1,303
SO_2 equivalent	36,218	2,382	33,836
Carbon dioxide (CO_2)	35,488,963	498,379	34,990,584
Methane (CH_4)	124,028	1,453	122,575
Nitrous oxide (N_2O)	2,569	20	2,549
CO_2 equivalent	39,006,141	535,156	38,470,985

Source: Umweltbundesamt (2013b).

TABLE 16: TOTAL AVOIDED EMISSIONS FROM SOLAR PV (INCLUDING EMISSIONS THROUGH UPSTREAM PRODUCTION ACTIVITIES) BY TYPE OF EMISSION, 2012 (IN TONNES)

	AVOIDED EMISSIONS (GROSS)	GENERATED EMISSIONS	AVOIDED EMISSIONS (NET)
Sulphur dioxide (SO_2)	10,490	5,906	4,584
Nitrogen oxides (NOx)	15,612	4,370	11,242
Particulate matter (PM)	1,139	2,301	-1,162
Carbon monoxide (CO)	5,108	6,284	-1,176
Non-methane volatile components (NMVOC)	1,008	2,355	-1,347
SO_2 equivalent	21,393	8,948	12,445
Carbon dioxide (CO_2)	20,997,032	1,798,213	19,198,819
Methane (CH_4)	73,137	5,096	68,041
Nitrous oxide (N_2O)	1,720	70	1,650
CO_2 equivalent	23,058,843	1,926,946	21,131,897

Source: Umweltbundesamt (2013b).

Numerous life-cycle assessments of the ecological balance sheet of alternative energy sources have been undertaken in recent years. The overall result of a comparatively much smaller carbon and ecological footprint of wind energy and solar PV is unequivocal. Relevant data for Germany lead to the conclusion that, in terms of CO_2, coal-based electricity generates around 100 times more emissions per unit than wind energy and 10 to 20 times more than solar PV. In terms of SO_2, the ratio for "coal over wind" is around 10 while the "coal over solar PV" ratio is in the range of 1.5 to 2 and thus significantly lower (Krewitt & Schlomann, 2006, p.35; for similar Swiss data: Swissolar, 2008).

The latter aspect is also confirmed by the 2012 data in Table 16, which shows a stark difference for solar PV in gross and net SO_2 equivalents: emissions caused by upstream production phases are in the order of more than two thirds (42 per cent) of gross emissions avoided. This is explained by the use of some hazardous chemicals in the solar cell manufacturing process, mostly in connection with cleaning and purifying the semiconductor surface.

As already mentioned in Chapter 4, total environmental benefits from avoided greenhouse gas emissions and other airborne pollutants are estimated at €8 billion (2011) for electricity generation from renewables (Lehr et al., 2012). A different way of looking at this is to calculate the environmental damage caused by various energy sources in terms of hypothetical increases in electricity costs, which is done in Table 17.

TABLE 17: EXTERNAL ENVIRONMENTAL COSTS BY ENERGY SOURCE IN € CT/KWH, 2011 (PROVISIONAL ESTIMATES)

	COSTS FROM GREENHOUSE GASES	PARTIAL INTERNALIZATION THROUGH CO_2-CERTIFICATES*	COSTS FROM AIR POLLUTION
Wind energy	0.1	-	0.2
Solar PV	0.6	-	0.6
Natural gas	3.9	0.5	1.0
Hard coal	7.4	1.0	1.6
Lignite	8.7	1.4	2.1

** Assuming an average CO_2 certificate price of €12.9/tonne for 2011.*
Source: BMU (2012, p. 52).

It emerges that the spectrum of additional costs from GHG[37] and air pollution[38] combined, ranges from 0.3 € ct/kWh for wind energy and 1.2 € ct/kWh for solar PV all the way up to 9 € ct/kWh for hard coal and 10.8 € ct/kWh for lignite—with the partial internalization through CO_2 certificates being just slightly above 10 per cent. In this context, it is recalled that in comparison, the electricity surcharge on account of EEG-FiT amounts to € 5.3 ct/kWh for 2013.

5.6 Energy Security

As elaborated above (see Section 5.3), the conventional understanding of energy security, defined above all in terms of reducing import dependence on various types of fuels, has been diminished in the German debate on the country's energy transition. This is all the more surprising as the country's dependence on imported fossil fuels is exceedingly high, as will be shown below. Rather, objectives and concerns related to climate change and environmental repercussions have been at the forefront.

Nevertheless, the impact of the move towards renewable sources of energy on various dimensions of energy security has been an integral element of the national discourse. In this context, it is important to underline the broad notion of energy security that is being applied in Germany—looking at both economic and technical security aspects, as well as both domestic and global factors. While not aiming at being exhaustive, Table 18 summarizes the key dimensions of energy security.

---

[37] This covers the costs of climate change in terms of direct income losses, as well as damage in terms of land degradation, health, water resources and ecosystems.

[38] This covers the costs of health damage, harvest losses, material damage and negative impacts on biodiversity.

TABLE 18: KEY DIMENSIONS OF ENERGY SECURITY

Economic and political considerations
• Availability: Continuity of imports; diversity of import sources • Accessibility: Political risks associated with import sources • Affordability: Energy prices from both imported and domestic sources
Technical infrastructure
• Grid capacity: Expansion requirements • Grid stability: Response capability to cope with energy source diversification • Storage capacities: "Buffers" to deal with fluctuations in renewable energy supply
Fundamental technology risks
• Climate change • Nuclear accidents • Nuclear waste disposal • Chemical contamination (e.g., related to shale gas)

Some of the above dimensions have already been discussed in other sections, such as the impact of a move towards renewables on energy affordability and on GHG emissions. Others are beyond the scope of this report, such as the assessment of technology risks around nuclear energy. However, the latter has formed an important part of the German energy transformation debate. Recently, the issue of identifying a final nuclear waste deposit has even dominated fears of nuclear accidents. Given the nature and wide range of assumptions required (both in terms of potential damage costs and relevant probabilities), it is virtually impossible to come up with reasonable monetary estimates. Also, the very validity of putting monetary values to potential nuclear disasters can be (and has been) questioned on ethical grounds. Suffice it to say here that even with conservative assumptions the full external costs of nuclear energy easily surpass those of all other sources of energy.[39]

We will, albeit not in much detail, highlight two other aspects illustrated in Table 18 above, namely availability and accessibility of energy imports, and grid and energy storage aspects. Let us begin with reviewing the German situation with regard to import dependence on fossil fuels.

Energy Import Dependence

---

[39] "Estimates of the external cost of nuclear power range from 0.1 c/kWh to 320 c/kWh, thus diverging by a factor of 3,200" (Greenpeace & BWE, 2012, p. 11).

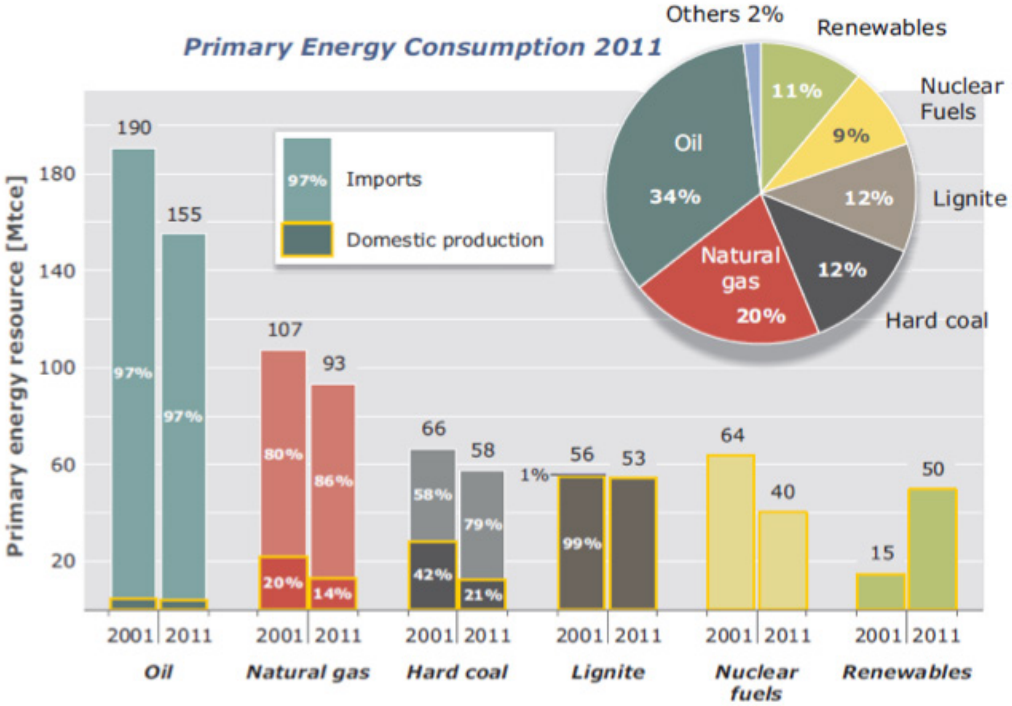

FIGURE 13: PRIMARY ENERGY CONSUMPTION BY ENERGY SOURCE AND IMPORT SHARE (2011)

Source: Deutsche Rohstoffagentur (DERA) (2012, p. 10).

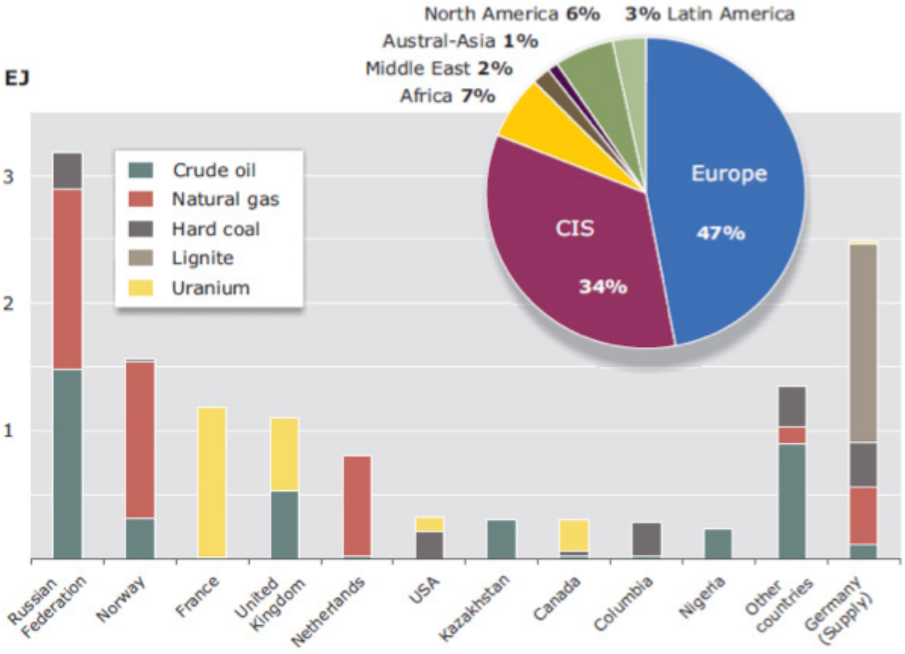

FIGURE 14: ENERGY RESOURCE IMPORTS BY COUNTRY (2011)

Source: Deutsche Rohstoffagentur (DERA) (2012, p.11).

From Figures 13 and 14 the following broad picture emerges:

- Germany's highly developed economy is exceedingly dependent on fuel imports to power its growth. With regard to crude oil, import dependence is close to 100 per cent
- Concerning fossil fuel substitution through renewable energy (electricity-related), natural gas, hard coal and lignite are particularly relevant. While the latter is entirely of domestic origin, the import ratios for natural gas and hard coal amount to 86 per cent and 79 per cent, respectively
- Imports of coal are characterized by a fairly high geographical diversification. To a lesser extent, this also applies to imports of natural gas, which are mainly supplied by Russia (around 40 per cent), Norway (around 35 per cent) and The Netherlands (slightly above 20 per cent), in all cases through cross-border pipelines
- Among the sources of energy imports, Russia stands out as it supplies large volumes of crude oil, natural gas and hard coal. Mounting concerns about this dependency are also to be seen against the backdrop of anticipated long-term reductions in energy production levels of some other European suppliers (oil from the United Kingdom; natural gas from The Netherlands).

The remaining relatively small domestic production of hard coal will be terminated in the near future. The German government, in consultation with the EC, decided to phase out—following more than four decades of massive support for this sector—all subsidies for the remaining five hard coal mines by 2018. Given their lack of competitiveness at world market prices, this will force them to close down. However, the resulting full dependence on coal imports is widely considered to be unproblematic in light of the availability of diversified import sources.

The same cannot be said for natural gas, where increasing import dependence (from 80 per cent in 2001 to 86 per cent in 2011) is coupled with growing supplies from Russia and related economic and political vulnerabilities. At the same time, natural gas will have to play a strong role in Germany's energy transition scenario—as a replacement for phased-out nuclear energy, as a substitute for carbon-intense coal power plants and as a flexible backup for fluctuating renewable energy supplies. Accordingly, the capacity of combined cycle gas turbines is expected to more than double to reach 50 GW by 2030 (IEA, 2012, p. 18).

Significant shale gas deposits have been identified in Germany. Based on a conservative assumption of exploitable resources being just 10 per cent of total deposits, these resources would be of a magnitude about 10 times higher than natural gas resources (DERA, 2012). However, there is massive resistance against commercial exploitation of shale gas in view of related ground water contamination risks. A final policy decision on a (partial or full) ban is in the making.

A quantitative analysis of the contribution of renewables to energy security in Germany was recently undertaken by Lehr (2009). The study applies the Shannon-Wiener diversity index and expands it to also incorporate import country dependence, associated political risks (drawing on the "Hermes" indicator, which is used in Germany's official Export Guarantee Scheme) and affordability (by factoring in price increases stemming from subsidized renewable energy sources). In essence, the results establish a positive correlation between higher shares of renewable energy and enhanced energy security. This applies in particular to the political target scenario (assuming a share of renewables in electricity generation of 50 per cent in 2030 and 80 per cent in 2050), which renders better results (higher energy security) for all indicators used, when compared to a more conservative reference scenario. Significantly, the initially higher prices for renewables would experience a turnaround already in 2020 and from then onwards contribute positively even to the price dimension of energy security. However, as Lehr points out, there is an emerging need to also address potentially new forms of import dependence in terms of imported raw materials and components for some renewable energy sources. Specifically, this relates to the use of rare earths in both thin film solar PV and wind turbine magnets.

In terms of reduced fossil fuel imports attributable to the growth of renewable energy, estimates are available up to 2011. Between 2008 and 2011, annual import savings were in the range of €6 billion to €7 billion, based on market prices and hence subject to significant oil price fluctuations. Slightly more than 40 per cent of these savings resulted from using renewables for electricity generation (Lehr et al., 2012). Considering that wind energy and solar PV combined account for roughly half of renewable electricity, it can be assumed that in 2011, they generated savings of approx. €1.5 billion of fossil fuel imports.

Finally, the expansion of renewable sources of energy raises a whole set of questions around the necessary grid infrastructure, back-up capacity and storage facilities—all of which must be regarded as integral elements of a broader understanding of energy security. The locational separation between renewable energy generation and consumption, the largely decentralized and widely dispersed generation of green electricity, as well as the immense fluctuations in the time patterns (particularly of solar energy), call for a holistic perspective and will necessitate huge investments into a new energy infrastructure that is suitable for the future. Let us treat these issues one by one.

Transmission Grid

The capacity for long-range energy transport from the North to the South must be the infrastructural backbone of the post-transition energy scenario so as to respond to the increasing spatial decoupling of energy supply and demand. Most of Germany's wind energy is generated in near-coastal Northern regions and rapidly growing offshore facilities while industrial energy consumption centres are concentrated in the central and southern parts of the country. The challenge will be exacerbated by the fact that the majority of nuclear plants to be switched off within the next 10 years are located in the South. Thus, the German Government passed the Grid Expansion Act and the Grid Expansion Acceleration Act in 2009 and in 2011, respectively.

In concrete terms, the German Energy Agency (DENA) has identified requirements of 1,850 kilometres of additional high-voltage transmission lines by 2015 and another 3,800 kilometres by 2023. This comes on top of modernization requirements of 4,400 kilometres for the already-existing transmission lines (DENA, 2013). However, according to the Federal Grid Agency, implementation of the 24 identified national priority projects is seriously lagging behind: Of the 1,850-kilometre grid expansion targeted by 2015, only 268 kilometres (some 15 per cent) were achieved by end of March 2013. Even more worrisome, no additional expansion is anticipated for the remainder of 2013 and several priority projects have been subject to considerable delays, both due to complex infrastructure planning procedures (involving both federal and state level authorities) and public opposition to specific grid corridors (Bundesnetzagentur, 2013).

Distribution Grid

Another set of challenges is connected with the low-voltage distribution grid for regional and municipal energy transport. Originally, this was never intended to cope with the large-scale grid integration of renewable energy sources and to adjust to the natural cycles that apply specifically to solar PV and wind energy. It is estimated that by 2015, between 135,000 kilometres and 190,000 kilometres of the distribution grid needs to be modernized or completely renewed. Exactly what share of solar and wind energy can be absorbed is subject to debate and depends, among other things, on the willingness to shoulder the costs for back-up reserves. For instance, in the case of Western Denmark, integration of a 20 per cent share of wind energy has been successfully achieved, although not without relying on inter-connectivity to other Nordic and German grids as a buffer (Ölz, S., Sims, & Kirchner, 2007, p. 29.)

Storage Capacity

In addition to innovative "smart grid" approaches to load management, a huge requirement will remain for developing effective storage capacities. The new KfW incentive scheme for battery-based energy storage paired with solar PV (see Section 3.2 above) is widely seen as an important step in the right direction; however, it will not obviate the need to develop a new large-scale storage infrastructure. Beyond the well-established pumped storage plants, various innovation paths are being actively pursued, ranging from power to gas to compressed air storage. Significantly, in mid-2013 the Federal Association of Energy Storage was established with a view to creating a network of companies active in this field and with the intention to define an energy storage roadmap for Germany.

BOX 11: VIEWPOINTS OF THE FEDERAL GRID AGENCY (BNA)[40] AND THE AGENCY FOR RENEWABLE ENERGY (AEE)[41]

From the techno-economic perspective of the Federal Grid Agency, the targets for renewable energy established for the German energy transition are ambitious yet feasible. While their achievement obviously depends on speedy grid expansion and new storage capacities, a great hidden potential is also seen in mobilizing demand flexibilities. This relates in particular to energy-intensive industrial companies that could adjust internal production processes to energy availability patterns. Furthermore, closer supply-demand coordination at the European level (e.g., capitalizing on temporal differences of production cycles at country level) could contribute to grid stability.

A medium-term scenario of oversupply of electricity from renewable sources (in particular in view of the predicted onshore wind capacity expansion) is considered realistic. This is to be seen in the context of the continued need to rely on conventional power plants to safeguard the controlling power range for grid stability. More specifically, a "must run" capacity of 18–20 GW of conventional electricity is required and would thus not be available as demand for renewable electricity. New generation wind and solar PV installations that can contribute to grid stability and integration are welcome, although their impact is not yet considered significant.

In the long run, energy supply security could benefit from synergies to be derived from planning combined renewable energy parks (e.g., wind plus solar PV) together with storage capacities such as "power to gas" and contracts with conventional energy suppliers for back-up purposes.

The latter point is reinforced by the Agency for Renewable Energy with reference to an ongoing research project carried out by a public-private consortium led by Fraunhofer IWES and funded by BMU. Results indicate that a stronger reliance on combined renewable power plants (solar, wind, biomass) could capitalize on different energy generation cycles. In this context, the inclusion of biomass is seen as critical due to its relatively easy storability. A flexible grid-stabilization capacity of up to 16 GW from biomass is considered as realistic in the medium term. However, tapping into this potential would require a modified incentives structure and a new business model for biomass plants (for details, see Renews Spezial, 2013).

---

[40] Based on interview conducted with Achim Zerres, Head of Energy Department.

[41] Based on interview with Claudia Kunz, Energy Advisor.

5.7 Contrasting Wind and Solar PV: Costs and Benefits in a Nutshell

In Figure 15, a stylized summary of the main quantitative results of Chapter 5 is presented, complemented by the EEG electricity surcharge per unit as proxy for the additional cost of wind and solar. While not amounting to an objective assessment of each sector, the comparison between wind energy and solar PV would indicate that the wind energy sector is leading in all performance dimensions: capacity deployment, electricity generation, employment creation, share in renewable electricity, competitiveness, technological innovation and avoided CO_2 emissions—and does so with lower subsidy levels, as measured by the EEG electricity surcharge per unit.

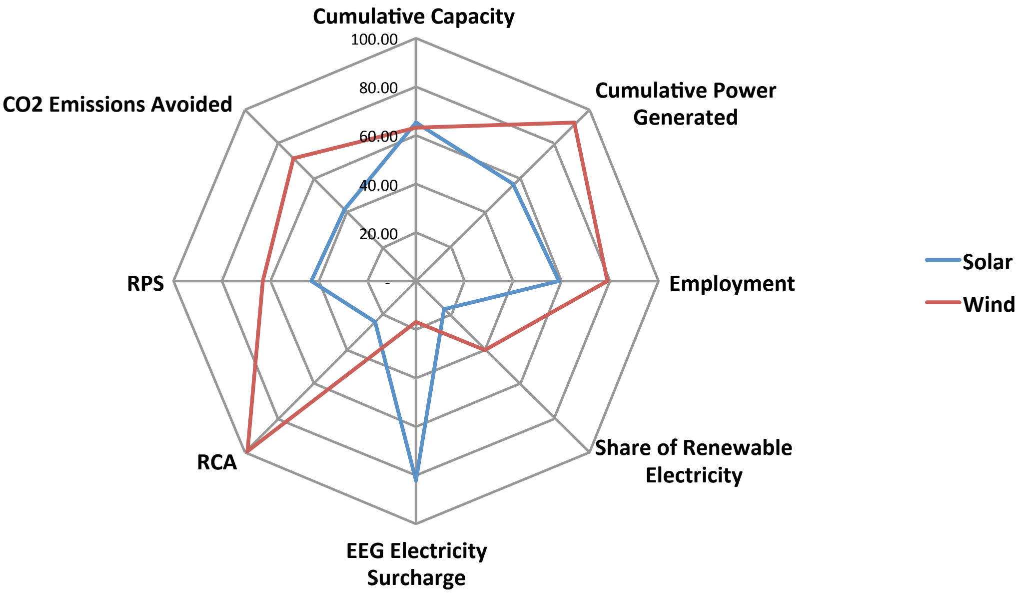

FIGURE 15: STYLIZED PROFILE OF WIND ENERGY AND SOLAR PV BY PERFORMANCE DIMENSION (LATEST AVAILABLE YEARS)

Source: Based on Tables 2, 4, 6, 11, and 14, and Figures 3, 6, and 9–11 in this report.

Note: An appropriate scaling was introduced for each performance dimension. Specifically, the following values were defined as 100 per cent:

- Cumulative capacity: 50 MW
- Cumulative power generated: 50 GWh
- Employment: 150,000 jobs
- Share of renewable electricity: 100 per cent
- EEG electricity surcharge: 300 €/MWh
- RCA: 200 (based on -100 to +100 range)
- RPS: 200 (based on -100 to +100 range)
- CO_2 emissions avoided: 50 million tonnes

Also, in terms of medium-term LCOE projections for wind energy and solar PV in Germany (Fraunhofer ISE, 2012), onshore wind plants are considered the most cost-effective renewable energy technology. Currently at 8 ct/kWh (at 2000 full-load hours per year), the LCOE for onshore wind energy is forecast to marginally decrease further to 7 ct/kWh in 2030. Solar PV systems are expected to remain more costly; however, they are coupled with much faster cost decreases due to a steeper technological learning curve. Overall, this would lead to onshore wind plants becoming cost-competitive with a conventional (fossil plus nuclear) electricity mix by 2017, while the same would apply for ground-mounted solar PV systems by 2022.

The above stylized comparison of solar PV and wind energy has a number of broader industrial policy implications, which will be discussed in Chapter 6.

Chapter 6: Navigating the Policy Space: Moving from Details to the Big Picture

In view of the critically important role of FiT in the German policy debate and its detailed assessment in this report, this final policy chapter first summarizes the impact and effectiveness of FiT as a policy tool before proceeding to various proposals within the ongoing debate on reform requirements and options (Section 6.1.). The obvious need to adopt a systemic perspective leads to broader considerations of green industrial policy in Germany (Section 6.2.) and an emphasis on issues of integration and coherence of policy approaches and institutional frameworks.

6.1 The FiT Impact and Reform Debate

While green industrial policy in Germany targets many sectors (for example resource-efficient environmental technologies, waste management, biofuels production or electro-mobility), the energy transition (*Energiewende*), with its focus on renewable energy sources, is certainly the most prominent national project. It places Germany among the most ambitious countries worldwide in the promotion of a transition to sustainable energy. However, public debate in Germany about the *Energiewende* in general and its different features in particular is highly politicized, and often driven by ideology or vested interests. This report has sought to provide a balanced assessment drawing on the best available evidence and quantifying explicitly what costs and benefits are excluded or included.

Germany has a variety of policies in place to support the *Energiewende*. Among them are mechanisms targeting all stages of renewable energy technology development from basic research to deployment. The FiT is the core element of Germany's policy package, and as such deserves closer analysis. In the energy policy community, there is widespread agreement that the FiT mechanism in general, and its application in Germany in particular, has proven to be an exceedingly effective policy instrument for pushing renewable energies into the market (Haas, Panzer, Resch, Ragwitz, Reece, & Held, 2011; Held, Haas, & Ragwitz, 2006; Matschoss 2013). Its efficiency, however, hinges on the appropriate determination of tariff levels. Based on a comparative assessment of renewable energy support policies in its member states, the EC concludes that "*well-adapted* FiT regimes are generally the most efficient and effective support schemes for promoting renewable electricity" (EC, 2008, p. 3).

Two recent econometric analyses based on FiT policies (one looked at 35 European countries and the other at 26) have addressed issues of the relationship between FiT design elements, capacity expansion and cost-effectiveness (Zhang, 2013; Groba, Indvik, & Jenner, 2011). Overall, they confirm a positive correlation between the provision of FiT and additional deployment of wind and solar PV installations, more strongly in the case of the latter. They also both emphasize the strong role of specific FiT design elements—such as contract duration, technology-specificity, tariff levels and degression rates—in determining the various schemes' success. While the question of assessing the marginal impact or, conversely, the redundancy ratio of FiT incentives eventually remains elusive, both studies identify a positive correlation between FiT enactment and capacity deployment, and underline the importance of providing a stable and predictable setting for risky, long-term investment decisions to be taken. Specifically in the case of wind energy, they concluded that high remuneration levels are less important for capacity deployment than are contract duration and grid connection guarantees.

The German FiT scheme has been characterized by a long contract period (20 years), guaranteed grid priority, technology-specific tariffs on a degressive scale coupled with a direct selling option (market premium) and recently, provisions for tariff evolution in response to deployment trends (the "flexible ceiling"). These design elements have created a stable investment environment and hence a strong readiness of capital markets to finance renewable energy projects at relatively low interest rates. Furthermore, the technology specificity—with differing FiT subsidy bands for each source of renewable energy—has had the advantage of encouraging the early deployment and upscaling of a wide spectrum of technologies. On the downside, it has not allowed for a focus on the most cost-efficient decarbonization technologies. A premium was thus placed deliberately on creating a broad foundation for various renewable energy technologies to develop and become commercially viable. However, this premium seems to have led to a bubble in the German solar PV manufacturing industry. Obviously, the critical challenge is to identify a sufficiently high incentive (subsidy) level for investments to be triggered without creating excessively high rents in terms of windfall profits. This presupposes correct assumptions about future technological learning curves and price trends as a basis for making well-informed decisions about an optimal tariff degression scale. The assumptions in the case of solar PV did not correspond with the considerable cost reductions of PV installations since 2009 (Bundesverband Solarwirtschaft, 2013).

The solar PV glut that is now being corrected by market forces has triggered a more fundamental debate about reform requirements and reform options of the FiT scheme in Germany. Before addressing this debate, it is worth recalling that in general, FiT incentives as a policy tool correspond to key criteria of rational industrial policy measures:

- Within the FiT approach, promising industrial sectors/technologies are being targeted and not individual companies—that is to say, it is about "picking potential" and not "picking winners."
- The incentives are provided in a time-bound manner, with decreasing support levels over time ("infant industry" rationale).
- Flexibility is built into the system by way of allowing exemptions from the EEG electricity surcharge for energy-intensive industries although, as experience has shown, this has opened the door to political capture in the case of the German FiT regime.

Against this backdrop, the current FiT reform debate in Germany revolves around the following key issues:

Making Tariff Adjustments More Flexible

Set against the unexpectedly fast expansion of solar PV capacities, there are proposals to introduce elements of a flexible "built-in" tariff adjustment. Rather than legal provisions predetermining tariff reduction schemes, these would be designed to periodically follow actual price and capacity installation developments. This approach would obviate the need for anticipating future price trends, which so far has resulted in a pattern of predicted price drops trailing behind actual developments and new PV installations regularly exceeding projected levels. At the same time, a trade-off needs to be recognized between flexibility requirements on the one hand and long-term investment stability on the other.

Introducing Competitive Elements

By introducing competitive elements into the FiT provision, cost-effectiveness could be enhanced. In particular for new large-scale installations, such as offshore wind facilities, reverse auctioning schemes could be considered with a view to prioritizing the least costly investment offers. Reverse auctioning schemes have recently been applied in a number of emerging economies (Pegels, 2014). There are lessons to be learned (for a summary see Box 12). Also, it could be an option to combine, in a two-stage approach, a basic general tariff with technology-specific additional tariffs resulting from auctioning schemes (Matschoss, 2013).

BOX 12: REVERSE AUCTIONING SCHEMES – A CASE FOR REVERSE LEARNING (SOUTH-NORTH)?[42]

"Reverse auctioning" (also referred to as "reverse bidding" or "reverse tendering") schemes—while often presented as a policy instrument sui generis—can actually be considered as a possible complement to FiT schemes allowing for tariff levels to be determined in a competitive manner, that is to say, testing the market before granting subsidies. Apart from the United Kingdom, they have been applied primarily in emerging economies like China, India, Brazil and South Africa. In actual implementation (for instance for wind energy projects in China and Brazil, for solar projects in India and for various renewable energy technologies in South Africa), the overall impact has been positive with the principal drawback having been a high incidence of "frivolous" bidding: investment proposals that were deliberately underpriced and not followed through once approved. This has led to introducing safety mechanisms such as bidding fees and potentially high penalties to be paid (India) or awarding contracts based on the average bidding price rather than the lowest bidding price (China).

With the diversified experience gained and lessons learned in these emerging markets, designing an effective auctioning scheme in Germany could be one option for rendering the country's FiT scheme more cost-effective. It would also constitute an intriguing case of "exporting" a policy scheme 1.0 and, in time, "importing" its improved version 2.0.

Beyond such considerations, a more fundamental debate has recently been reignited in which the current FiT system is juxtaposed with a quota system as being applied, for example, in the United Kingdom and in Sweden. While proponents of the quota system refer to its alleged theoretical superiority (assuming well-functioning markets for green energy certificates), its critics point to a lack of investment security and the risk of creating a single renewable monoculture (investors going for the currently most cost-efficient technology) rather than a diversified mix of sources (Diekmann, Kemfert, Neuhoff, Schill, & Traber, 2012b). Bofinger (2013) argues that the added investment risks of a quota system would increase financing costs, which would ultimately increase costs for the consumer. He advocates a reverse bidding system as described above, pointing out that this would allow for price differentiation between renewable electricity suppliers, which would in turn minimize producer rents and thus also contribute to lower total costs for the consumer.

Considering Income Distribution Effects

Presently, exemptions from the EEG electricity surcharge are granted to energy-intensive enterprises meeting certain eligibility criteria. On the one hand, this has led to concerns about non-conformity with provisions of the EU competition law; on the other hand, the resulting cross-subsidization of industry by households—and of high-income households by low-income households—has triggered a debate on distributional justice, which increasingly jeopardizes popular support for Germany's energy transition. With electricity prices and the EEG surcharge bound to rise further, there is a need to find a balance between competition objectives (in support of energy-intensive industries operating on global markets) and income distribution objectives. This would require a broader look at the social security system with a view to alleviating the burden for low-income households. Furthermore, there is mounting evidence of political capture in terms of exemptions being granted to far too many companies not subject to global competition while exempted companies are not forced to improve the energy efficiency of their operations.

---

[42] For details see: Cozzi (2012); Altenburg & Engelmeier (2012); Pegels & Becker (in press); Pegels (2011); Becker & Fischer (2012).

Moving From Deployment to Innovation

The FiT scheme in its current form has primarily been a strong engine of pushing wind and solar PV capacity expansion. Price-based tariff incentives have favoured the early adoption and deployment of existing technologies, although not, however, the development of new technologies. Hence, it would appear to be time now to shift to a stronger emphasis on R&D incentives and to consider options for integrating elements of technological innovation into a revised FiT scheme.

Adopting an Energy System Approach

A broader issue coming to the fore now is the need to put the FiT provision into the systemic perspective of energy system requirements. As elaborated above (see Section 5.6), a growing mismatch between wind and solar capacity expansion, grid expansion and management, as well as energy storage facilities is endangering the German energy transition. More than hitherto, it will be necessary to coordinate the growing shares of wind and solar PV electricity with grid absorption capacity and stability boundaries. This only bears testimony to the fact that renewable electricity has grown from being a niche player to becoming an integral element of Germany's electricity system.[43] It may be worthwhile to consider introducing a time-related fine-tuning of future FiT tariffs, such as offering special incentives to "high value" feed-in for grid stabilization. The implications of a systemic perspective for broader green industrial policy aims are further elaborated below.

6.2 Green Industrial Policy in Germany: A Systemic Perspective

In terms of technology deployment, the German FiT-centred support system can indeed be considered a success. Both wind and solar PV capacity have seen tremendous growth rates. However, the effects on such aims of green industrial policy as innovation, energy security, environmental protection, competitiveness and employment are less evident.

Figure 15 seemingly presents an unequivocal outcome of the comparison between wind and solar support, showing the superior performance of wind energy for all indicators. However, the policy implications of these empirical findings are less clearcut than they may appear at first glance. Should all eggs be put into the wind basket? In the direct comparison of wind and solar energy, the answer could be "yes," on grounds of cost-efficiency and broader benefits. Yet just like in the case of financial investments, there are advantages to be had from diversification. Hence, Figure 15 needs to be interpreted dynamically and from a systemic perspective. While wind energy currently performs better, it may be wise to also support solar PV and, for that matter, a variety of other sources of renewable energy. The technology learning curve of solar PV may still promise strong cost reductions, while wind energy is already mature (Diekmann et al., 2012b). The solar resource and thus deployment potential in other world regions may further support these reductions. Once a particular energy source achieves grid parity, deployment may go up steeply and give other performance indicators a boost as well. Technologies in their earlier stages may also hold a higher potential for innovation than their mature counterparts. This includes solar PV, but also such other early stage renewables as offshore wind or tidal and wave energy. Innovation as an aim of green industrial policy could thus benefit from the support of diverse renewable energy technologies.

---

[43] On June 16, 2013, the contribution of wind and solar installations in meeting Germany's electricity demand reached a short-term record level of 61 per cent.

However, diversification as such does not guarantee success in fostering innovation and competitiveness. Has the German policy-induced creation of a lead market led to a first-mover advantage or disadvantage?[44] Is it more a question of the early bird catching the worm or the second mouse getting the cheese? On the one hand, Germany has succeeded in building up world-class renewable energy technologies and has captured large segments of the world market. If well exploited, this lead position can secure competitiveness, employment and positive innovation dynamics for years to come. On the other hand, there are strong elements at play here of other countries appropriating part of the benefits of Germany's lead market role. This may be seen as a "successful internationalization of the photovoltaic strategy (and) . . . a tribute to Germany's contribution to meeting global energy and climate challenges" (Diekmann et al., 2012a, p. 3). Alternatively and in a more pointed manner, the verdict may be that "German households have, through the renewable subsidies they pay, made the world a gift of solar technology which China has now been happy to exploit" (Buchan, 2012, p. 4).

Also from the perspective of the company profiles presented in Chapter 2, it would seem that in general, companies in the wind energy sector are exhibiting a sharper strategic focus, a stronger innovation drive and a distinct reliance on the strengths of the German manufacturing sector as compared to a tendency of parts of the solar PV sector to rely on standardized mass production with higher vulnerability to price-based competition.

Be that as it may, it is hard to escape the conclusion that the deployment of solar PV in particular has in recent years been out of line both with its long-term expansion potential and its reasonable relative weight within the renewable energy mix—in a country with less-than-ideal climatic conditions for heavy reliance on solar energy. Also, in the harsh judgment of Eicke Weber, Director of Fraunhofer ISE, "Germany's energy policy has created a market for photovoltaics—not an industry" (Paris Tech Review, 2012, p. 5). This indicates that deployment under the soft conditions of heavy subsidies was given priority, without sufficient attention to forming an innovative industry pushing the technological frontier. In a nutshell: expansion was put above upgrading. In the analysis of the CEO of SunnysideUp, a German solar consultancy, too many companies decided to "deliver a standard product in a growing market . . . we will lose if we just follow this race on a price level" (PV Magazine, 2011).

Moreover, at the broader level of the energy system and within a supply scenario increasingly based on renewable energy, a variety of different intermittent sources in the electricity grid are required to support overall grid stability—the sun may shine when the wind does not blow. This contributes to security of supply, in particular if investments in transmission lines keep pace and connect geographically dispersed locations of renewable electricity generation. Unfortunately, German investments in grid expansion and solutions for electricity storage lag behind requirements. At the same time, Germany will need to deploy a variety of renewable energy sources if it takes the *Energiewende* seriously. The generation potential of onshore wind energy alone will not suffice to cover the full requirements of German electricity demand.

The systemic perspective cannot, however, be restricted to renewables: the energy sector must be seen in its entirety. The pace of German renewable energy deployment has taken many actors by surprise. This has led to unintended effects on energy planning, which in turn affect the overall aims of green industrial policy, in particular its environmental dimension. To safeguard energy security, Germany currently builds two energy systems in parallel: a base-load focused, centralized and fossil fuel-based system; and an intermittent, decentralized and renewable system. These systems increasingly interact. To compensate for the phase-out of nuclear power, the German government has decided to support highly efficient new coal- and gas-fired power stations, financing this support out

---

[44] For a more thorough discussion of lead market strategies see the results of the Lead Markets project of the Centre for European Economic Research (ZEW) at http://kooperationen.zew.de/en/lead-markets/project-description.html.

of the Energy and Climate Fund (Deutsche Bundesregierung, 2012). Together with the unexpectedly high generation from renewable sources, Germany currently produces much more electricity than it consumes. In 2012, electricity exports exceeded imports by a record level of 22.8 terawatt hours (TWh), up from 6 TWh in 2011 and 17.6 TWh in 2010 (Statistisches Bundesamt, 2013). This oversupply, combined with low input prices and the low price of carbon emission certificates traded under the European Emissions Trading Scheme, lowers electricity prices to the extent that, at times, only the cheapest sources—hard coal and, in particular, lignite in the case of Germany—are still competitive. Lignite, however, is exceedingly damaging to the environment and human health. As a result, total German CO_2 emissions have been stagnating in the past four years, and even rising in 2012 (Umweltbundesamt, 2013b). Paradoxically, the rapid deployment of renewables thus does not currently lead to decreasing total GHG emissions.

At the same time, the low electricity prices at the electricity stock exchange do not improve the competitive position of small and medium enterprises. Including 99 per cent of German enterprises and providing more than 60 per cent of jobs (May-Strobl & Haunschild, 2013; BMWi, 2012), the *Mittelstand* is widely considered as the backbone of Germany's economy. However, their electricity prices are among the highest in Europe—at least partly due to the added cost of renewables (DIHK, 2012). The blow to the competitiveness of the largest electricity consuming companies is of course softened by exemptions from the electricity surcharge. These, however, call the equity of the current support system into question, as further elaborated above in Section 6.1 in the context of the FiT reform debate. Currently, the net effects of Germany's energy transition on overall employment remain unclear, since empirical studies concentrate on gross employment created by the emerging renewable energy industry.

To reach the broader aims of green industrial policy and manage the energy transition effectively, Germany will need to address the systemic challenges outlined above. Special emphasis is to be put on three broader dimensions: institutional fragmentation, interacting policy schemes and transformational alliances.

Institutional Fragmentation

As repeatedly mentioned in this study, the promotion of wind energy and solar PV in Germany is part of a much more fundamental agenda of transitioning to a decarbonized development trajectory. The contribution of renewables to electricity generation has reached proportions that call for simultaneous policy attention to capacity expansion, competitiveness, technological innovation, grid management and storage capacities—a systemic perspective. However—and this may be surprising for a country often portrayed as a poster child of institutional effectiveness—the current institutional setup leaves a lot to be desired. As pointed out in Section 3.1, several federal ministries have important roles to play, and specialized subsidiary agencies are proliferating. There is a strong case for pooling the political responsibilities, possibly in the form of creating a new Ministry of Energy. This could be all the more important given that in the typical German scenario of a coalition government there is a high likelihood of interlinked functions being spread across political party lines.

Interacting Policy Schemes

The FiT policy tool as the cornerstone of Germany's energy policy is not operating in complete isolation. In fact, it runs parallel to the European ETS. The interactions between both policy spaces thus need to be analyzed. On the one hand, it can be argued that any FiT-induced lowering of CO_2 emissions would lead to the availability of additional certificates, which, once sold, would generate corresponding emissions elsewhere.[45] On the other hand, the political decision of where exactly to fix a cap for emissions may itself be partly influenced by anticipating trends of future renewables capacity (Lechtenböhmer & Samadi, 2011, p. 10). In essence, the parallel operation of FiT and ETS will crowd out most of the former's emission reduction benefits—not, however, the other benefits it creates.

A second dimension of policy interaction is related to transcending national boundaries. Quite obviously, the multiplicity of national FiT schemes, for example, in the European Union, is an ineffective response to the potential of a unified European energy policy. A unified European, or even trans-Mediterranean, grid could largely balance out inherent grid instability caused by intermittent renewable energy sources. At the same time, there is a danger of a conceivable common approach being designed as the lowest common denominator of conflicting country interests. As a result, the more ambitious energy policy of Germany as a lead market for renewables may be severely compromised.

Transformative Alliances

Rightly or wrongly, green industrial policies in Germany are almost equated today with the energy transition. We are dealing with a national project of the first order. There are winners and losers, proponents and adversaries. In this economically and politically highly charged setting, the formation of transformative alliances and the definition of a compelling narrative are key (Schmitz, Johnson, & Altenburg, 2013; WRI & Greenpeace 2013). Such alliances may see unlikely bedfellows. Just as parts of the business establishment are embracing the transition and investing in the energy technologies of the future,[46] heavy resistance is coming from parts of the traditional green movement. Alliances will thus have to go beyond conventional boundaries.

Having created the largest lead market for upscaling deployment and having brought down prices of renewables is not going to be a winning argument in the public discourse. The German FiT-driven renewables revolution may have been "arguably the most successful development cooperation programme ever in this field" (Hombach, 2013), yet this is not the yardstick used by the public at large when assessing costs and benefits. In Germany, any transformative alliance can only succeed if it builds on a platform of employment, competitiveness and innovation. Furthermore, the creation of decentralized energy systems and hence strengthened regional and local economic structures (above all in economically weak regions) should be highlighted more than hitherto.

---

[45] "In the presence of a binding emissions cap, additional renewable policies of any kind do not affect emissions. Those additional policies can address other market failures, but their effects on the ETS should be recognized" (Fischer & Preonas, 2010, p. 30).

[46] This has become evident also in the current debate around EU protective measures against Chinese solar module imports. They are heavily opposed by the German machine-building industry, which is delivering approximately 80 per cent of all machinery for solar panel production to China.

References

Agentur für Erneuerbare Energien. (2012, November). *Akzeptanz und Bürgerbeteiligung für erneuerbare Energien, Renews Spezial.* Retrieved from http://www.unendlich-viel-energie.de/mediathek/hintergrundpapiere/?cont=145

Altenburg, T. (2011). *Industrial policy in developing countries: Overview and lessons from seven country cases* (Discussion Paper 4/2011). German Development Institute. Retrieved from http://www.die-gdi.de/CMS-Homepage/openwebcms3.nsf/(ynDK_contentByKey)/ANES-8EAHQ3/$FILE/DP%204.2011.pdf

Altenburg, T. & Engelmeier, T. (2012). *Rent management and policy learning in green technology development. The case of solar energy in India* (Discussion Paper 12/2012). German Development Institute. Retrieved from http://www.die-gdi.de/CMS-Homepage/openwebcms3.nsf/(ynDK_contentByKey)/ANES-8ZDH97/$FILE/DP%2012.2012.pdf

Altenburg, T. & Pegels, A. (2012). Sustainability-oriented innovation systems–managing the green transformation. *Innovation and Development*, 2(1), 5–22.

Andersen, C. (2012). *Makers: The new industrial revolution*. New York: Random House.

Arbeitsgruppe Erneuerbare Energien Statistik (AGEE-Stat). (2013, February 28). *Erneuerbare Energien 2012*. Retrieved from http://www.bmu.de/fileadmin/Daten_BMU/Pools/Broschueren/20130430_erneuerbare_energien_2012_bf.pdf

AGEE-Stat. (2012, July). *Zeitreihen zur Entwicklung der erneuerbaren Energien in Deutschland*. Retrieved from http://www.erneuerbare-energien.de/fileadmin/ee-import/files/pdfs/allgemein/application/pdf/ee_zeitreihe.pdf

Barua, P., Tawney, L., & Weischer, L. (2012, November). *Delivering on the clean energy economy: The role of policy in developing successful domestic solar and wind industries* (World Resources Institute Working Paper). World Resources Institute. Retrieved from http://pdf.wri.org/delivering_clean_energy_economy.pdf

Bazilian, M., Oneyeji, I., Liebreich, M., MacGill, I., Chase, J., Shah, J., Gielen, D., Arent, D., Landfear, D., & Zhengrong, S. (2013). Re-considering the economics of photovoltaic power. *Renewable Energy, 53* (2013), 329–338.

Becker, B. & Fischer, D. (2012). *Promoting renewable electricity generation in emerging economies* (Discussion Paper 9/2012). German Development Institute. Retrieved from http://www.die-gdi.de/CMS-Homepage/openwebcms3.nsf/(ynDK_contentByKey)/ANES-8VEC8P/$FILE/DP%209.2012.pdf

Bierenbaum, D., Frank, M., Lenox, M., & Maheshwari, R. (2012, April). *Winning the green innovation economy. An analysis of worldwide patenting.* Batten Institute, University of Virginia, Greentech Innovation Series. Retrieved from http://www.darden.virginia.edu/web/uploadedFiles/Darden/Batten_Institute/Publications/Greentech_041212_Email.pdf

Boeckle, R., Dua, M., Henriques, D., Simon, P., & Tronci, F. (2010, April 27). *The German wind technology cluster. Microeconomics of competitiveness.* Harvard Business School. Retrieved from http://www.isc.hbs.edu/pdf/Student_Projects/Germany_Wind_Power_2010.pdf

Bofinger, P. (2013). Förderung fluktuierender erneuerbarer Energien: Gibt es einen dritten Weg? Gutachten im Rahmen des Projekts „Stromsystem - Eckpfeiler eines zukünftigen Regenerativwirtschaftsgesetzes." Auftraggeber: Baden-Württemberg Stiftung gGmbH unter Federführung der IZES gGmbH. Retrieved from http://www.tagesspiegel.de/downloads/8809704/3/Bofinger%20Gutachten

Bointner, R. (2012). *Energy R&D expenditures and patents in selected IEA countries.* Proceedings of the Venice IAEE European Conference 2012. Retrieved from http://www.eeg.tuwien.ac.at/eeg.tuwien.ac.at_pages/publications/pdf/BOI_PRO_2012_2_abstract.pdf

BSW-Solar. (2013, February). *Statistic data on the German solar power (Photovoltaic) industry.* Retrieved from http://www.solarwirtschaft.de/fileadmin/media/pdf/2013_2_BSW-Solar_fact_sheet_solar_power.pdf

Buchan, D. (2012, June). *The Energiewende—Germany's gamble.* The Oxford Institute for Energy Studies. SP 26. Retrieved from http://www.oxfordenergy.org/wpcms/wp-content/uploads/2012/07/SP-26.pdf

Bundesministerium für Umwelt (BMU). (2012, July). *Erneuerbare Energien in Zahlen. Nationale und internationale Entwicklung.* Retrieved from http://www.bmu.de/fileadmin/Daten_BMU/Pools/Broschueren/ee_in_zahlen_bf.pdf

Bundesministerium für Wirtschaft und Technologie (BMWi). (2012). *German Mittelstand: Motor der deutschen Wirtschaft.* Retrieved from http://www.bmwi.de/BMWi/Redaktion/PDF/Publikationen/factbook-german-mittelstand,property=pdf,bereich=bmwi2012,sprache=de,rwb=true.pdf

Bundesministerium für Wirtschaft und Technologie (BMWi). (2013, April). *Energiewende auf Erfolgskurs.* Retrieved from http://www.bmwi.de/BMWi/Redaktion/PDF/E/energiewende-auf-erfolgskurs,property=pdf,bereich=bmwi2012,sprache=de,rwb=true.pdf

Bundesministerium für Wirtschaft und Technologie (BMWi)/Bundesministerium für Umwelt (BMU). (2011, September 28). *Research for an environmentally sound, reliable and affordable energy supply.* Retrieved from http://www.bmwi.de/English/Redaktion/Pdf/6th-energy-research-programme-of-the-federal-government,property=pdf,bereich=bmwi2012,sprache=en,rwb=true.pdfw

Bundesnetzagentur (2013). *Netze zukunftssicher gestalten.* Retrieved from http://www.netzausbau.de/cln_1911/DE/Projekte/EnLAG-Monitoring/enlag-monitoring_node.html;jsessionid=A53EEFE951E13788AA59DF11279A6607

Bundesverband der Energie- und Wasserwirtschaft (BDEW). (2013, January 31). *Erneuerbare Energien und das EEG: Zahlen, Fakten, Grafiken (2013).* Retrieved from https://www.bdew.de/internet.nsf/id/17DF3FA36BF264EBC1257B0A003EE8B8/$file/Energieinfo_EE-und-das-EEG-Januar-2013.pdf

Bundesverband WindEnergie. (2012). *Jahresbilanz Windenergie, Facts to Go 2012.* Retrieved from http://www.wind-energie.de/sites/default/files/download/publication/jahresbilanz-facts-go/20130313_bwe_facts-to-go_final.pdf

Bundesverband Solarwirtschaft. (2013). *Statistische Zahlen der deutschen Solarstrombranche (Photovoltaik).* Retrieved from www.solarwirtschaft.de/fileadmin/media/pdf/2013_2_BSW_Solar_Faktenblatt_Photovoltaik.pdf

Cleantech Magazine. (2012). Wind turbine manufacturers—Global market shares. *Cleantech Magazine, 6*(2). Retrieved from http://www.cleantechinvestor.com/portal/wind-energy/10502-wind-turbine-manufacturers-global-markt-shares.html

Cozzi, P. (2012, May). *Assessing reverse auctions as a policy tool for renewable energy development.* The Center for International Environment & Resource Policy, Tufts University. Retrieved from http://fletcher.tufts.edu/CIERP/Publications/more/~/media/Fletcher/Microsites/CIERP/Publications/2012/May12CozziReverseAuctions.pdf

Deutsche Bundesregierung. (2012). *Gelder aus dem Energie- und Klimafonds für das Förderprogramm für fossile Kraftwerke, Antwort der Bundesregierung auf die Kleine Anfrage der Abgeordneten* Oliver Krischer, Sven-Christian Kindler, Hans-Josef Fell, weiterer Abgeordneter und der Fraktion BÜNDNIS 90/DIE GRÜNEN. Drucksache 17/8674, 14 February 2012. Retrieved from http://dipbt.bundestag.de/dip21/btd/17/086/1708674.pdf

Deutsche Energie-Agentur (DENA). (2013, July). *Die Energiewende—das neue System gestalten*. Berlin. Retrieved from http://www.dena.de/fileadmin/user_upload/Newsletter/pdf-ausgaben/deutsch/20130722_Newsletter_03_RZ.pdf

Deutsche Industrie- und Handelskammer (DIHK). (2012). *Faktenpapier Strompreise in Deutschland.* Retrieved from http://www.dihk.de/presse/jahresthema-2012/faktenpapier-strompreise.pdf

Deutsche Rohstoffagentur (DERA). (2012). *Energy study 2012. Reserves, resources and availability of energy resources.* Hannover. Retrieved from http://www.bgr.bund.de/DE/Gemeinsames/Produkte/Downloads/DERA_Rohstoffinformationen/rohstoffinformationen-15e.pdf;jsessionid=82C6AED102BE91642D81F307DE0550A2.1_cid289?__blob=publicationFile&v=3

Deutsche Welle (DW). (2012, June 16). Chinese exports crushing German solar industry. Retrieved from http://www.dw.de/chinese-exports-crushing-german-solar-industry/a-16031596

Deutsche WindGuard. (2012). *Calendar Year 2012. Status of Wind Energy Development in Germany.* Retrieved from http://www.wind-energie.de/sites/default/files/attachments/page/statistics/fact-sheet-en-2012-12-31.pdf

Die Stiftung Offshore-Windenergie. (n.d.). *Sprachrohr der Offshore-Windenergie in Deutschland.* Retrieved from http://www.offshore-stiftung.com/Offshore/aktuelles/-/51,51,60005,liste9.html

Diekmann, J., Kemfert, C., & Neuhoff, K. (2012a). The proposed adjustment of Germany's renewable energy law—A critical assessment. *DIW Economic Bulletin 2*(6), 3–9.

Diekmann, J., Kemfert, C., Neuhoff, K., Schill, W. & Traber, T. (2012b). *Erneuerbare Energien: Quotenmodell keine Alternative zum EEG, DIW Wochenbericht,* 45, 15–23.

Dosi, G., & Galambos, L. (Eds.) (2013). *The third industrial revolution in global business.* Cambridge: Cambridge University Press.

Eichhammer, W., & Walz, R. (2009, September). *Indicators to measure the contribution of energy efficiency and renewables to the Lisbon targets.* Karlsruhe: Fraunhofer Institute for Systems and Innovation Research (Fraunhofer ISI). Retrieved from http://www.odyssee-indicators.org/publications/PDF/report_competitiveness_indicators.pdf

Enercon. (2010, August). *Wind Energy Converters PartnerKonzept.* Retrieved from http://www.enercon.de/p/downloads/Enercon_EPK_uk.pdf

EurActiv. (2012, November 30). *EU probes alleged misuse of Germany's green energy incentives.* Retrieved from www.euractiv.com/search/apachesolr_search/eu%20probes%20alleged%20misuse

EurObserv'ER. (2013, April). *Photovoltaic Barometer.*

European Commission. (2008, January). *The support of electricity from renewable energy sources* (Commission Staff Working Document). Brussels: European Commission. Retrieved from http://ec.europa.eu/energy/climate_actions/doc/2008_res_working_document_en.pdf

European Commission. (2011, December 15). *Energy roadmap 2050: Impact assessment and scenario analysis.* Brussels: European Commission. Retrieved from http://ec.europa.eu/energy/energy2020/roadmap/doc/roadmap2050_ia_20120430_en.pdf

European Commission. (2012, October). *PV Status Report 2012* (JRC Scientific and Policy Reports).

European Court Reports (2001). Judgment of the Court of 13 March 2001, Case C-379/98. Retrieved from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:61998J0379:EN:HTML#SM

European Photovoltaic Industry Association (EPIA). (2012, September 24). *Economic benefits of solar photovoltaics.* The PV value chain (EPIA Fact Sheet).

Federal Ministry for the Environment (BMU). (2012, August). *Renewably employed. Short- and long-term impacts of the expansion of renewable energy on the German labour market.*

Fischer, C. & Preonas, L. (2010 March). *Combining policies for renewable energy. Is the whole less than the sum of its parts?* (Resources for the Future Discussion Paper). Retrieved from http://www.rff.org/documents/RFF-DP-10-19.pdf

Fraunhofer ISE. (2012, May). *Levelized cost of electricity. Renewable Energies.* Freiburg. Retrieved from http://www.ise.fraunhofer.de/en/publications/veroeffentlichungen-pdf-dateien-en/studien-und-konzeptpapiere/study-levelized-cost-of-electricity-renewable-energies.pdf

Fraunhofer IWES. (2013). *Wind energy report Germany 2012.* Kassel.

Frondel, M., Ritter, N., Schmidt, C., & Vance, C. (2009). *Economic impacts from the promotion of renewable energy technologies. The German experience* (Ruhr Economic Papers, No. 156). Retrieved from http://www.rwi-essen.de/media/content/pages/publikationen/ruhr-economic-papers/REP_09_156.pdf

German Solar Industry Association (BSW-Solar). (2013, June). *Statistical data on the German solar power (photovoltaic) industry.*

Germany Trade & Invest (GTAI). (2013a, June). *Industry overview. The photovoltaic market in Germany.*

GTAI. (2013b, March). *Gemany's wind energy industry. Market conditions, investment environment and business opportunities.*

Global Wind Energy Council. (2013, April). *Global wind report. Annual market update 2012.*

Grau, T. (2012). Targeted support for new photovoltaic installations requires flexible and regular adjustments. *DIW Economic Bulletin, 2*(6), 11–15.

Grau, T., Huo, M., & Neuhoff, K. (2011, March). Survey of photovoltaic industry and policy in Germany and China (Climate Policy Initiative (CPI) Report). Retrieved from http://www.diw.de/documents/publikationen/73/diw_01.c.373394.de/dp1132.pdf

Greenpeace & German Wind Energy Association (BWE). (2012, August). *The full costs of power generation. A comparison of subsidies and societal cost of renewable and conventional energy sources.* Retrieved from http://www.foes.de/pdf/2013-03-full-costs-of-power-generation.pdf

Groba, F., Indvik, J., & Jenner, S. (2011). *Assessing the strength and effectiveness of renewable electricity feed-in tariffs in European Union countries* (Deutsches Institut für Wirtschaftsforschung Discussion Papers, No. 1176). Retrieved from http://www.diw.de/documents/publikationen/73/diw_01.c.390079.de/dp1176.pdf

Haas, R., Panzer, C., Resch, G., Ragwitz, M., Reece, G., & Held, A. (2011). A historical review of promotion strategies for electricity from renewable energy sources in EU countries. *Renewable and Sustainable Energy Reviews, 15,* 1003–1034.

Held, A., Haas, R., & Ragwitz, M. (2006). On the success of policy strategies for the promotion of electricity from renewable energy sources in the EU. *Energy and Environment, 17,* 849–868.

Hombach, B. (2013, January 15). *Deutsche Stromrevolution in armen Ländern, Handelsblatt.* Retrieved from http://www.handelsblatt.com/meinung/kolumnen/werber-rat/der-werber-rat-deutsche-stromrevolution-in-armen-laendern/7616230.html

International Energy Agency. (2012). *Oil & gas security. Emergency response of IEA countries.* Germany. OECD/IEA 2012. Retrieved from http://www.iea.org/publications/freepublications/publication/name,34977,en.html

Jordan-Korte, K. (2011). *Government promotion of renewable energy technologies. Policy approaches and market development in Germany, the United States and Japan.* Wiesbaden: Springer Gabler.

KfW (n.d.). *Renewable energy.* Retrieved from www.kfw.de/inlandsfoerderung/Companies/Renewable-energies/

KfW and Federal Environment Ministry launch programme to promote use of energy storage in solar PV installations. (2013). Press release. Retrieved from http://www.kfw.de/KfW-Group/Newsroom/Aktuelles/Pressemitteilungen/Pressemitteilungen-Details_107136.html

Krewitt, W. & Schlomann, B. (2006, April 6). *Externe Kosten der Stromerzeugung aus erneuerbaren Energien im Vergleich zur Stromerzeugung aus fossilen Energieträgern.* Retrieved from http://www.erneuerbare-energien.de/fileadmin/ee-import/files/erneuerbare_energien/downloads/application/pdf/ee_kosten_stromerzeugung.pdf

Krugman, P. (1994). Competitiveness: A dangerous obsession. *Foreign Affairs, 2*(73), 28–44.

Langness, O. (2006, September 6). *The German 250-MW wind program.* Retrieved from http://www.resource-solutions.org/pub_pdfs/German_250_MW_Wind_II.pdf

Lechtenböhmer, S. & Samadi, S. (2011, March). *Brief analysis on the current debate about costs and benefits of expanding the use of renewable energies in electricity generation.* Wuppertal Institute for Climate, Environment and Energy. Retrieved from http://boell.org/downloads/Wuppertal-engl.pdf

Lee, B., Iliev, I. & Preston, B. (2009, September). *Who owns our low carbon future? Intellectual property and energy technologies* (Chatham House Report). London: Chatham House.

Lehr, U. (2009). *More baskets? Renewable energy and energy security* (Gesellschaft für wirtschaftliche Strukturforschung (GWS) Discussion Paper, 2009/8). Retrieved from http://www.gws-os.com/discussionpapers/gws-paper09-8.pdf

Lehr, U., Breitschopf, B., Diekmann, J., Horst, J., Klobasa, M., Sensfuß, F. & Steinbach, J. (2012). *Renewable energy development—Do the benefits outweigh the costs?* (GWS Discussion Paper, 2012/5). Retrieved from http://www.gws-os.com/discussionpapers/gws-paper12-5.pdf

Lehr, U. & Drosdowski, T. (2013, March). *Soziale Verteilungswirkungen der EEG-Umlage* (GWS Discussion Paper 2013/3). Retrieved from http://www.gws-os.com/discussionpapers/gws-paper13-3.pdf

Lema, R., Berger, A., & Schmitz, H. (2012). *China's impact on the global wind power industry* (German Development Institute Discussion Paper 16/2012). Bonn: Deutsches Institut für Entwicklungspolitik gGmbH. Retrieved from http://www.die-gdi.de/CMS-Homepage/openwebcms3_e.nsf/(ynDK_contentByKey)/ANES-92WG9J/$FILE/DP%2016.2012.pdf

Lütkenhorst, W. (2010, August 4). A changing climate for industrial policy. *Making It Magazine: Industry for Development, 3,* 16–19.

Marsh, P. (2012). *The new industrial revolution: Consumers, globalization and the end of mass production.* New Haven: Yale University Press.

Matschoss, P. (2013). *The German energy transition. Status, challenges and the Finnish perspective* (FIIA Briefing Paper, No. 128). Retrieved from http://www.fiia.fi/en/publication/338/#.Uq-AFPRDu9U

May-Strobl, E., & Haunschild, L. (2013). *Der nachhaltige Beschäftigungsbeitrag von KMU. Eine sektorale Analyse unter besonderer Berücksichtigung der FuE-und wissensintensiven Wirtschaftszweige.* Bonn: Institut für Mittelstandsforschung, Materialien Nr. 206. Retrieved from http://www.ifm-bonn.org//uploads/tx_ifmstudies/IfM-Materialien-206_01.pdf

Morris, A., Nivola, P., & Schultze, C. (2012). Clean energy: Revisiting the challenges of industrial policy. *Energy Economics, 34,* 534–542.

Navigant Research. (2013, March). *Wind market update 2012.*

Nordex und Vestas: Krise schüttelt Windradbauer durch. (2012, September 14). *Financial Times Deutschland.*

O'Sullivan, M., Edler, D., Bickel, P., Lehr, U., Peter, F. & Sakowski, F. (2013). *Bruttobeschäftigung durch erneuerbare Energien in Deutschland im Jahr 2012* (BMU research project 0324052B). Retrieved from http://www.erneuerbare-energien.de/fileadmin/Daten_EE/Dokumente__PDFs_/bruttobeschaeftigung_ee_2012_bf.pdf

Ölz, S., Sims, R., & Kirchner, N. (2007, April). *Contribution of renewables to energy security* (IEA Information Paper, OECD/IEA). Retrieved from http://www.iea.org/publications/freepublications/publication/so_contribution.pdf

Paris Tech Review. (2012, April 13). *The German solar energy crisis: Looking for the right incentive scheme.* Retrieved from http://www.paristechreview.com/2012/04/13/german-solar-crisis/?media=print

Pegels, A. (2011). Pitfalls of policy implementation: The case of the South African feed-in tariff. In H. Haselip I. Nygaard, U. Hansen, & E. Ackom (Eds.), *Diffusion of renewable energy technologies: Case studies of enabling frameworks in developing countries* (pp. 101–-110). UNEP Risoe Center Technology Transfer Perspectives Series.

Pegels, A. & Becker, B. (in press). Implementing green industrial policy. In Pegels, A. (Ed.), *Green industrial policy in emerging countries.* London: Routledge.

Pegels, A. (Ed.). (in press). *Green industrial policy in emerging countries.* London: Routledge.

Photon. (2013). Aus der Traum. *Photon, 1,* 16–24.

PriceWaterhouseCoopers. (2010). *Die deutsche Photovoltaik-Branche am Scheideweg.*

PriceWaterhouseCoopers. (2012, February 2). *Unter Strom—Ausbau der Offshore-Windkraft schafft bis zu 18.000 neue Jobs.* Retrieved from http://www.pwc.de/de/pressemitteilungen/2012/unter-strom-ausbau-der-offshore-windkraft-schafft-bis-zu-18.000-neue-jobs.jhtml

Prognos. (2011). *Organische Photovoltaik – eine Technologie mit Potenzial, Prognos trendletter 2/2011.* Retrieved from http://www.prognos.com/fileadmin/pdf/publikationen/trendletter/trendletter_2011_2_Energiewende_Seite_12.pdf

PV Magazine. (2011, March 18). Importance of PV module quality to increase. Retrieved from www.pv-magazine.com/news/details/beitrag/importance-of-pv-module-quality-to-increase_100002460/#axzz22Up5WzYb

PV Magazine. (2013a, April 16). Thin film opportunities as PV downturn draws to a close. Retrieved from www.pv-magazine.com/news/details/beitrag/thin-film-opportunities-as-pv-downturn-draws-to-a-close_100010920/#axzz2ZgYfTiWP

PV Magazine. (2013b, April 22). Wind-solar hybrid plants up to twice as efficient. Retrieved from www.pv-magazine.com/news/details/beitrag/wind-solar-hybrid-plants-up-to-twice-as-efficient_100010997/#axzz2ZgYfTiWP

PV Magazine. (2013c, May 2). Fall in market share for top ten PV inverter suppliers. Retrieved from http://www.pv-magazine.com/news/details/beitrag/fall-in-market-share-for-top-ten-pv-inverter-suppliers_100011132/#axzz2dpu7XsWu

Quitzow, R. (2012, October 31). *Green investment in Germany: The case of solar energy.* Presentation at UNEP Workshop on Green Investment, Beijing.

Renews Spezial. (2013, August). *Bioenergie im Strommarkt der Zukunft, No.67.*

Research at Alpha Ventus. (2010, September). Retrieved from http://rave.iwes.fraunhofer.de/raveResources/welcome/RAVE_Brochure_e_komplett_www.pdf

Rifkin, J. (2011). *The third industrial revolution. How lateral power is transforming energy, the economy, and the world.* New York: Palgrave Macmillan.

Schmitz, H., Johnson, O., & Altenburg, T. (2013). *Rent management—The heart of green industrial policy* (IDS Working Paper no. 418). Retrieved from http://www.ids.ac.uk/files/dmfile/Wp418.pdf

Solarpraxis. (2012, October). *Solar Energy in Germany.*

Statistisches Bundesamt. (2013, February 2). *Deutschland exportierte auch 2012 mehr Strom als es importierte* (press release). Retrieved from www.destatis.de/DE/PresseService/Presse/Pressemitteilungen/2013/04/PD13_125_51pdf.pdf

Swissolar. (2008, June). *Energie- und Umweltbilanz der Solarenergie.* Retrieved from http://www.nw.ch/dl.php/de/4f313d1caf012/Energie-_und_Umweltbilanz_der_Soalrenergie.pdf

The Economist. (2012, April 21). A third industrial revolution. Special Report Manufacturing and Innovation. Retrieved from http://www.economist.com/node/21552901

Umweltbundesamt. (2013, June). *Potenzial der Windenergie an Land.* Retrieved from http://www.umweltbundesamt.de/daten/energie-als-ressource/potenzial-der-windenergie-an-land

Umweltbundesamt (2013a, February). *Emissionsbilanz erneuerbarer Energieträger. Durch Einsatz erneuerbarer Energien vermiedene Emissionen im Jahr 2012.* Retrieved from http://www.umweltbundesamt.de/uba-info-medien/3761.html

Umweltbundesamt (2013b, February). *Treibhausgasausstoss in Deutschland 2012 – vorläufige Zahlen aufgrund erster Berechnungen und Schätzungen des Umweltbundesamtes.* Retrieved from http://www.umweltbundesamt.de/publikationen/treibhausgasausstoss-in-deutschland-2012

United Nations Industrial Development Organisation (UNIDO). (2011). *Industrial policy for prosperity: Reasoning and approach* (Development Policy, Statistics and Research Branch Working Paper 2/2011). Retrieved from http://www.unido.org/fileadmin/media/documents/pdf/Publications/111125/WP022011_Ebook.pdf

Urban, F., Nordensvärd, J., Lema, R., & Moller Andersen, S. (in press). *Technological trajectories project: Wind energy in Europe (Germany and Denmark).*

Wilke, M. (2011, August). *Feed-in tariffs for renewable energy and WTO subsidy rules. An initial legal review* (International Centre for Trade and Sustainable Development, Issue paper No. 4). Retrieved from http://ictsd.org/downloads/2011/11/feed-in-tariffs-for-renewable-energy-and-wto-subsidy-rules.pdf

Windräder: Wind gesät, Flaute geerntet. (2012, August 15). *Financial Times Deutschland.*

Windkraftbranche: Enercon zeigt wie's geht. (2012, September 16). *Financial Times Deutschland.*

World Wildlife Fund & World Resources Institute. (2013, June). *Meeting renewable energy targets: Global lessons from the road to implementation.* Retrieved from http://awsassets.panda.org/downloads/meeting_renewable_energy_targets__low_res_.pdf

Zhang, F. (2013, February). *How fit are feed-in tariff policies? Evidence from the European wind market* (World Bank Policy Research Working Paper 6376). Retrieved from http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2013/02/27/000158349_20130227084149/Rendered/PDF/wps6376.pdf

Further details and contact information

For further information contact Lucy Kitson at +41 22 917-8869 or Damon Vis-Dunbar at +41 22 917-8848

International Institute for Sustainable Development
Global Subsidies Initiative
International Environment House 2, 9 chemin de Balexert, 1219 Châtelaine, Geneva, Switzerland
Tel: +41 22 917-8373 | Fax: +41 22 917-8054

www.iisd.org/gsi

GSI is an initiative of the International Institute for Sustainable Development