SRU German Advisory Council on the Environment

Shaping the Electricity Market of the Future

Special Report

November 2013

German Advisory Council on the Environment (Sachverständigenrat für Umweltfragen – SRU)

Prof. Dr. Martin Faulstich
(Chair)

Professor of Environmental and Energy Technology
at the Clausthal University of Technology and
Director of CUTEC Institute of Environmental Technology

Prof. Dr. Karin Holm-Müller
(Deputy Chair)

Professor Resource and Environmental Economics
at the Department of Agricultural at the
Rheinische Friedrich Wilhelm University, Bonn

Prof. Dr. Harald Bradke

Honorary Professor at the University of Kassel and
Head of the Competence Center for Energy Technologies
and Energy Systems at the Fraunhofer Institute for Systems
and Innovation Research ISI in Karlsruhe

Prof. Dr. Christian Calliess

Professor of Public Law, especially Environmental Law, and European Law
at the the Freie Universität, Berlin

Prof. Dr. Heidi Foth

Professor of Environmental Toxicology and
Director of the Institute of Environmental Toxicology at
the Martin Luther University, Halle-Wittenberg

Prof. Dr. Manfred Niekisch

Professor of International Nature Conservation
at the Goethe University, Frankfurt, and
Director of Frankfurt Zoo

Prof. Dr. Miranda Schreurs

Professor of Comparative Politics and
Director of the Environmental Policy Research Centre
at the Freie Universität, Berlin

This report is based on the expert and dedicated work of the staff of the SRU. During the work on this report, the scientific staff of the SRU included:

DirProf. Dr. phil. Christian Hey (Secretary General), Dipl.-Pol. Julia Hertin (Deputy Secretary General), Dr.-Ing. Mechthild Baron, Dr. rer. nat. Henriette Dahms, Dr. rer. nat. Ulrike Doyle, Ass. iur. Miriam Dross LL.M., Dipl.-Vw. Carl-Friedrich Elmer, Dipl.-Geogr. Stefanie Jung, M.Sc. Ann Kruse, Dipl.-Ing. agr. Till Kuhn, Lisa Nabitz M.A., Dr. rer. nat. Markus Salomon, Dr. rer. nat. Elisabeth Schmid, Dr. phil. Sibyl D. Steuwer, Dr. agr. Sabine Täuber, Annette Volkens M.A., Ass. iur. Sophie Wiegand, Dipl. Ernähr. Jan Wiese.

The staff of the SRU Office also included: Petra Busch, Ute Fritsch, Susanne Junker, Rainer Kintzel, Pascale Lischka, Dipl.-Bibl. (FH) Susanne Winkler and Sabine Wuttke.

Geschäftsstelle des Sachverständigenrates für Umweltfragen (SRU)
Luisenstraße 46, 10117 Berlin, Germany
Tel.: +49 (0)30 26 36 96-0, Fax: +49 (0)30 26 36 96-109
info@umweltrat.de, http://www.umweltrat.de

(Copy deadline: 30 September 2013)

Acknowledgements

The SRU wishes to thank the representatives of the ministries and agencies at federal and *Länder* level and the representatives of the academic world and stakeholder groups that it consulted, without whose knowledge, research and experience this report would not have been possible:

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU): MinDir Dr. Urban Rid, MinDirig Franzjosef Schafhausen, RDir Dr. Volker Oschmann, Dania Röpke, Kristin Walter

Federal Ministry of Economics and Technology (BMWi): MinR Michael Schultz, MinR'in Stephanie von Ahlefeldt, RDir Dr. Stefanie Neveling

Federal Environment Agency (UBA): Thomas Klaus

8KU: Dr. Matthias Dümpelmann, Executive Manager, Berlin Office

Agora Energiewende: Dr. Patrick Graichen, Deputy Director

British Embassy, Berlin: Kristin Reißig

Bundesverband Erneuerbare Energie (BEE): Harald Uphoff, Deputy Managing Director

Bundesverband der Energie- und Wasserwirtschaft (BDEW): Dr. Stephan Krieger

Deutsches Institut für Wirtschaftsforschung (DIW): Prof. Karsten Neuhoff, Ph.D.

Ecofys: Max Rathmann, Dr. Steffen Jenner

Fraunhofer-Institut für System- und Innovationsforschung ISI: Dr. Mario Ragwitz, Business Field Manager, Renewable Energy

FU Berlin, Forschungsstelle für Umweltpolitik: PD Dr. Achim Brunnengräber

Helmholtz Centre for Environmental Research (UFZ): Prof. Dr. Erik Gawel

Institute for Advanced Sustainability Studies (IASS): Dr. David Jacobs, Project Manager, Energiewende, Dr. Kathrin Goldammer

IZES – Institut für ZukunftsEnergieSysteme: Prof. Dr. Uwe Leprich

The Regulatory Assistance Project: Andreas Jahn

Verband der Industriellen Energie- und Kraftwirtschaft (VIK): Dr. Annette Loske, Executive Secretary

Verband kommunaler Unternehmen (VKU): Michael Wübbels, Deputy Executive Secretary

University of Würzburg: Prof. Dr. Peter Bofinger

At its meetings, the SRU held two hearings at which it investigated the views of representatives of the academic world and important industrial and environmental associations. In the course of 2013 consultations and meetings were held with the relevant departments of the Federal Environment Ministry (BMU) and the Federal Economics Ministry (BMWi).

A major contribution to the report was made by Dr. rer. pol. Patrick Matschoss. He helped to draw up the essential design features of an electricity market in a system based largely on renewable energy, and analysed the need for and design of capacity mechanisms.

In recent years, members of the SRU and its office have also taken part in numerous meetings and events. Such events provide the SRU with important suggestions and contacts for its report work, and also afford opportunities to keep its work in line with the latest developments in the ongoing discussion:

- “Direktvermarktung EEG”, Clearingstelle EEG, Berlin (23.11.2012)
- Event with a delegation from the UK Energy and Climate Ministry on European Climate and Energy Policy after 2020, British Embassy (29.01.2013)
- “Zukunft des EEG”, Agora-Energiewende, Berlin (13.02.2013)
- “Strompreis als Effizienzanreiz?” Forum Ökologisch-Soziale Marktwirtschaft, Berlin (13.02.2013)
- “Energiemarkt im Wandel – zur Rolle von Verbraucherpolitik, Wettbewerb und Regulierung”, Bundesnetzagentur/Verbraucherzentrale Bundesverband, Berlin (18.02.2013)
- “Jenseits des Völkerrechts: Klima-Koalitionen der Willigen als Alternative”, Deutsche Gesellschaft für Auswärtige Politik, Berlin (18.02.2013)
- “Erneuerbare (neu) vernetzt! intelligent – stabil – bezahlbar – bürgernah. 3. Kongress der DUH zum Umbau der Stromnetze, Deutsche Umwelthilfe, Berlin (19./20.02.2013)
- “Der Strommarkt der Zukunft – zwischen Quotenmodell und Kapazitätsmarkt”, Gesellschaft zum Studium strukturpolitischer Fragen, Berlin (28.02.2013)
- “Weltweiter Erdgasboom: Verliert Europa den Anschluss?”, Shell Energiedialog (28.02.2013)
- “EEG Dialog: Ausbaupfade, Szenarien, Kosten, Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit”, Berlin (05.03.2013)
- “So geht Energiewende!”, Bündnis 90/Die Grünen, Berlin (07.03.2013)
- “Energiesysteme für eine Low-Carbon Society”, Deutsches Klima Konsortium, Berlin (11.03.2013)
- “Französisch-deutscher Energiekongress”, Energy Cities, Stuttgart (19.03.2013)
- “Netzausbau in Deutschland und den europäischen Nachbarländern – Ist weniger mehr?” DIW/Stiftung Mercator/Technische Universität Berlin, Berlin (05.04.2013)
- “Treffen Netzwerk Energiewende”, Deutsche Umwelthilfe, Berlin (08.04.2013)

- "Energiewende – Europäisch denken!", Heinrich Böll Stiftung, Berlin (09./10.04.2013)
- "18. Umweltrechtliches Symposium, Versorgungssicherheit in der Energiewende", Universität Leipzig, Leipzig (18.04.2013)
- Dialogforum "Speicher, Netze, Last- und Einspeisemanagement – Wie kann die Integration der erneuerbaren Energien effizient erfolgen?", Deutsche Energie-Agentur (dena), Berlin (24.04.2013)
- "Netzausbau mit der Natur – Lösungen für die Energiewende im Dialog", Bundesamt für Naturschutz, Berlin (15.05.2013)
- "Energiemesse 2013", St. Gallen (23.05.2013)
- "Berliner Energiekonferenz – Dezentrale Energieversorgung", Technische Universität Dresden/TK-Verlag, Berlin (24.06.2013)
- "Die Rolle der Europäischen Union für die Energiewende", Heinrich-Böll-Stiftung, Stuttgart (26.06.2013)
- "Leibnitz Forschungsinitiative – Energie 2050", Universität Hannover, Hannover (11.07.2013)
- "Workshop zur strategischen Weiterentwicklung des EEG", Senat der Freien und Hansestadt Hamburg, Hamburg (30.08.2013)
- "Energiewende in den Bundesländern – Akzeptanz stärken", Agentur für Erneuerbare Energien, Berlin (03.09.2013)
- "DWA Energietage – Biogas", Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall (DWA), Garching (09.09.2013)
- "Energiewende", Deutscher Akademischer Austauschdienst (DAAD), Berlin (19.09.2013)

The members of the German Advisory Council on the Environment take full responsibility for this report.

Contents

List of figures

Glossary and List of abbreviations

acatech	=	Deutsche Akademie der Technikwissenschaften
Advanced Adiabatic Compressed Air Energy Storage (AA-CAES)	=	In Advanced Adiabatic Compressed Air Energy Storage (AA-CAES) the heat of the compressed air is temporarily stored in a heat storage system. This takes the form of a solid storage unit.
Backloading	=	Postponing auctions and withdrawing emission allowances in the European emissions trading scheme
Back-up capacity	=	Reserve capacity for generating electricity in situations of unusual relative supply scarcity
BDEW	=	Bundesverband der Energie- und Wasserwirtschaft (Federal Association of the Energy and Water Industries)
BDH	=	Bundesindustrieverband Deutschland Haus-, Energie- und Umwelttechnik e. V. (Federal Industrial Association of Germany House, Energy and Environmental Technology)
BDI	=	Bundesverband der Deutschen Industrie e. V. (Federation of German Industry)
BEE	=	Bundesverband Erneuerbare Energie e. V. (Federal Association for Renewable Energy)
BET	=	Büro für Energiewirtschaft und Technische Planung GmbH
BMBF	=	Federal Ministry of Education and Research
BMELV	=	Federal Ministry of Food, Agriculture and Consumer Protection
BMF	=	Federal Ministry of Finance
BMU	=	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
BMVBS	=	Federal Ministry of Transport, Building and Urban Development
BMWi	=	Federal Ministry of Economics and Technology

BNetzA	=	Bundesnetzagentur (Federal Network Agency)
BSH	=	Bundesamt für Seeschifffahrt und Hydrographie (Federal Institute for Navigation and Hydrography)
C	=	Carbon
CAES	=	Compressed Air Energy Storage
CCL	=	Climate Change Levy
CH_4	=	Methane
Clearing	=	Transmission, reconciliation and, if necessary, confirmation of transactions and ensuring their settlement
CO_2	=	Carbon dioxide
Day-ahead market	=	Trade in electricity that is to be generated and supplied the next day. Trade in 24-hour blocks at constant capacity for base-load demand, peak-load blocks for several hours' increased demand and contracts for individual hours.
dena	=	Deutsche Energieagentur (German Energy Agency)
Dispatch	=	Decision on the deployment of the various adjustable power stations available
DIW	=	Deutsches Institut für Wirtschaftsforschung (German Institute for Economic Research)
ECC	=	European Commodity Clearing AG
EEG	=	Erneuerbare-Energien-Gesetz (Renewable Energy Source Act)
EEX	=	European Energy Exchange AG
EnergieStG	=	Energiesteuergesetz (Energy Tax Act)
EnWG	=	Energiewirtschaftsgesetz (Energy Industry Act)
ErdölBevG	=	Erdölbevorratungsgesetz (Energy Stockpiling Act)

EWI	=	Energiewirtschaftliches Institut der Universität Köln (Energy Institute of the University of Cologne)
Fischer-Tropsch synthesis	=	Large-scale process for liquefaction of coal into a broad spectrum of gaseous and liquid hydrocarbons
Fraunhofer ISE	=	Fraunhofer-Institut für Solare Energiesysteme (Fraunhofer Institute for Solar Energy Systems)
FVEE	=	ForschungsVerbund Erneuerbare Energien (Renewable Energy Research Alliance)
Base-load electricity	=	Volume of electricity for which demand exists at all times all year round
GW	=	gigawatt(s)
H_2	=	Hydrogen
IASS	=	Institut for Advanced Sustainability Studies
IEA	=	International Energy Agency
Intraday market	=	Trade in electricity contracts for supply on same or following day
kWh	=	kilowatt-hour(s)
CHP	=	Combined heat and power generation
kW_p	=	kilowatt peak = nominal capacity of photovoltaic installations
Merit order	=	Sequence of deployment of power plants
Minute reserve (tertiary balancing energy)	=	Provision of short-term power reserves (control energy) for balancing fluctuations in the German electricity grid after a lead time of 15 minutes
Missing-money problem	=	Debate about whether deregulated energy markets are able to generate sufficient contributions to cover the cost of generation capacity

Momentary reserve	=	Property of the electricity supply system that arises from the rotating inertial mass in the generators of conventional power stations
MWh	=	megawatt-hour(s)
Ofgem	=	Office of Gas and Electricity Markets (UK energy regulation authority)
OLG	=	Oberlandesgericht (Higher Regional Court)
OTC	=	Over-the-counter (off-floor trading)
PJM market	=	Electricity market in Pennsylvania, New Jersey and Maryland
Price spread	=	Electricity price difference between different points in time or between different markets
PSW	=	Conventional pumped-storage power stations
PtG	=	Power-to-Gas = production of gas (H_2) from (surplus) electricity
Regulating power	=	ensures that electricity customers are supplied with exactly the electrical capacity needed in the event of unforeseen incidents in the power grid
Remaining load	=	different between the power needed and the power supplied by non-flexible power stations
Sabatier process	=	chemical reaction in which carbon dioxide and hydrogen are converted into methane and water
SDLWindV	=	German Ordinance on System Services by Wind Energy Installations, 3 July 2009
Smart meter/grid/appliances	=	information technology for improving demand control without direct intervention by the consumer
Spot market	=	used to optimise the generation or consumption portfolio for, as a rule, the next day. Trading takes place both on electricity exchanges and OTC.

SRU	=	Sachverständigenrat für Umweltfragen (German Advisory Council on the Environment)
StromNEV	=	Stromnetzentgeltverordnung (Power Grid Charges Ordinance)
Futures market	=	Electricity for coming years is traded on the futures market. It serves to safeguard generation and requirements in the long term.
TWh	=	terawatt-hour(s)
UBA	=	Umweltbundesamt (German Federal Environment Agency)
ULCOS	=	Ultra-Low Carbon Dioxide (CO_2) Steelmaking
VIK	=	Verband der Industriellen Energie- und Kraftwirtschaft (Association of the Energy and Power Industry)
VKU	=	Verband kommunaler Unternehmen (Association of Municipal Enterprises)
WWF	=	World Wide Fund for Nature

Key recommendations

Introduction

***1.** Climate-neutral electricity generation is both necessary and possible. It is necessary because the Federal Republic of Germany, together with the other Member States of the European Union, has committed itself to the target of reducing greenhouse gas emissions by at least 80 *per cent* from 1990 levels by the year 2050. This is the industrialised countries' minimum contribution to the internationally agreed target of preventing global average temperature from rising more than 2°C above pre-industrial levels. This target can only be achieved by moving to an electricity supply system based largely on renewable sources, as substantial emission reductions are easier and less expensive to implement in the electricity sector than in other sectors.

At the same time it is technically possible to meet electricity requirements almost entirely from renewable energy sources by 2050. And this while ensuring a high level of supply security. This will be possible at costs which in the long term will be lower than those of conventional power supplies, since fossil fuel prices will in all probability rise in the coming decades, despite shale gas production in the USA. In agreement with many other reports for Germany and the EU, the German Advisory Council on the Environment (SRU) drew attention to this in 2011 in its special report "Pathways towards a 100% renewable electricity system".

The present special report, "Shaping the electricity market of the future", is intended to extend the line of the 2011 special report and address issues concerning the organisation of the electricity market. The central concern of this new special report is to put forward ideas for a new organisation that not only offer answers to the current challenges, but are also compatible with the long-term goal of a renewables-based power system. This paper provides a summary of the SRU's main recommendations.

Energy supply in Germany is going through a period of radical change. In 2010 and 2011 the German Government approved climate objectives and renewable energy expansion targets for the period up to 2050 and decided to phase out nuclear power by 2022. Although this system of objectives was supported by a broad political consensus transcending party boundaries, there are widely differing views about how the transition should be organised in practice. The public debate focuses on security of supply and the cost of promoting renewable energy. Many political and scientific contributions to this debate lose sight of the fact that in the long term the energy supply system needs to be built on a foundation of renewable energy if the climate objectives are to be achieved. They focus on short-term solutions and in some cases advocate a fundamental change in the renewables promotion system or moves to curb the expansion of renewable energy and to introduce new mechanisms for promoting conventional power stations.

The SRU, by contrast, is primarily concerned with the question of how to assure continuous expansion of renewable energy so that the long-term goals can be achieved as well. Central topics here are energy efficiency and the financing of investments in renewable energy systems, storage facilities, and the supporting infrastructure, such as grids. The focal issues in the special report are: To what extent can the electricity market ensure the expansion of renewable energy and of storage and demand side management, and what supplementary measures are needed to achieve this?

For an electricity market largely dominated by renewable energy, the answers to these questions need to be different from those appropriate to the present situation. The SRU has therefore decided to adopt a backcasting approach that works backwards from the goal in view: First it identifies plausible characteristics of a future electricity market based on renewable energy. Then it proposes steps for the transition that are in line with the long-term perspective.

The energy market of the future

***2.** The SRU assumes that in several decades' time wind energy and photovoltaic systems will be the main technologies of a future energy system. At times of strong winds or bright sunshine, electricity generation from renewable sources will be very high, but in different weather conditions or at certain seasons or times of day it may be low. Such fluctuations may occur very quickly, may cover a considerable range, and can only be foreseen to a limited extent. The entire energy system will have to adapt to these new challenges by becoming more flexible. To this end, the market system needs to send the right signals.

In the long term there are many ways of adapting to these challenges:

– Firstly, demand for electricity – especially industrial and commercial demand – should respond more flexibly to fluctuations in generation, thereby making a contribution to load balancing.

– Secondly, further expansion of the long-distance power grid should make it possible to balance supply and demand over large areas. In addition to optimisation of the national grid, a factor of special importance here is the expansion of cross-border transmission lines. Greater EU-wide integration of power grids can help to ensure that different national supply and demand profiles balance each other out.

– Thirdly, in order to achieve the climate objectives, the demand for energy in all sectors of use (heating, transport and industrial processes) should increasingly switch to electricity as the main form of energy. The present separation of sectors will disappear. An increasingly integrated energy system will emerge, with many new flexibility options. This will make it possible to divert temporary surpluses of electricity into other use sectors (e.g.

heat or electric mobility). It will also enable the market to absorb temporary very high levels of electricity generation.

- Finally, other long-term flexibility options lie in the mutual convertibility of various forms of energy (e.g. power to gas) and a wide variety of storage options in Germany and abroad. These permit further load balancing.

What these combinations of different load balancing options mean for the electricity market is that even at times of high generation there will be opportunities to use electricity outside the electricity market in the strict sense (e.g. for gas production). The resulting demand will almost always lead to a positive market price, even in a future dominated by renewable energy. Although renewable energy will thus be able to generate considerable earnings on the market, it will very probably not be able to recover its capital costs in full. Insurance-like solutions, such as reserves or storage facilities for rare lengthy periods of very low feed-in, are unlikely to succeed in paying for themselves via the energy-only market.

On the whole, there will in the long term, i.e. in several decades' time, still be a need for a combined payment for renewable energy, insurance-like services and supplementary infrastructure. This payment is made up of a price per kilowatt-hour determined by the existing electricity market, and a supplementary contribution which meets the additional finance required. The framework for determining this contribution, like the ratio of the two payment components, depends on future costs, technologies and market conditions and is therefore impossible to predict at present.

These structural elements of an electricity market that can be foreseen in the long term make it possible to draw conclusions about steps for a gradual transition towards a more market based approach.

Reform of electricity market organisation

1 Ensuring continuity during transition

***3.** The Renewable Energy Sources Act (EEG) is a successful model and a driving force behind the German *Energiewende* (transformation of the energy system). At comparatively low cost, it has triggered substantial growth of renewable energy. This success story is spreading beyond Germany's boundaries. Similar systems have been introduced in many other countries. At present this development is one of the encouraging factors in international climate policy. The *Energiewende* provides answers to the foreseeable increase in fossil fuel prices and the risks and serious environmental follow-on costs of the present power generation structure, and offers a perspective for a sustainable energy supply system. The transformation of the power generation system is also a great opportunity for Germany as a source of innovation.

There is nevertheless a need for reform. With regard to weather-dependent generation from renewable energy sources there is a short-term need both for the conventional power plant portfolio to adapt as speedily as possible to the new flexibility requirements, and for the renewable energy sources to adapt – as far as technically and economically practicable – to the requirements of the market. To this end the renewable energy sources must increasingly be exposed to market signals. Moreover, other challenges arise from the cost of promotion and, in the medium term, security of supply.

Within these constraints the SRU advocates cautious reforms that will make it possible to maintain the dynamic development of renewable energy at a sustainable high level. This is indispensable in view of the longer-term political objectives and the potential of renewable energy. At the same time care should be taken to avoid measures that are obviously incompatible with the long-term climate objectives, e.g. subsidising new coal-fired power stations or keeping existing ones in service on a long-term basis.

2 Subordinating conventional power generation to the needs of renewable energy

***4.** The growing proportion of renewable energy makes great demands on the flexibility of conventional power generation. It has to adapt to the weather-dependent nature of wind and solar power. At present there is a surplus of non-flexible capacity due to nuclear and lignite power stations. This results in low spot market prices, exports of surplus power to other countries, and profitability problems for gas-fired power stations. However, gas power stations are needed as a flexible means of meeting the residual load requirement. For this reason a variety of promotion mechanisms are currently under discussion with a view to ensuring the availability of flexible generating capacity, and hence long-term security of supply despite the profitability problems on the electricity market.

The SRU is of the opinion that, first of all, it is necessary to exploit those options which effectively address these challenges and at the same time strengthen the functional capacity of the energy market.

These options include incentives for greater demand flexibility on the part of major industrial consumers in particular. They have a variety of technical means of reducing their electricity consumption in times of low power supply. Making the market more flexible, especially to reinforce the role of short-term markets with better integration of the grid operator, could help to cater for the rapid fluctuations in supply which are difficult to predict exactly. In the short term, expanding transmission line capacity between Germany and its neighbouring countries could make a contribution to greater security of supply.

However, the most important individual objective – over and above the phasing-out of nuclear power – is to reduce the overcapacity of power stations that are not flexible for economic or technical reasons, in order to create better market conditions for flexible power stations, especially gas-fired ones. This applies in particular to power generation from lignite, which is both relatively inflexible and very CO_2-intensive. The success of the *Energiewende* is therefore crucially dependent on an adequate carbon price signal.

3 Substantially raising carbon prices

***5.** A high carbon price level will speed up the urgently needed process of structural change in the conventional power plant portfolio. It is the most important lever for increasing the competitive strength of flexible and relatively low-CO_2 gas-fired power stations. A higher carbon price increases the production costs of fossil-fuel power stations. This raises market prices – which benefits highly efficient and flexible power stations in particular – and thereby improves the functioning of the electricity market. Thus a strong carbon price signal should be introduced before making any far-reaching intervention in the market such as the various capacity mechanisms currently under discussion.

At present, the carbon price is determined by the European emissions trading scheme. Owing to an over-generous supply of emission allowances, especially as a result of the economic recession in the EU, the price of emission allowances has slumped in recent years.

The SRU therefore recommends the German government to take action at European level and urge effective measures to restore the incentive function of the emissions trading scheme. In particular, this includes an ambitious European climate objective for 2030 as well as the temporary withdrawal of emission allowances during the current trading period (“backloading”). This should form part of a consistent overall climate and energy policy package, which must also be compatible with the long-term objectives for 2050.

If moves for a speedy reform of the European emissions trading scheme are not successful, Germany should follow the British example and introduce a national minimum carbon tax. This would best be done by abolishing the exemptions for power generation plants in the Energy Tax Act. The level of taxation must also be geared to the specific carbon content of the individual fuels. Last but not least, the German Government could consider using regulatory measures to reduce CO_2 emissions by power stations and to make power supply more flexible.

4 Strengthening the European dimension of the Energiewende

***6.** Right from the start, the *Energiewende* has been embedded in a European context. It is also a contribution to the objectives approved by the European Union in 2008 for climate action, renewable energy expansion and greater energy efficiency by 2020. The task of updating these objectives for 2030 is currently on the agenda of the European Union. Ambitious European targets for all three aspects of energy and climate policy are of vital national interest in order to create a climate of certainty for investment and planning, promote convergence of the Member States' policies, and avoid competition-law risks in relation to the – still much needed – promotion of renewable energy. To ensure continuity and be able to take account of interactions between the three objectives, the EU should focus on a triad of targets for 2030 as well.

The SRU therefore recommends the German Government to advocate a European climate objective for 2030 that seeks to reduce greenhouse gas emissions by at least 45 percent compared with 1990 by means of measures within the EU. The renewables share of gross final energy consumption should be increased to at least 40 percent. Full advantage should be taken of the existing energy efficiency potential, which permits a reduction of up to 50 percent in primary energy consumption compared with 2010. This should be enshrined in binding targets. Depending on their own national targets and abatement costs, individual countries such as Germany can and must exceed these targets.

5 Ensuring security of supply in conformity with the market

***7.** The growing proportion of renewable energy and Germany's decision to finally phase out nuclear power by 2022 present new challenges for ensuring security of supply. Under current market conditions, neither the construction of new flexible gas power stations nor the continued operation of existing ones is assured. To ensure the provision of adequate and flexible generating capacity, various approaches to capacity markets and a strategic reserve are currently under discussion. In the final analysis, capacity markets are mechanisms for subsidising new power plants or maintaining existing ones, or they provide incentives to invest in flexibility options. The strategic reserve is a safeguard against supply shortage situations. Under this instrument, power stations that would otherwise be withdrawn from the market are kept as a reserve.

Introducing capacity markets involves risks. If they are not designed correctly, e.g. if the need for new power plants is overestimated or there are no requirements regarding flexibility or limiting CO_2 intensity, there is a risk that the transformation of the power supply system will be brought to a halt or that the cost of promoting it may be excessive. Nevertheless, one cannot exclude the possibility that a capacity market may be necessary for security of supply in the medium term. However, every new intervention in the market needs thorough prior investigation in order to avoid incorrect design.

On the whole, the SRU considers the proposed strategic reserve to be the more suitable instrument, since this represents the smallest intervention in the energy market. Removing power stations that only operate in the event of shortages from the energy market will improve the earnings potential in this market.

6 Ensuring a more objective debate about the cost

***8.** One frequently voiced justification for a basic need to reform the EEG is that it gives rise to high electricity costs and that steps must be taken to halt their continued growth. However, this debate confuses a number of different arguments. Firstly, it explains the increase in electricity prices in recent years as being due entirely to the expansion of renewable energy. Secondly, the discussion focuses on an indicator that is unsuitable for determining the actual cost of promoting renewable energy. Thirdly, it exaggerates the resulting social problems and the overall importance of such developments for the economy as a whole.

The SRU expressly warns against such misinterpretations. The doubling of the price of household electricity over the last decade was due above all to the rise in fossil fuel prices. Moreover, the EEG surcharge is not a suitable indicator of the cost of renewable energy. One reason for the increase in the surcharge – as the difference between feed-in payment and market price – is that the cost of the generous exemptions for a number of industrial companies is allocated to all other electricity customers. Another reason for the rise is, paradoxically, that spot market prices are going down because of falling carbon prices and the increasing amounts of renewable energy fed into the system. However, neither of these effects is a cost of promoting renewable energy. Incorrect indicators could lead to misguided reforms that might slow down the expansion of renewable energy and thereby endanger the overall objective of the *Energiewende*.

The SRU therefore recommends introducing a better indicator of whether or not the renewable energy portfolio is becoming less expensive. A suitable candidate for this purpose would be the average EEG payment for new installations. A comprehensive macroeconomic cost concept should also be used. This must compare the costs attributable to renewable energy with the costs – and especially the external costs – arising from the construction and operation of fossil energy supply facilities (differential cost approach).

7 Reforming the variable market premium

***9.** The EEG originally funded the renewable energy sources by means of fixed feed-in tariffs. This was criticised because in this model, power generation does not react flexibly to market signals. Thus, in 2012 the option of selecting a variable market premium was introduced. The variable market premium pays for that portion of renewable energy costs which is not covered by market income. Since market prices are subject to large fluctuations and are difficult to predict for decades ahead, the amount of the variable market premium is adjusted to average spot prices, thereby cushioning part of the market risks for renewable energy sources.

Other direct marketing models (e.g. fixed market premium or auctioning) pass on excessive market risks to the renewable energy sources, thereby considerably increasing the cost of refinancing and hence the cost of promotion. Proposals of a more far-reaching nature such as quota models risk interrupting the development process. Moreover, they are also more expensive than differentiated technology-specific promotion.

The SRU therefore recommends introducing the variable market premium as a binding basis for all new installations. Since its introduction in 2012, as much as half the capacity from renewable sources has been transferred to direct marketing, and in the case of onshore wind energy the figure is as high as 80 percent. Practical experience is thus available which holds promise of a smooth transition.

However, the SRU recommends modifying the basis for calculating the premium in a way that increases the incentive to gear installations to maximising market revenues, not the amount of energy generated. The SRU envisages calculating the variable market premium in such a way that producers can, under realistic conditions, expect at least the same income as at present with the fixed feed-in tariff. The realisable market revenues and the market premium should be calculated on the basis of suitable technology-specific and site-specific indicators. Instead of a 20-year limit on promotion, a limit on the number of kilowatt-hours promoted should be used. As yet it is still possible to increase the absolute amount of funding received by gearing the installation to maximise the number of kilowatt-hours produced in the 20-year promotion period. By contrast, the kilowatt-hours contingent implies similar absolute funding for all installations. This ensures an overall income, even if payments are no longer made when electricity is not fed in. The level of the market premium must nevertheless be continuously adjusted to the actual development of technology costs and must be geared to a portfolio of renewable energy sources that is both inexpensive and reasonable from an energy system point of view.

In view of the serious additional environmental impacts and undesirable relocation effects, consideration should be given to discontinuing the promotion of cultivated biomass.

The SRU recommends having the level of the market premium determined by a public authority. This should work on the basis of politically decided objectives with regard to the levels of expansion and the renewables portfolio, in accordance with clear rules and in a transparent procedure. The fact that the feed-in tariffs are specified in the EEG has in the past prevented a sufficiently flexible response to market and cost developments. This can be achieved better by a solution where the market premium is determined by a public authority.

8 Bundling coordination in the Federal Chancellery

***10.** A large number of actors from politics, industry and society are involved in implementing the *Energiewende*. Even individual elements of the *Energiewende*, like the electricity market reform, are complex and require a great deal of coordination. And the need for coordination between the various elements is all the greater, e.g. between grid expansion and the growth of renewable energy, or between climate policy and the development of renewable energy sources. In this connection it is often suggested that responsibility for energy policy should be bundled in a separate energy ministry.

However, there are a number of arguments against this:

- The coordination requirements far exceed the competence of a single ministry. Decisions concerning the *Energiewende* are taken not only at federal level, but in a complex multi-level system, and implemented on a centralised basis. There is thus a need for coordination not only between the federal ministries, but also between the federal and *Bundesland* level and between Germany and the EU.
- The *Energiewende* is not merely the responsibility of the economics and environment ministries. Other ministries also play an important part, e.g. the ministries of transport, research or agriculture. It would be unrealistic to bundle all these tasks in a single ministry.
- Furthermore, inter-ministerial discussion of issues increases the transparency of the basis for political and technical decisions.
- And finally, each ministry acts as a point of contact for specific stakeholder groups. If these interests are spread among different ministries, there is competition between the ministries to innovate, and in recent years this has acted as a driving force behind the *Energiewende*.

Rather than creating an energy ministry, it would therefore make more sense to institutionalise these responsibilities under the policy-making powers of the Federal Chancellor. The SRU advocates establishing a steering body with the rank of a Minister of State within the Federal Chancellery. This function should be equipped with appropriate resources and should have the task of balancing interests between the ministries and optimising coordination between the Federal Government, *Länder* and EU. This can strengthen the importance of the *Energiewende* as an overarching and cross-cutting task and as a national policy coordination task between the federal, regional and EU levels.

9 Transferring detailed control to federal authorities

***11.** The SRU recommends an increasing and systematic transfer of numerous concrete implementation tasks, the technical and economic basic knowledge and fine tuning of the *Energiewende* to the Federal Environment Agency and the Federal Network Agency. These two authorities should also be required to coordinate under the rule of common agreement.

It would overstrain the legislature to deal with the numerous technical parameters and the specific implementation tasks of the *Energiewende*, especially fixing and regularly adjusting the market premium, working out any necessary capacity mechanisms or implementing the emissions trading scheme. The legislature should focus on laying down the fundamental objectives, instruments, procedures and rules for the further process of the *Energiewende*.

10 Passing a Climate Change Act

***12.** Especially in view of the diversity of actors and levels involved and the great variety of interests, the *Energiewende* needs a clearly defined vision and a binding goal for the various processes which cannot be controlled centrally. For this reason the SRU recommends passing a Climate Change Act laying down the climate objectives for Germany up to 2050. The Climate Change Act should set out these objectives in ten-year steps. It should also formulate sectoral objectives for the climate-relevant sectors: transport, agriculture, industry, small-scale industries, trade and services, as well as heat. The Greenhouse Gas Emission Allowance Trading Act (TEHG) and other climate-relevant acts should be merged with the Climate Change Act. The objectives of this Act should also be underpinned by a sub-statutory programme, which should be a mandatory requirement. This programme should lay down measures and regular monitoring processes. A Climate Change Act can improve the consistency of political decisions and reinforce broad public acceptance of climate and energy policy measures.

Outlook

***13.** The *Energiewende* is going through a critical transition phase. There is a need for reform, but the reforms must not risk interrupting the development process. One of the central political tasks for the coming term of parliament will be to find this balance between continuity and change.

1 Introduction: Redesigning Germany's electricity market

1. Electricity generation in Germany is going through a process of transformation. This process was set in motion by the far-reaching political decisions on phasing out nuclear power by 2022, expanding renewable energy and taking action to protect the climate. On the basis of a broad political consensus, the Federal Government made a commitment to climate action and thereby set the central framework of targets. By 2050 greenhouse gas emissions in Germany are to be reduced by 80 to 95 per cent compared with 1990. In the same year the renewables share of electricity supplies is to reach at least 80 percent. In line with numerous research studies, the German Advisory Council on the Environment (SRU) has shown that a full supply of renewables-based electricity is possible, and indeed essential for achieving the climate protection objectives, as substantial emission reductions are easier and less expensive to implement in the electricity sector than in other sectors (SRU 2011). For an electricity supply system based on renewable energy sources it will be necessary to modify the present design of the market. This report examines the central requirements.

2. The transformation of the energy system (*Energiewende*) pursues a triad of objectives concerned with environmental viability, efficiency and security of supply. It provides answers to the foreseeable increase in fossil fuel prices and the risks and serious environmental follow-on costs of the present power generation structure, and offers a perspective for a sustainable energy supply system. If taken seriously in this way, the transformation is also a great opportunity for Germany as a seat of innovation. It is no longer merely a question of the technological development of renewable energy sources. Today it is much more a matter of integrating the various system components in such a way that renewable energy sources become the lead technologies of the energy system and – in interaction with grid expansion and reconstruction, demand management, use of storage technologies, and integration of the electricity, heating, transport and industrial sectors – are in the long term able to provide 100 percent of supplies. This must never lose sight of the environmental impacts, as the SRU explained in detail in its special report of 2011 (SRU 2011, Item 119 ff.).

3. The Renewable Energy Sources Act (EEG) is the hinge-pin of the transformation process. It has shown that the market launch of new technologies is possible on a scale that was previously unimaginable. In little more than a decade, thanks to the EEG, the renewables share of electricity supplies rose from 6.7 percent in 2001 to 22.9 percent in 2012 (BMU 2013). This success story has spread beyond Germany's borders, and today it is one of the encouraging factors in international climate policy.

As a result of this increase, renewable energy sources have now outgrown their market niche and are causing considerable adaptation problems for the old energy system, both for conventional power generation and for the long-distance transmission and distribution networks. There is therefore a need for reforms. However, these reforms must not – as frequently demanded – focus entirely on renewable energy, but must in particular include necessary adjustments to the traditional, conventional energy system, which still dominates the supply of energy in Germany.

The present debate about costs focuses on an indicator – the EEG surcharge – which is not suitable for providing an appropriate picture of the costs of the *Energiewende*. Cost efficiency and electricity price curbs, greater market orientation and system responsibility are the keywords of the current debate about reforms. However, many proposals for reform amount to explicit or *de facto* efforts to slow down the growth of renewable energy. Few attempts are made to analyse whether reform ideas motivated by short-term considerations are in fact compatible with the long-term expansion targets.

4. The SRU has therefore decided to start by looking at the qualitative long-term perspective. In the present report it investigates the direction that the development of the energy supply system can and must take in the long term, and what its principal structural features will be. The focus is on the characteristics of the electricity market for an electricity supply system based on renewable energy, and on what form the transition to this situation should take.

However imponderable or uncertain a longer-term forecast may be, it can be regarded as certain that the weather-dependent generation of energy by wind and sun will determine the character of the system as a whole, and that other system components will have to adapt to this. In this connection people often take a sceptical view of the energy-only market, because they fear that a market which confines itself to taking account of short-term variable costs of generation (i.e. quantity-dependent costs) will not be capable of financing the investment needed for renewable energy. Less attention is paid to the opportunities for dynamic development of the market that could arise from the fact that the heating and transport sectors and the basic industries are operating more and more on the basis of electricity, or that the availability of storage technologies is increasing. In this special report the SRU will examine the fundamental issues of technical ways and means of integrating the sectors.

A special challenge of the transition to an electricity supply system based on renewable energy is that the larger the share generated by sources subject to rapid and substantial fluctuations, the more flexible the supply system as a whole needs to be. This raises the question: How can the EEG be developed into a more market-driven regime, while maintaining the dynamic expansion of renewable energy sources? This central issue implies a number of other questions: How can cost trends be dealt with in the short term, and how can costs and benefits be shared equitably? How can security of supply be maintained by the – initially conventional – flexible residual load? Are there any measures that need to be taken in any case before considering new mechanisms for promoting conventional residual load (“no-regret measures”)? Which ultimately leads to the question of what form the promotion of other components of the energy system should take.

Redesigning the electricity market is not something that happens in a space devoid of interests and actors. A crucial factor for success is the framework of participation, competence and decision rules within which the reform process takes place (referred to below as “governance of the *Energiewende”*). The SRU therefore comments on the current proposals for reform, e.g. the need for an energy ministry.

However, proposed reforms and the associated costs have to be accepted by society. One precondition for this is greater participation and the development of a vision for the *Energiewende*. It is the government’s task to press ahead with the development of this vision and coordinate the many and various reform activities with the local, regional and federal levels. Participation in this comprehensive sense can place the *Energiewende* on a broad footing.

In this special report the SRU seeks to contribute to the discussion about how an electricity market based largely on renewable energy needs to be designed. First of all, Chapter 2 explains how the electricity market works at present. Chapter 3 takes a cursory look at technical ways and means of making the electricity system more flexible, including integration of the heating, transport and basic industries sectors. Chapter 4 then describes the requirements which an electricity market needs to satisfy in a supply system based on renewable energy. Chapter 5 draws conclusions about the transition to electricity supplies based on renewable energy, and puts forward recommendations for the current debate. Chapter 6 examines the challenges that the *Energiewende* presents for coordination and decision systems.

2 How the electricity market works

5. This chapter aims to show the present structure of the German electricity market, in order to clarify the aspects in need of reform which are discussed in this special report. Electricity markets can basically be organised in very different ways, as revealed by a comparison with other countries. In many countries, electricity suppliers have regional monopolies, while other countries have organised their electricity supply system as a state monopoly. Deregulated electricity markets can also vary considerably in structure (EHLERS 2011 with further references).

Moreover, the electricity market is characterised by a number of special features. Since large-scale storage of electricity has not been possible to date, there must be an exact balance of generation and consumption at all times. Demand for electricity is subject to substantial fluctuations depending on the season and the time of day. A mismatch of generation and consumption can lead to changes in line frequency, which may result in the grid becoming unstable. The relatively large fluctuations in grid load are exacerbated by a demand situation which – at least at present – still displays a high degree of short-term price inelasticity (Federal Cartel Office 2011). In view of the need to prevent a mismatch of generation and consumption in the power grid to avoid unstable grid situations, all electricity generated has to be adapted to actual consumption at all times. However, both the demand for capacity and the supply fed into the system may display rapid fluctuations. To some extent it is possible to predict these fluctuations in capacity requirements (e.g. increased consumption during cold weather). If the fluctuations can be predicted, the market responds by covering its requirements on the electricity exchange. Unforeseen fluctuations in consumption and generation are balanced by means of what is known as “balancing energy”.

Accordingly, the German energy-only market can be subdivided into various markets, namely the wholesale market and the market for system services, essentially balancing energy (Fig. 2-1, cf. Federal Cartel Office 2011). In terms of the volume traded, the wholesale market is several orders of magnitude larger than the market for balancing energy and the market for energy to cover grid losses (LEPRICH et al. 2012, p. 26).

The wholesale market trades exclusively in electrical energy, i.e. work in megawatt-hours (MWh), and is consequently known as the energy-only market. Trading is based on three different time frames (reference periods). The futures market, the first segment, trades in electricity supplies up to seven years in advance. The second segment, the day-ahead market, is concerned with electricity supplies for the following day. Finally, the third segment, the intra-day market, deals in electricity supplies for the day in progress (MATTHES et al. 2012, p. 36).

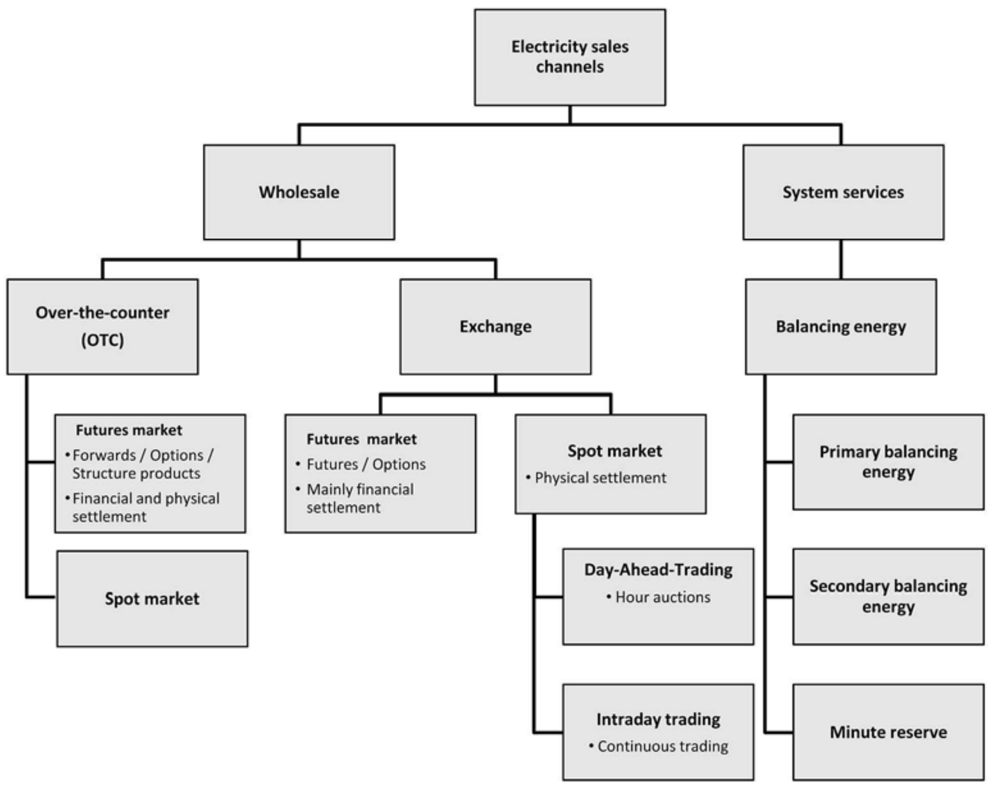
At present there is little incentive to make supply-oriented changes in demand for electricity. As a rule, households and businesses with low to medium electricity consumption have fixed electricity tariffs, i.e. the price of the electricity remains the same regardless of when it is consumed. These tariffs not only lag behind price trends on the other markets, but also include other cost components such as taxes or grid fees (for a breakdown of electricity prices in 2012, see BDEW 2012). As a result, these electricity customers do not have any incentive to adapt their consumption to the availability of electricity – in other words to save electricity when it is in short supply, postpone consumption, or possibly even adapt to the market by drawing electricity from their own storage facilities, CHP plants or photovoltaic installations.

In electricity trading, a basic distinction must be made between trading on electricity exchanges and over-the-counter (OTC) trading (cf. Fig. 2-1). Providers acquire large amounts of the electricity they need through OTC transactions, i.e. through direct transactions with the supplier. Some of the remaining capacity is reserved for use in the balancing energy market or to provide other system services such as the minute reserve, and only the capacity that is left is offered for sale through the exchange on the spot market (LEPRICH et al. 2012, p. 26). Thus purchases and sales on the spot market only serve to offset variations in consumption that become apparent in the short term. As a rule, however, the price prevailing on the electricity exchange is also used as a reference price for OTC transactions (Federal Cartel Office 2011, p. 14).

The availability of balancing capacity serves to compensate deviations from forecasts and to stabilise line frequency, and is organised via central tendering through the transmission system operators. To optimise the use of balancing energy, control energy products are distinguished with different activation requirements and tender frequencies. The transmission system operators procure primary balancing power and secondary balancing power for a period of a week. Primary balancing power has to be capable of activation within 30 seconds, secondary balancing power within 5 minutes. The minute balancing power, also known as the tertiary balancing or minute reserve, is offered for six periods of 4 hours each every day, and has to be activated within 15 minutes (decision by Chamber 6 of the Federal Network Agency: BK6-10-097).

Figure 2-1

Electricity sales channels



* Over-the-counter
Source: Federal Cartel Office 2011

6. Until it was deregulated, the German electricity market had a monopolistic structure and was thus excluded from private-sector competition. This means that competition-based prices and the decoupling of generation and grid operation are relatively recent developments. The deregulation of the electricity market was ushered in by the Internal Electricity Market Directive 96/92/EC, which provided for a gradual opening of the markets (KONSTANTIN 2009, p. 41). Since the transposition of this directive in the German Energy Industry Act (EnWG) in 2005, electricity generation and trading has been exposed to competition. Even after the unbundling of ownership of electricity generation and grid operations, the grid sector remains a natural – line-dependent – monopoly that is subject to regulation, especially of grid fees, by the Federal Network Agency and authorities at *Länder* level.

In the early stages of deregulation, both long-term and short-term trading of electricity took place on an exclusively bilateral basis. Very soon, however, exchanges developed as centres for electricity trading and merged in Germany to form the European Energy Exchange AG (EEX) based in Leipzig (OCKENFELS et al. 2008, p. 6), where spot-market and futures trading in electricity, CO_2 allowances, coal and gas is carried on. The EEX has more than 200 participants from 22 countries and is the leading energy exchange in mainland Europe. Since large-scale storage of electricity has not been possible to date, trading in electricity on the exchange calls for relatively complex rules and careful attention to numerous technical restrictions in electricity generation and transmission (OCKENFELS et al. 2008, p. 4).

7. EEX transactions are handled by European Commodity Clearing AG (ECC), which specialises in the physical supply of energy and related products. While exchange dealings account for only a small proportion of wholesale trading, it is difficult to estimate the exact volume traded on the exchange. The volume traded on the spot markets is steadily rising: according to the Federal Cartel Office and the Federal Network Agency, a total of 240 TWh was traded on the spot market in 2011, and the figure on the futures market was 457 TWh (Federal Network Agency and Federal Cartel Office 2012, p. 17). However, EEG electricity for which a feed-in payment is made also has to be traded on the exchange. This is not a binding requirement for EEG plant operators who have opted for direct marketing.

The three main functions of the energy-only market: operational management, flexibility improvement, financing

8. Under the present system, the energy-only market provides the main instrument for controlling the use of capacities, in other words for balancing supply and demand (operational management).

The various product categories on the market ensure a certain flexibility when it comes to smoothing out fluctuations in supply and demand (flexibility improvement).

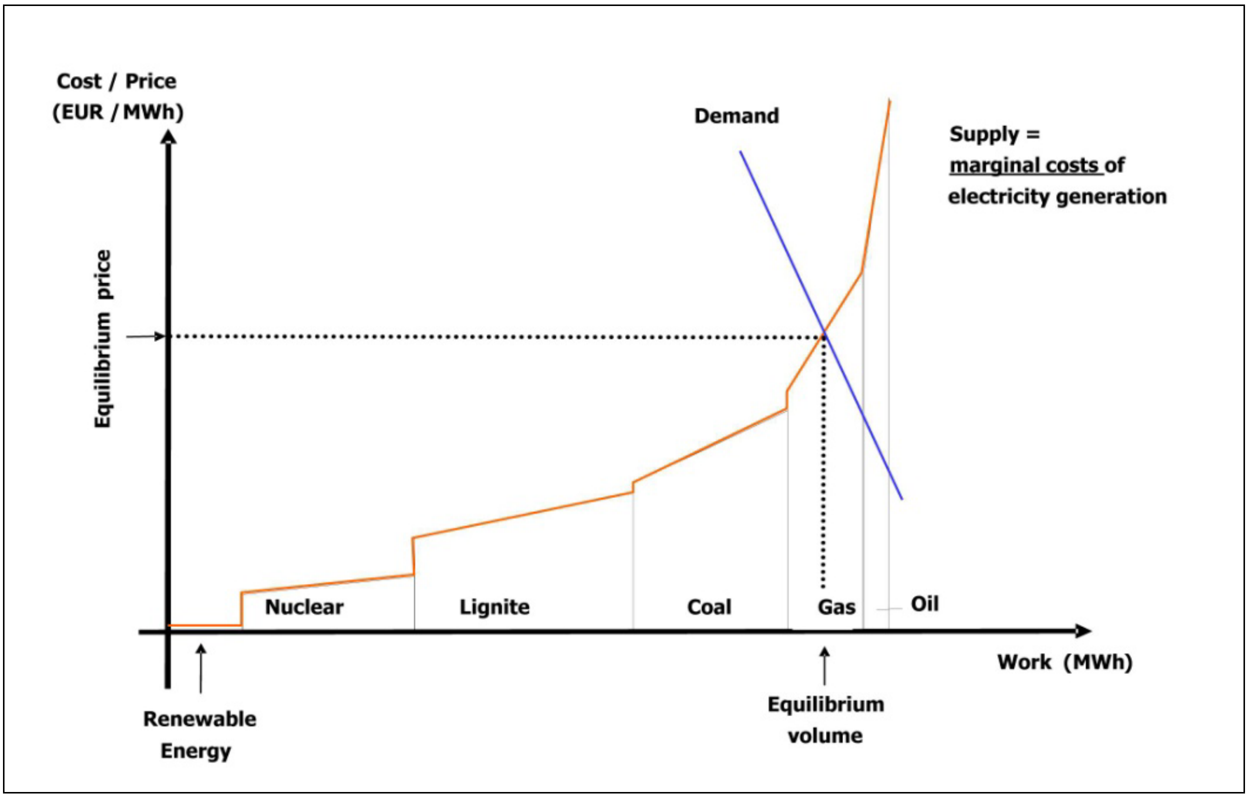
However, the wholesale trade also sends out signals for investment in power stations and incentives to invest in flexibility, such as storage facilities. If prices are high enough, investments are made or flexibility options are used and created; if prices are low, capacity is reduced. Thus in the present system the energy-only market – at least theoretically – performs the financing function, and in this way it is supposed to make the necessary capacity available and hence ensure security of supply. What investment is made in power station capacity depends in turn on annual load curves, fuel prices and carbon prices (LEPRICH et al. 2012, p. 29).

9. In the past, demand for electricity in the course of the day and year has been met by base-load, medium-load and peak-load power stations. To meet the demand for electricity fully at all times, decisions are taken at 15-minute intervals about the forthcoming deployment of the various controllable power stations available (dispatch).

In general, pricing on the energy exchange is based on the variable costs of the power stations, in other words fuel costs, the cost of emission allowances, and any other variable costs of the power stations available. The power stations are deployed in ascending order of their marginal costs, the “merit order”. The merit order is determined by the variable (non-capital) costs of electricity generation. Starting with the lowest marginal costs, power stations with the next-higher marginal costs are added until the demand is met. The merit order also takes account of opportunity costs. The electricity price needed to clear the market, the price at which electricity is sold on the energy exchange, is determined by the most expensive power station, the “marginal power station”, that has to be deployed to meet the demand (von ROON and HUCK 2010, p. 2; SRU 2011, Item 235; Fig. 2-2).

Figure 2-2

Price formation on the electricity market



Source: BODE 2008

To date, base-load power has been produced by large central nuclear and lignite power stations. Although their capital cost is high, their fuel costs and hence their variable costs are comparatively low (NICOLOSI 2010, p. 2). Because of their merit order, they tend to be deployed before gas-fired power stations with relatively high fuel-related variable costs. The emissions trading scheme places a larger burden on coal than on gas, owing to its greater emission intensity. Ideally, carbon pricing under the emissions trading scheme leads to a greater increase in variable costs and to correspondingly higher prices, and hence to a shift in the merit order to the disadvantage of coal-fired power stations. Unlike fossil-fuel or nuclear power stations, hydro-power, wind and photovoltaic installations do not need any fuel. This means their variable costs are very low. Thus in the merit order driven by variable costs they come before controllable power stations, which are only then brought in to meet the remaining demand (SRU 2011, Item 235).

The fact that renewable energy is fed in on a priority basis has recently resulted in the remaining conventional power stations acquiring a new function: instead of always producing the same base-load capacity, it is now of central importance to balance the residual load, i.e. the difference between the demand and the electricity generated from renewable sources with its large and possibly rapid fluctuations (LEPRICH et al. 2012, p. 24). Thus instead of the terms “base load”, “medium load” and “peak load”, the term “residual load” is becoming increasingly relevant.

3 Technical characteristics of a flexible, electricity-based energy system

10. When reforming the electricity market it is always important to bear in mind the long-term view, because changes can make their effects felt over several decades. The SRU has therefore decided to adopt an approach that starts from the goal of electricity supplies based on renewable energy. Chapter 3 outlines the technical features of a future energy system based much more on electricity. Close interactions exist between these and an efficient market framework for a sustainable energy sector. For this reason, Chapter 4 asks questions about the performance of an energy market for supplies based largely on renewable energy and draws conclusions about requirements for the market design of the future. Chapter 5 then goes on to develop elements of a viable electricity market design for the transition.

The SRU expects future energy supplies to be considerably more electricity based than in the Federal Government's existing strategy. In future, renewable energy sources will largely account for the supply of electricity and will also dominate the entire energy supply for the heating, transport and industrial sectors (SRU 2011). At the same time the sectors will be increasingly interconnected, e.g. through electric mobility and electricity-based heating. The transformation of the energy supply system broadens the demand base for electricity and offers flexibility options that have not been available in the past.

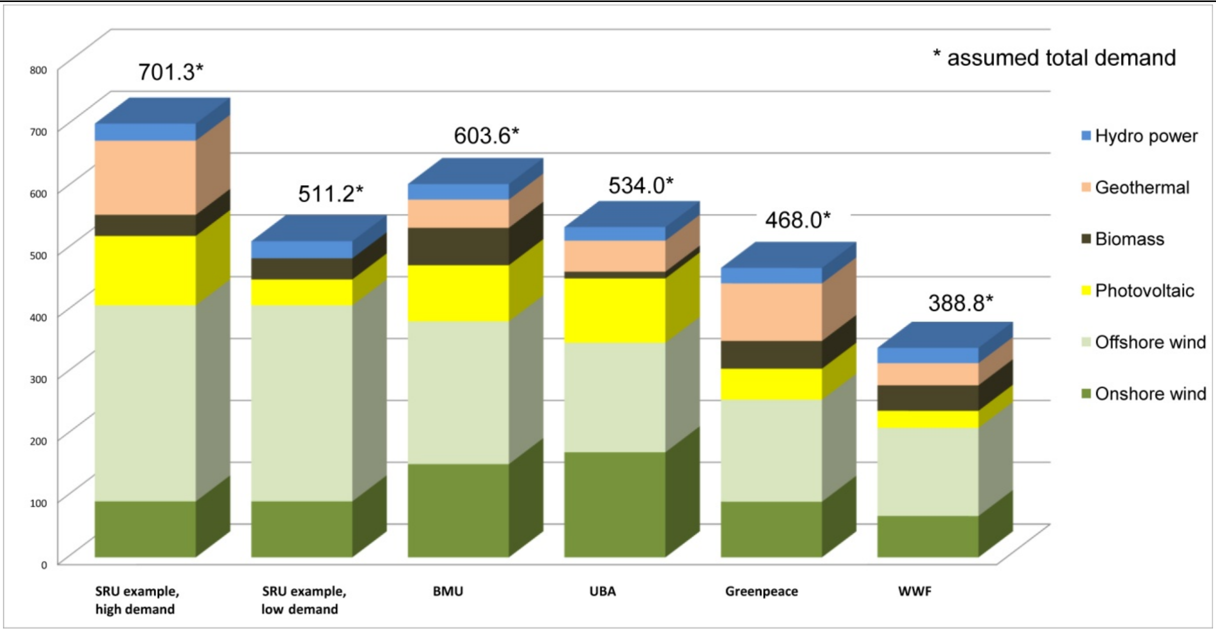
3.1 Dominance of fluctuating generation

11. Even if there are many different paths towards electricity supplies based on renewable energy, it is already possible to provide a robust description of a number of central characteristics. Various actors have presented studies of the energy supply situation in 2050. Scenarios for an energy supply system based entirely on renewable sources include those presented by the SRU (2011), the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (NITSCH et al. 2012), the Federal Environment Agency (KLAUS et al. 2010), Greenpeace (BARZANTNY et al. 2009), the WWF (Öko-Institut and Prognos AG 2009), the Federation of German Industry (BDI) (GERBERT et al. 2013), the Federal Association for Renewable Energy (KRZIKALLA et al. 2013) and the Fraunhofer ISE (HENNING and PALZER 2012).

12. The studies are based on widely differing portfolios for the various renewable energy generation technologies (Fig. 3-1). It is clear from the broad spectrum shown that the future mix of renewable energy sources for electricity generation can only be predicted within broad ranges (e.g. WINKLER 2011).

Figure 3-1

Spectrum of different generation technologies in an electricity supply system based entirely on renewable energy (in TWh)



SRU/SG 2013/Fig. 3-1

However, the studies are all agreed that hydro power capacity in Germany is largely exhausted. Furthermore, the availability of land for the cultivation of biomass and the quantity of usable wood and imported biomass are limited, considering that production has to be geared to minimising environmental impact and maximising intergeneration equity (JERING et al. 2012). The Federal Environment Agency (UBA), for example, takes a very restrictive approach to biomass in its mix of energy sources. In view of the move away from cultivated biomass and the focus on waste and residual substances, biomass only plays a minor role in the UBA study (KLAUS et al. 2010).

13. Thanks to their greater and relatively inexpensive potential – as shown by the studies mentioned – wind power and photovoltaic systems will be the two main generating technologies. These will be supplemented by small amounts of hydro power and biomass, and possibly also by geothermal energy and wave energy (e.g. IPCC 2011).

Great need for flexibility

14. Electricity generation from wind and solar power depends on availability. The amount fed in fluctuates greatly depending on the weather and the season or time of day. It is therefore possible that over a given period certain facilities may feed in their full capacity or may even not supply any electricity at all. The changes can be very sudden, for example when photovoltaic output is reduced by a bank of clouds. It is also conceivable that at certain times sun and wind together will generate hardly any electricity, e.g. on calm nights. Thus unlike the present power plant portfolio dominated by fossil fuels, there will be limits to the extent to which the greater part of the electricity generated can be controlled.

As a result, supply security and system stability are among the great challenges of an energy system geared to sun and wind: The overall structure of the energy supply and energy management system will have to adapt to the very substantial and rapid fluctuations in the renewable energy sources and possess a high degree of flexibility.

Alternative technologies for system services

15. To ensure secure electricity supplies it is necessary to take certain measures to stabilise the grid: these are known collectively as system services. The most important system service is balancing power, which is used by transmission system operators to compensate for short-term imbalances of electricity supply and demand. Capacity kept for this purpose is capable of adjusting its generation or consumption within seconds or minutes. Another system service is the provision of reactive power. Reactive power is the electrical power which is needed to build up magnetic or electric fields, but cannot be used by the consumer. In many cases reactive power is an undesirable phenomenon and has to be compensated by taking suitable countermeasures. Black start capacity is the ability of power generators to restart without an external power supply after a power outage, in order to rebuild the grid.

Today system services are provided to a large extent by fossil and nuclear power stations. When these facilities are replaced, the system services will have to be offered by other technologies, for example storage facilities or condensers. Here too, renewable energy sources can make a major contribution. Even today the newly constructed renewable energy installations have to provide system services . These functions must be catered for when designing the installations. First steps to make it easier for fluctuating renewable installations to show that they satisfy these criteria for the provision of system services have been taken with the introduction of the Ordinance on System Services by Wind Energy Installations (SDLWindV) and requirements for photovoltaic installations (LEPRICH et al. 2012, p. 45 f.; Consentec et al. 2011). There is however a need for further research into the question of how to provide efficient incentives for system services and what requirements make sense for renewable energy installations.

3.2 Load balancing options

16. There is a broad spectrum of options for load balancing. Particularly important factors are local distribution through the mains grids, and demand side management to compensate for the expected large fluctuations over time. Furthermore, in addition to controllable renewable energy, storage systems can be used to ensure system stability and above all to compensate lengthy supply outages resulting from meteorological conditions. In situations with extremely high renewable feed-in it is also possible to curtail the output of renewable energy installations.

3.2.1 Grid reinforcement and grid expansion as the most important flexibility option

17. The grid infrastructure connects generation and consumption at the various levels (distribution grid, high-voltage and extra-high-voltage grid, and also, in future: overlay grid). It needs to be adjusted to the changed electricity generation structures. Centralised and decentralised structures can be expected to exist in parallel. Grid reinforcement and grid expansion are the first and most important flexibility option: statistically speaking, maximising the large-scale interconnection of a wide range of capacity, supply and demand profiles ensures better management of generation and load peaks. Grid optimisation is not only cheaper and faster to implement than many storage solutions, but is also a precondition for making use of other flexibility options both on the supply side and on the demand side. In particular, adapting the grid infrastructure would tap potential for demand side management (cf. Section 3.2.3, Smart Grid) and cater for the greater coordination needs resulting from increasingly decentralised feed-in (IPCC 2011, Chapter 8; Agora Energiewende 2013b; MATSCHOSS 2012).

Adapting the grid infrastructure should not be confined to the national level. Pan-European interconnection is the lowest-cost option for making efficient use of renewable energy. Not enough attention is paid to this aspect, especially in studies confined to Germany (KRZIKALLA et al. 2013; ADAMEK et al. 2012; GERBERT et al. 2013). An optimised pan-European grid would permit large-scale cross-border compensation of regional or technology-specific supply fluctuations across a number of renewable energy sources and regions. A pan-European grid could certainly help to compensate, at least partially, for the different load profiles in various European countries (SRU 2011; ECF 2010). A European system would also make it possible to integrate more potential from countries outside Europe in the system.

3.2.2 Making electricity supply more flexible

18. Once the installations are in place, electricity generation from wind and sun can only be controlled by curtailment. Temporarily reducing output means forgoing electricity generation, with the result that the installation is less well utilised and becomes more expensive for the operator because of the longer payback period. In individual cases, however, it is possible that from the point of view of the economy as a whole “doing without a few kilowatt-hours […] may be less expensive than costly grid expansion or long-term storage of energy” (KRZIKALLA et al. 2013, p. 38; similarly Deutscher Bundestag 2012, p. 34). Another factor is that feed-in peaks only occur for a relatively small number of hours a year (KRZIKALLA et al. 2013, p. 39). If, on the basis of the data available for 2011 and 2012, one were to limit the joint feed-in of all wind and photovoltaic installations to 80 percent of the maximum feed-in recorded, less than 1 percent of the generatable electricity would be lost (KRZIKALLA et al. 2013).

At present, biomass plants for generating heat and power (co-generation, CHP) are used for generating base load. Technically, however, it is possible to use them for supply-side management. To permit more electricity-driven operation, existing installations need to be expanded by adding a heat storage facility and, in the case of biogas plants, a gas storage unit as well. In principle, the biogas generated can also be fed into the existing natural gas network, obviating the need for a separate gas storage unit (KRZIKALLA et al. 2013; SRU 2011).

Power storage facilities and electricity generation using methane produced from renewable sources can also help to control the amount of electricity supplied (Section 3.2.5).

3.2.3 Making demand more flexible

19. An electricity system based on renewable energy calls for a paradigm change when it comes to balancing supply and demand. Whereas in the past generation has been geared to the load, i.e. supply geared to demand, in future the load will – as far as possible – also have to adjust to the fluctuating supply due to wind and sun. The classic mechanisms of load shifting, i.e. shifting the timing of demand, include in particular the adaptation of industrial demand for electricity, as already practised today in individual cases. Many industrial processes, such as cooling, can be suspended or reduced for a limited period (Agora Energiewende 2013b, p. 27 f.). The potential for load shifting tends to diminish as the duration increases. For example, there is a marked drop in the possibility of stepping up the load to “catch up” if the period concerned is more than one hour (KRZIKALLA et al. 2013, p. 30). A lengthy cutback in production is not necessarily followed by a corresponding increase in production, which may result in load shedding rather than load shifting.

There is uncertainty about the scale on which it will be possible to make economic use of industrial load shifting and load shedding in future. Many studies, however, assume that considerable technical potential already exists, but has not yet been tapped – because of the rarity of price peaks today, the generally low price differences in the wholesale trade and because of conflicting framework conditions (e.g. KRZIKALLA et al. 2013, p. 28 ff.; Agora Energiewende 2013b, p. 27 f.; 2013a). Larger fluctuations in wholesale electricity prices in future could however provide suitable incentives.

Demand side management potential also exists in small-scale industries, in the trade and services sector (GHD) and in private households (GERBERT et al. 2013; APEL et al. 2012). To date, however, this potential is largely untapped and more widely distributed, which would make it necessary to integrate a much larger number of electricity consumers.

Exploiting the potential technically available presupposes the creation of new grid infrastructures with information and communication technologies (smart grids). Smart meters make it possible, by interacting with load-dependent tariffs, to use more low-cost electricity at low-load times and to smooth out peak loads by temporarily reducing demand (IPCC 2011; APEL et al. 2012). There is also a need for appliances that can be controlled by smart meters (smart appliances). To date, however, these are not sufficiently mature for the market. In view of the average replacement frequency of household appliances, such appliances can be expected to come into extensive use some eight to twelve years after market launch (KRZIKALLA et al. 2013).

At present it is uncertain how great the potential is in the household and GHD sectors and whether the necessary investment is worthwhile (Agora Energiewende 2013b; Deutscher Bundestag 2012). The cost of smart meters could be at least partially offset by positive aspects such as help with reducing electricity consumption and remote reading (SRU 2008, Item 123). Many potential customers have (as yet) failed to see the additional benefits, and the energy supply companies have displayed little inclination to make the necessary investments. According to a study for the Federal Economics Ministry (BMWi) by Ernst & Young, private households and small-scale industrial consumers can currently expect the increased costs to be fully compensated by energy savings if their annual electricity consumption is upwards of 6,000 kWh (EY 2013). Furthermore, efficient use of smart grids is only possible if the consumers are prepared to permit external control of at least part of their consumption. However, the use of smart meters and external control of consumer appliances runs into economic, psychological and data privacy obstacles, especially in the case of private households (KRZIKALLA et al. 2013; BRUNS et al. 2012).

20. On the whole, considerable technical potential exists, especially in industry. The integration of new electricity consumers like the heating and transport sectors will also tap further potential for increasing flexibility. However, the extent to which this can be used is very uncertain and depends in part on the further design of interfaces between the electricity, heating and transport sectors. In the household and GHD sectors, further cost-benefit analyses are necessary to determine the extent to which the necessary initial investment makes economic sense. In view of changes in the technical, legal and social framework, it is not possible at present to make any reliable statements about future developments. However, more volatile wholesale prices in the future can be expected to offer considerable incentive to increase the flexibility of demand.

3.2.4 Conversion of electricity

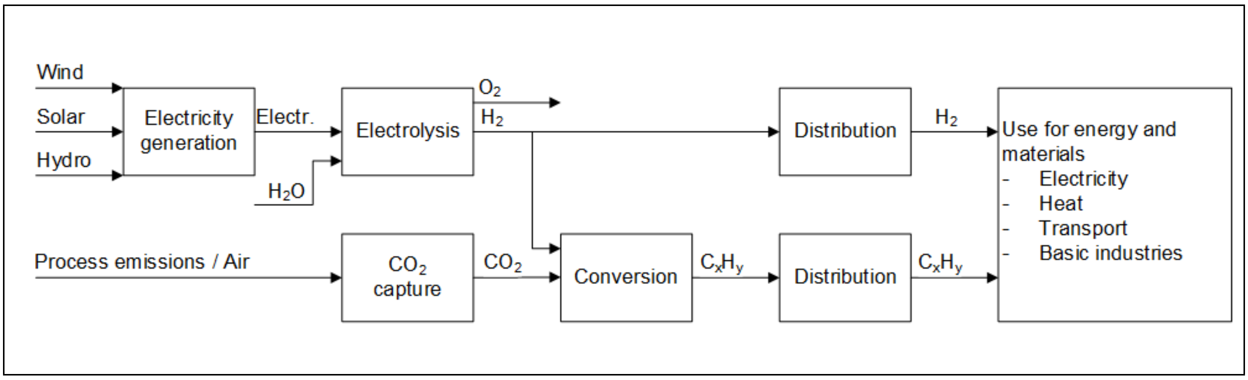
21. The current debate ascribes the greatest development potential to conversion of renewables-based electricity to hydrogen (H_2) or methane (CH_4) – “power-to-gas” (PtG). This is due above all to the possibility of directly using hydrogen or renewables-based gas or storing it for long periods and – especially in the case of methane – making extensive use of the existing natural gas infrastructure (e.g. NITSCH et al. 2012).

22. PtG technology is more expensive and involves greater losses than other storage technologies. Using PtG to generate electricity only makes economic sense if more efficient load balancing technologies are exhausted. Moreover, the gas generated can be used directly in other sectors, and especially for heating purposes.

But PtG offers a wide range of other possibilities. If the energy input is sufficiently high, CO_2 and water can be used to synthesise the main hydrocarbons (C_xH_y) (HÖHLEIN et al. 2003). In further synthesis processes, methane can be converted to longer-chain hydrocarbons such as ethylene, propylene and even synthetic fuels – "power-to-liquid" (PtL). Direct synthesis routes are also conceivable. As well as being used for energy purposes in combustion engines or fuel cells, the hydrocarbons produced in this way using renewable energy have a wide variety of potential industrial uses, e.g. as central synthetic building blocks in the chemical industry. In view of their high energy density, hydrocarbons in gaseous or liquid form are suitable for worldwide transport in proven logistics infrastructures. Figure 3-2 shows the production of methane from renewables-based electricity and the wide range of uses to which it can be put.

Figure 3-2

Conversion processes in an electricity-based energy infrastructure



SRU/SG 2013/Fig. 3-2

23. The efficiency of PtG technology varies depending on how it is used. The overall efficiency of electricity generation from methane produced with renewables-based energy is only about 30 percent. If the methane is used directly as a gas, e.g. in a heating network, the efficiency is between 45 and 55 percent. The efficiency can be improved by making use of the heat produced during electrolysis and methanation (NITSCH et al. 2012). If the hydrogen produced in the first stage is used to generate electricity, an efficiency of around 50 percent is achieved (KRZIKALLA et al. 2013).

Production of synthetic fuels for the transport sector also reduces efficiency considerably to a level assumed to be in excess of 50 percent. This process is still under development, however; efficiency levels are expected to rise to about 70 percent (sunfire 2013). Moreover, the relatively low efficiency of present-day spark-ignition engines due to technical factors means that the overall efficiency of the electricity used in producing these synthetic fuels is around 25 percent.

On the whole, fossil natural gas should be replaced by renewable electricity, as is the case in the heating sector, for example ("power-to-heat"). Converting electricity from renewable energy sources into gas with attendant high losses only makes sense once more efficient flexibility options have been used. When using this renewables-based methane, priority should be given to those applications that display the greatest efficiency.

The cost of methane production is essentially made up of the cost of the electricity for conversion, electrolysis, methanation, and capturing the CO_2 needed for methanation (e.g. NITSCH et al. 2012). It is assumed that the plant-related capital cost will fall over time as a result of technological advances, economies of scale and greater maturity and market penetration (ADELT et al. 2013; TICHLER 2011).

3.2.5 Load balancing using storage facilities

24. Electricity storage facilities can serve very different purposes and may be used at various grid levels. Depending on the technology, they can be used for short, medium and long-term load balancing, and also for providing system services. The storage technologies available today range from small decentralised battery units though compressed-air storage units to large, centralised pumped-storage system that are already in use. Another option is the conversion of electricity into chemical energy sources.

A major factor in the choice of storage technology is the electricity production costs, in other words the cost per energy unit reintroduced into the market. It may be assumed that the market price of the electricity to be stored is close to zero, since only electricity that is not sought on the market by direct consumers will be stored. The electricity production costs are therefore dominated by capital costs and operating costs, and by the discharge frequency of the storage facility. The spectrum of use for the various storage technologies varies depending on the quantity of energy to be stored, the storage duration and the speed of response. A description of the main technologies is given below, with a comparison of their costs.

Pumped storage

25. Conventional pumped storage power plants have an efficiency of between 65 and 85 percent, and their electricity production costs are between 4 and about 10 cents per kWh (NITSCH et al. 2012; FAULSTICH 2011; MAHNKE and MÜHLENHOFF 2012). They are technologically mature, so the parameters available today with regard to costs, efficiency and storage duration can be used to draw conclusions about the situation of pumped storage in the energy system of the future. Pumped-storage systems have been used in Europe for decades and are currently regarded as the most cost-effective storage technology for the foreseeable future (KRZIKALLA et al. 2013; GERBERT et al. 2013; SRU 2011).

In Germany storage capacity is around 6.6 GW, and by 2050 this figure could increase to 10 GW (HENNING and PALZER 2012). Pumped storage systems of the order of 4 GW are currently at various stages of the planning process. KRZIKALLA et al. (2013) believe that these could be available by 2020. The possibilities for expanding the existing pumped-storage capacity in Germany are limited because of the necessary geographical conditions. The technically feasible potential is nevertheless thought to be considerably higher than the 10 GW mentioned above. However, since conventional pumped storage systems involve serious encroachments on nature, environment and landscape, there are major social and environmental restrictions which limit the potential that can actually be used (KRZIKALLA et al. 2013; BRUNS et al. 2012).

Research is under way into the option of installing pumped storage systems in abandoned open-cast mines (SCHULZ 2009) and coal mines (NIEMANN et al. 2012). When using abandoned open-cast mines, the existing excavation is used as the lower lake, and the upper lake is artificially created. Thus, as in conventional pumped-storage systems, this involves an encroachment on the environment and the landscape. By contrast, the visible impairments of the land surface when using coal mines are much less serious. On the other hand, BRUNS et al. (2012, p. 194) point out that the underground use involves substantial “environmental risks arising from pollution and possible displacement of pollutants”, and that there is also a risk of “the pumped water […] finding its way into the groundwater”. Moreover, pumping large quantities of water in and out could destabilise the mines.

Pumped storage systems in Germany are particularly suitable for providing system services and for short and medium-term storage. The volume of the available pumped-storage systems in Germany is not sufficient to address seasonal imbalances, for example if there is no wind for several days or even weeks. Pumped-storage systems in Germany could be supplemented, particularly in the context of a pan-European grid, by making use of storage facilities in the Alps and Norway for seasonal load management. The potential is considerable (FUCHS et al. 2012; SRU 2011; EURELECTRIC 2011; ESS et al. 2012). However, a number of economic, political and environmental obstacles to implementation have to be taken into account (BRUNS et al. 2012; OHLHORST et al. 2012; GULLBERG 2013).

Compressed-air storage

26. Conventional compressed air energy storage (CAES) systems are technologically mature, but the heat generated during storage cannot be used on retrieval. With a figure of slightly over 40 percent, their efficiency is lower than other technologies. Trials are in progress with advanced adiabatic compressed air energy storage (AA-CAES) systems, in which the heat produced during air compression is temporarily stored and reused when recovering the air for electricity generation. Although their efficiency, at 62 to 70 percent, is also lower than that of pumped-storage systems, research is in progress on increasing it by means of improvements in heat storage and compressor and turbine technology. In view of physical restrictions, however, compressed-air storage systems will not be able to reach the efficiency levels of pumped storage systems (KRZIKALLA et al. 2013).

While the capital cost of adiabatic compressed-air storage systems is about the same as for pumped-storage systems, their operating costs are higher (FREY 2007). The resulting electricity production costs of 10 to 23 ct/kWh (KRZIKALLA et al. 2013; NITSCH et al. 2012; FAULSTICH 2011; MAHNKE and MÜHLENHOFF 2012) mean that the economic efficiency of compressed-air storage systems is less than that of pumped-storage systems. When assessing the suitability of compressed-air systems for long-term storage it must also be remembered that they are affected by considerable losses of pressure, and hence capacity, in the course of time. It is also necessary to take account of conflicts of use due to geological factors, especially with regard to storage of natural gas and/or (in future) methane produced using renewable energy (KRZIKALLA et al. 2013; BRUNS et al. 2012). One advantage lies in the geological availability situation, because compressed-air storage systems can be created in central and northern Germany in particular. This means they are close to the main centres of wind energy generation (BRUNS et al. 2012; KRZIKALLA et al. 2013). The potential is put at 9 billion m^3 or 27 TWh (HARTMANN et al. 2012). This volume is sufficient to bridge a two week period of little or no wind (KRZIKALLA et al. 2013). Adiabatic compressed-air systems could supplement pumped-storage systems once the potential of the latter is exhausted.

Methane produced using renewable electricity

27. Estimates of costs for producing and storing renewables-based methane (PtG) are basically still very uncertain (NITSCH et al. 2012, p. 95). Whereas other technologies are dominated by the capital cost of storage capacity, the infrastructure for the storage of methane already exists in the form of the gas grid and gas reservoirs. The storage capacity available in Germany is sufficient to ensure electricity supplies for a period of about three months (KRZIKALLA et al. 2013). In this respect methane differs from the other storage technologies, where the costs of providing the infrastructure are of great significance.

In view of their high capital cost, PtG systems can only be run economically at a high level of full-load hours. It must nevertheless be remembered that surpluses generated from renewable energy, with correspondingly low market prices, only exist for a limited period of the year. The extent to which PtG systems can also be operated at times of high electricity prices depends on demand from other sectors, i.e. heating, transport and industry, and what they are prepared to pay. On the whole, it may be assumed that – as with electricity from other storage technologies – storage of renewables-based methane will only take place when there is no market demand for methane for direct use in the heating, transport and industrial sectors. As with the price of electricity for storage in pumped or compressed-air storage systems, this means that the market price of the methane for storage will be below average.

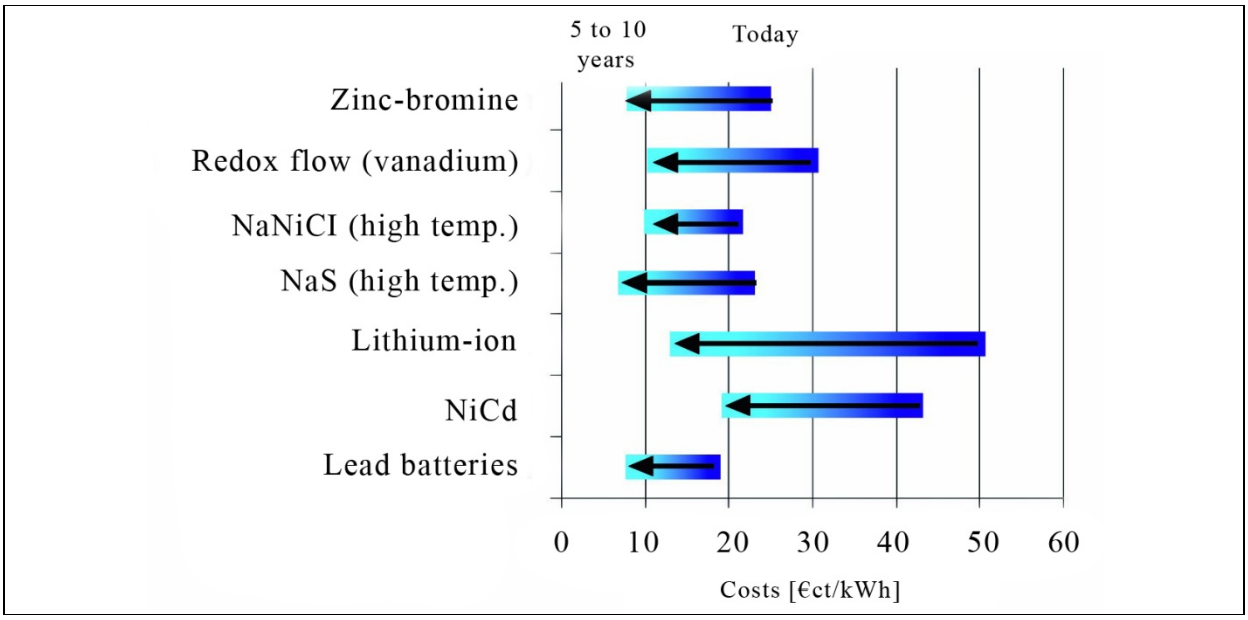
Using PtG-generated methane for seasonal storage is a promising long-term option, but as yet it is difficult to assess its real potential.

Battery storage

28. In the electrochemical storage sector one can distinguish between lead-acid batteries, nickel-based systems, high-temperature batteries, lithium-ion batteries, redox-flow batteries and zinc-air batteries (efzn 2013). At present, electrochemical storage systems are not economic because of their high costs. However, cost reductions can be expected for all technologies, especially in the case of lithium-ion batteries (Fig. 3-3).

Figure 3-3

Cost of battery storage systems



Source: efzn 2013

Among other things, electrochemical storage systems are suitable for providing system services. In particular, batteries with a fast response can be used to compensate the reduction in inertial masses in an electricity system based on renewable energy (momentary reserve), and to help with frequency stabilisation. Basically, battery storage systems are also suitable for short and medium-term load management. As a rule, however, they are not suitable for long-term load management in view of their limited storage capacity and self-discharge properties.

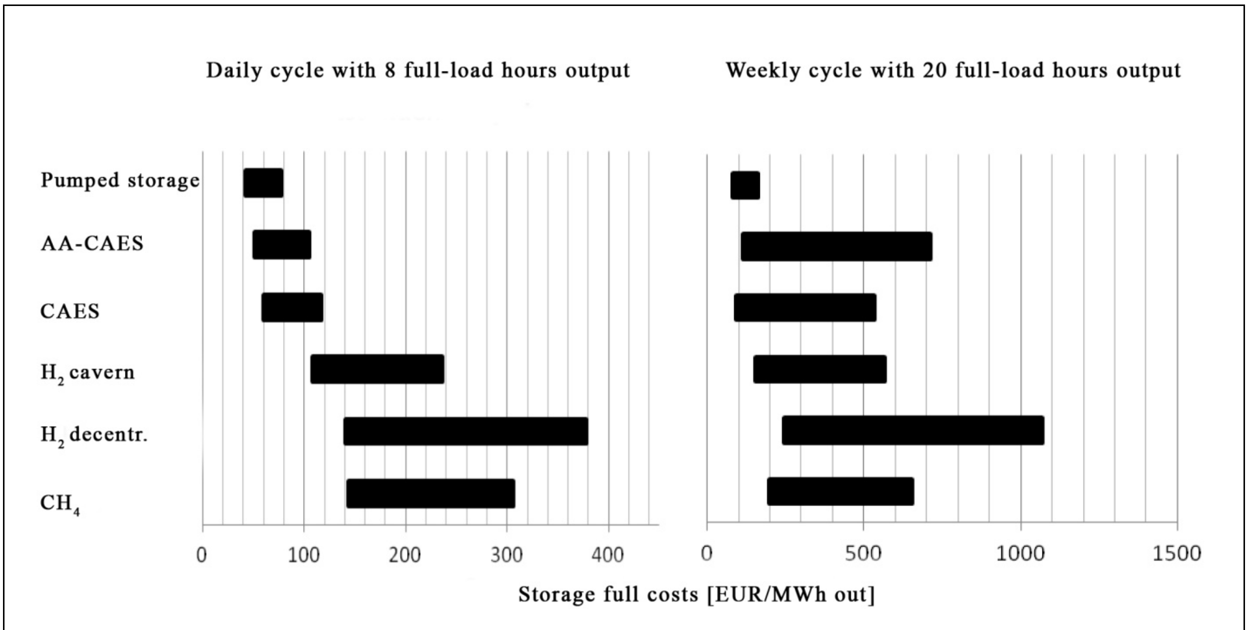
Evaluation

29. Storage systems can help to manage two challenges in particular. On the one hand they are capable of balancing a sizeable long-term difference between electricity supply and demand. In an electricity supply system largely based on renewable energy, storage systems are needed above all to bridge periods of low availability of sun and wind (KRZIKALLA et al. 2013; Agora Energiewende 2013b; Deutscher Bundestag 2012; SRU 2011; CZISCH 2009). In the long-term it is therefore necessary to build up storage capacity suitable for longer-lasting storage covering days and weeks. On the other hand they can provide system services independently of conventional power stations, such as momentary reserve, electricity balancing, reactive power and black start capacity.

30. As far as the economic assessment of storage technologies is concerned, the crucial factor is electricity production costs. They reflect not only the cost of the storage infrastructure and the operating costs, but also the efficiency of the technology or the losses it involves. The number of discharges is relevant here: the smaller the number of storage cycles, the higher the electricity production costs will be (GRÜNWALD et al. 2012). Thus the question of which technology is the most favourable depends, among other things, on how often it is used. Figure 3-4 shows that certain technologies – especially those where capital costs are high – become very expensive if they are not used very often. The spectrum of costs for the various technologies is based on different assumptions (GRÜNWALD et al. 2012).

Figure 3-4

Full costs comparison for storage technologies by type of use



SRU/SG 2013/Fig. 3-4; data source: GRÜNWALD et al. 2012

The profitability of storage facilities also depends on the electricity price difference ("spread") at the time of storage and retrieval. When considering the costs of compressed-air and pumped storage, it may be assumed that in a system based on renewable energy the market price for the electricity to be stored will be very low, since long-term storage facilities will usually only come into use if there is no market demand for direct use of the electricity generated.

Many promising technologies are in the early stages of development or not yet sufficiently mature for the market. This applies, for example, to synthetic production of methane, and also to adiabatic compressed-air storage, electrochemical storage and underground pumped storage. Before an electricity supply system largely based on renewable energy becomes a reality, we can therefore expect to see considerable technical advances which will have a positive impact on the cost structure of these still relatively immature technologies (GERBERT et al. 2013).

31. It is not possible to define precisely the renewables share above which the use of storage facilities will become necessary (BRUNS et al. 2012), especially because the storage requirements depend on the use made of the other flexibility options described. If flexibility is high, far fewer storage facilities will be needed than in a rigid overall system. A study by the German Institute for Economic Research (DIW) examines storage requirements and works on the basis of a renewables share of 85 percent of gross electricity generation. It finds that if total annual electricity generation from renewable sources in 2050 is curtailed by 1 percent, a capacity of 16 GW will be needed for longer-term storage. If there is no curtailment, for example because this is not felt socially or politically desirable, the storage requirement rises to 54 GW. If the overall system is not flexible, however, the DIW arrives at a storage requirement of 93 GW without curtailment and 61 GW with curtailment of 1 percent of the energy generated (SCHILL 2013).

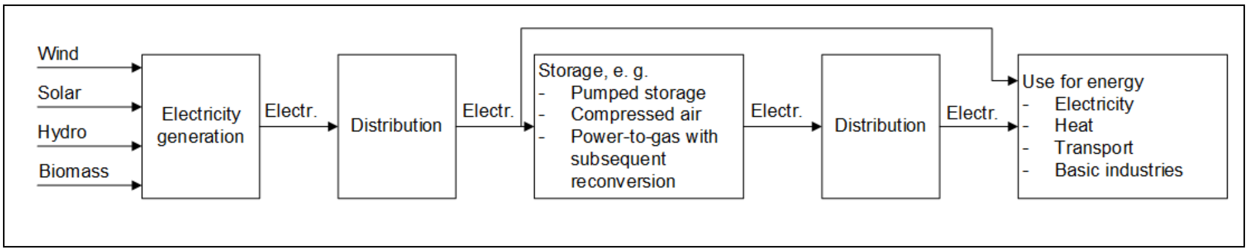
Recent studies (KRZIKALLA et al. 2013; Plattform Erneuerbare Energien 2012; ADAMEK et al. 2012; NITSCH et al. 2012) expect use of storage facilities to increase upwards of a renewables share of 35 to 40 percent or more of electricity generation. The pumped-storage systems already on the market will be used first. When the share rises to 50 percent or more, compressed-air systems will also play a part. By contrast, PtG will only come into use as a storage option for the electricity sector (reconversion) at a later stage, when the renewables share reaches 80 to 90 percent. Agora Energiewende draws attention to the fact that new storage technologies in particular, such as battery systems, adiabatic compressed-air storage or PtG, involve high costs, so using them only makes sense at a renewables share of 70 percent and over (Agora Energiewende 2013b).

3.3 Integrating the sectors

32. As described above, electricity supply will in future be much more electricity based than in the past. The heating, transport and industrial sectors will to a large extent be supplied with electricity from renewable sources (Fig. 3-5). This broadens the demand base for electricity, and gives rise to previously non-existent flexibility potential. A number of load balancing options emerge: For example, the heating sector can use electricity that has been generated but is not needed by electricity consumers. Electricity can be temporarily stored to shift the load in time, e.g. when electricity is stored in the batteries of electric vehicles. However, there is reason to expect that the electrification of other sectors will result in increased demand for electricity (UBA 2013). This additional demand for electricity should as far as possible be met at times when there is a surplus of renewables-based electricity.

Figure 3-5

Future energy infrastructure largely based on renewable energy



SRU/SG 2013/Fig. 3-5

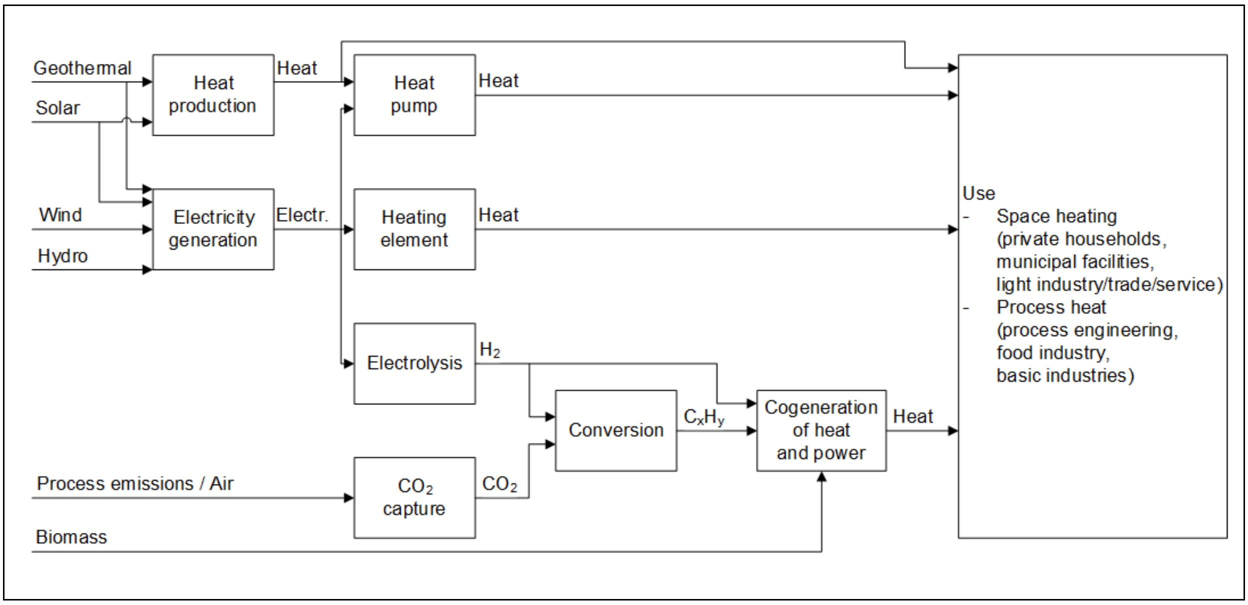
Heat

33. Heating in Germany is currently responsible for nearly 40 percent of the country's total CO_2 emissions. In the context of ambitious climate objectives, the heating supply system of the future must be founded on renewable energy (Fig. 3-6). According to a study by the Fraunhofer Institute for Solar Energy Research (ISE), it would be possible to meet Germany's electricity and heat requirements entirely from domestic renewable resources without imports (HENNING and PALZER 2012). This would cover about 62 percent of Germany's primary energy requirements.

In Germany some 10 percent of heat comes from renewable sources, with biomass accounting for a dominant 92 percent of this figure (UBA 2012). Solar thermal and geothermal energy contribute about 8 percent of heat supply from renewable sources (op. cit.).

Figure 3-6

System for supplying the heating sector with renewable energy sources



SRU/SG 2013/Fig. 3-6

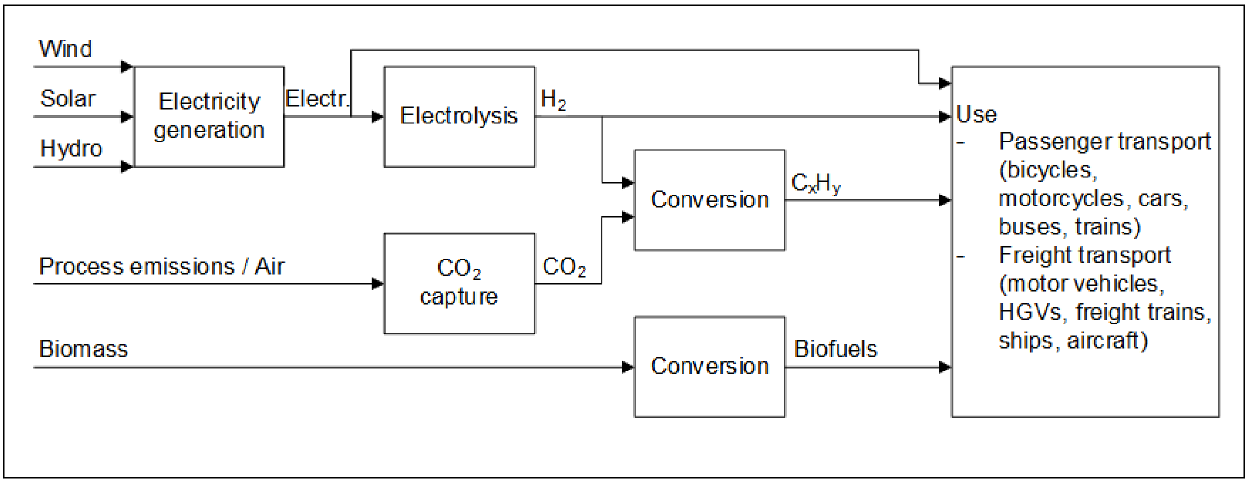
In the medium and long term electricity will play a much greater role in the heating sector. Whereas electric heating of existing buildings must currently be regarded as making little sense, passive houses in the future will have such low residual heat requirements that it does not even seem worthwhile laying a gas pipe, and heat can be supplied more efficiently on the basis of electricity. For existing buildings and industry, a sustainable heat supply system using hydrocarbons produced from renewables-based electricity would seem a possibility, in this case with methane as a substitute for natural gas. The synthetic natural gas can easily be fed into the existing gas network and used in high-efficiency combustion plants where and when it is needed.

Transport

34. Between 1999 and 2011, total passenger traffic in Germany increased by 7 percent and total freight traffic by 31 percent (BMWi and BMU 2012). As a result, despite substantial improvements in efficiency, final energy consumption in the transport sector showed only a slight decrease. In view of this trend, climate policy considerations make it necessary to put the transport sector as a major energy consumer on a sustainable footing (Fig. 3-7).

Figure 3-7

System for supplying the transport sector with renewable energy sources



SRU/SG 2013/Fig. 3-7

35. Full electrification on the basis of renewable energy would seem to be feasible in the motorised public and individual transport sector. In terms of total energy, changing the 43 million passenger vehicles in Germany to electric mobility would result in an annual increase of up to 100 TWh in demand for electricity (SRU 2011, Item 118).

It also seems possible to organise urban deliveries with small and medium commercial vehicles – e.g. post and parcel services – and taxis and some motorised local public transport on the basis of electricity. By using batteries, the electrified part of the transport sector could serve as a means of storing surplus electricity generated by sun and wind.

36. However, the technical and economic design of the interfaces is important if the transport sector is to make a contribution to load balancing. Here the transport sector's demand for electricity should be geared as closely as possible to the amount of electricity actually available at a particular point in time, without placing excessive restrictions on users' mobility needs. Research is currently in progress into reconversion from batteries into the electricity grid, which would turn the transport sector into a huge storage module ("Leuchtturmprojekt der Bundesregierung Intelligente Energie: Elektroautos mit Schwarmstrom", press release by Volkswagen AG, 30 May 2013). One should nevertheless be cautious when assessing this potential. There is also uncertainty as to when the technology will be sufficiently mature for the market and be able compete successfully with other storage technologies.

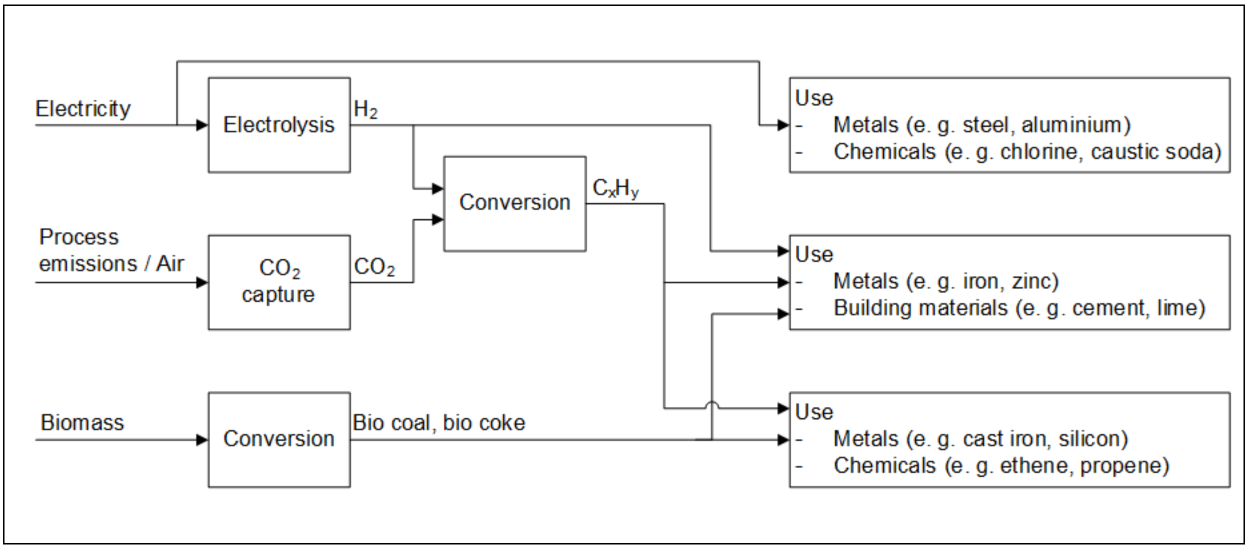
In road freight traffic, and also in sea and air transport, electrification is a much more difficult proposition, since as yet only the railway system is largely electrified. In the road freight sector, electric trolleys in the near-side lane could be supplied with electricity from overhead lines (SRU 2012). In an intelligent mixed system the trucks, equipped with hybrid technology, could be operated with renewables-based fuel on federal or regional roads where traffic levels hardly justify large-scale installation of overhead lines. In the sea and air transport sectors, however, only liquid fuels with a high energy density would seem to meet the requirements at present, in view of the very long distances and heavy loads. In principle it is conceivable that in the not too distant future aircraft or ships in particular could be run on fuels based on electricity generated from renewable sources.

Basic industries

37. Hydrocarbons (C_xH_y) are of great importance, both as fuels and as feedstocks for basic materials and intermediate products along the material value chain. In view of the need for decarbonisation, fossil hydrocarbons will increasingly be replaced by substitutes of renewable origin. This applies in particular to the manufacture of products in the metal industry and building materials such as cement or lime, and to various products of the chemical industry (a more detailed view can be found in EGNER et al. 2012, p. 53 f.). The element hydrogen plays a key role here. Electrolysis is used to convert electricity from renewable energy into hydrogen and oxygen. The hydrogen reacts with CO_2 to form storable products like methane, methanol or other hydrocarbons (BROOKS et al. 2007; Fig. 3-8, see also Item 22).

Figure 3-8

System for supplying the basic industries with renewable resources



SRU/SG 2013/Fig. 3-8

By using CO_2 as an alternative source of carbon, it appears possible in principle to replace the present basic fossil resources. This means there are alternatives to biomass as the only renewable source material for organic carbon chemistry. In future the hydrocarbons synthesised from electrolytic hydrogen and CO_2 – e.g. methanol – can be used as basic chemicals. Methanol is one of the most important and economic synthetic raw materials. Worldwide, some 90 percent of it is used in the chemical industry, and it can serve as a basis for manufacturing almost any desired conventional petrochemical product (KAUSCH et al. 2011; ARPE 2007).

Hydrogen or hydrocarbons produced from renewables-based electricity can also be used for metallurgical reduction processes such as iron smelting. In the blast furnace sector, carbon in the form of coke is essential as a reducing agent. The ULCOS (Ultra-Low Carbon Dioxide (CO_2) Steelmaking) research programme is currently investigating innovative electricity-based smelting technologies in which the fossil carbon needed for reduction is replaced by hydrogen or renewables-based hydrocarbons such as methane. In electric steel production and in non-ferrous metallurgy, electrolysis of copper and aluminium is in any case driven by electricity, and in the latter case this mostly comes from hydro power.

3.4 Interim conclusions

38. Transforming the energy system into a system where electricity is largely generated from fluctuating energy sources as lead technologies has very extensive implications going far beyond the mere substitution of fuels. What is in fact required is a fundamental restructuring of the entire energy system in which the focus is on the supply of electricity from wind energy and photovoltaic systems and all other system components have to be geared to the special features of these energy sources. All controllable capacity must serve to balance the supply of renewable energy.

There is basically a large portfolio of load balancing options. In the long term, this will have to be used to the full. What contribution the individual components make, and in what order they are used, depends on a large number of technical, economic and regulatory factors which will emerge as the transformation of the energy system progresses.

First of all, an energy system that draws its supplies largely from renewable energy means a supply system which is based much more on electricity and which breaks down the boundaries between the individual sectors. Other important features of this new system will be the possibility of converting between the various forms of energy (electricity, heat, fuels) and the interaction of the consumer sectors (buildings, transport, industry).

Grid optimisation and grid expansion in Germany are of special importance for load balancing. The grid is also a precondition for being able to take advantage of the options for more flexible supply and demand. Furthermore, there is a need for greater interconnection of the European power grids and markets, in order to balance rapid variations in electricity supply over as large an area as possible and cater for regional and timing differences.

Demand side management and storage facilities will play a major role in an energy supply system based largely on renewables. Their capacity to ensure secure supplies even in unfavourable meteorological situations by storing for long periods and shifting large quantities of energy is an important factor.

4 Design of an electricity market based entirely on renewable energy

39. As described in Chapter 3, the demand sectors heat, transport and industry will be increasingly integrated in future. A wide variety of storage technologies will be available, and further national and European options for flexible load balancing will have been developed. This will broaden the demand base for electricity, and will open up many new flexibility options that can be used to respond to the availability dependence of electricity generation from renewable sources.

An energy system of this kind, in which weather-dependent energy sources will be the lead technologies, has a number of characteristics and functions that differ from the present system (based on WINKLER 2011; WINKLER and ALTMANN 2012):

– A large proportion of the generating capacity cannot be fully controlled. This will make it more difficult to satisfy the constantly fluctuating demand. Demand side management will have to make a contribution to ensuring power supplies.

– The fact that electricity production is less predictable will present a challenge for forward transactions. All in all, events on the market will move faster, and contracts will be for smaller quantities.

– There will be changes in the cost structure of the electricity generation portfolio. It will be characterised by a large share of fixed-costs and a small share of variable costs.

– There will be a need for considerable back-up capacity, which will not be used very frequently.

40. These new technical features have consequences for the functioning of the electricity market, and hence also for the necessary market design. How the market is designed relates to the issue of the best balance between market and state coordination and how it is organised. Basically, this means that not only today, but also in a future electricity supply system based largely on renewable energy, the market design has to perform three main functions:

– managing power plant capacity deployment more efficiently,

– ensuring adequate flexibility to cover the residual load, i.e. the electricity demand that remains to be met after deducting the feed-in from availability dependent renewable energy sources, and

– reliably financing the capacity needed from a supply security point of view.

The following section analyses the extent to which the present energy-only market is likely to be able to perform the three functions in a system based on renewable energy.

4.1 Managing deployment

41. In the present energy system the energy-only market efficiently manages how capacity is deployed (cf. Chapter 2): The generation capacities (power plants, renewable energy installations and storage facilities) with the lowest variable costs are used first. Only if demand is higher do capacities with higher variable costs come into play. The deployment management function is concerned not only with generation capacity, but also essentially with demand: even today, large commercial electricity consumers cut back their demand if the wholesale price of electricity exceeds what they are prepared to pay.

In a future energy supply system based on renewables, wholesale prices will be much more volatile than today: in view of the large fluctuations in residual load there will be hours when electricity prices are very high and hours when they are very low (price spread). A high energy exchange price indicates a relative shortage of electricity supply. This provides generators (e.g. storage facilities and controllable renewable energy installations) with incentives to step up the amount of electricity they feed in to the market; flexible consumers have an incentive to reduce their power consumption. A low energy exchange price, by contrast, indicates a relatively abundant supply of electricity: flexible consumers can step up their demand in line with what they are prepared to pay, and storage facilities take electricity on board so that they can offer it to the market again when prices are high. Owing to the greater integration of the demand side in load balancing, the picture of supply security changes. Certainly there will still be a claim to security of supply in the sense of centrally organised system security (blackout protection). However, whereas most people today associate the term with constant availability of the electricity they want at a fixed price, in future there will be a price-driven or contractually agreed cut in demand when prices are high at peak-load times. Together with the interconnected electricity-based world described in Chapter 3 with the integration of other sectors, storage facilities and methanation plants, this will on the whole increase the price elasticity of demand and reduce maximum annual loads compared with a less flexible world.

If supply capacities are not inefficiently large, there will for large parts of the year be demand for larger quantities of energy than can be produced at the near-zero variable costs of renewable energy. These will be used, for example, for the needs of households and industry, and also to produce methane or methanol or to meet foreign demand. Because of the resulting rise in prices, there will come a point when capacity with higher variable costs comes into use, such as waste biomass, storage facilities and generating plants in other countries. If the shortages and prices continued to increase, methane production would be discontinued and reconversion in gas-fired power stations would begin in response to further substantial price rises (preceded by load shifting). The latter, however, would only happen in the event of significant price peaks, because the large efficiency losses of reconversion require a correspondingly broad price spread. On the whole the order in which generating capacity is deployed will depend on the variable cost rankings, or merit order.

On balance it can be said that, even with fluctuating renewable energies as lead technologies, capacity deployment can be managed cost-effectively by the energy-only market. Even if a large proportion of renewable energy installations are fluctuating and cannot be fully controlled (inelastic supply), the energy-only market ensures the most efficient use and carefully timed balancing of electricity supply and demand.

4.2 Increasing flexibility

42. Particularly on a long-term view, it is not possible to predict accurately the amount of electricity fed in by wind and photovoltaic systems. This gives rise to considerable requirements regarding controllable capacity on the supply and demand side to meet large and rapid fluctuations in residual load. To translate these technical requirements into market incentives, the market structures also need to be suitably flexible and fast-acting, and to cater for grid operator aspects. The aim is to minimise deviations from forecasts about fluctuating feed-in and the resulting balancing power requirements. It is also necessary to take a number of other measures that make the entire energy system more flexible (cf. Chapter 3) and thereby strengthen the energy-only market.

The shorter-term focus presents challenges for the forward transactions market. This is particularly important for hedging short-term price risks. Weather-dependent energy sources cannot offer reliable output to the same extent as controllable capacity. Some experts therefore see risks for futures trading and fear a need for high risk premiums (LEPRICH et al. 2012). At the physical level the necessary size of such premiums depends on access to balancing options and their costs, e.g. interconnection and storage facilities. At all events there will continue to be a demand for futures market products. Although weather-dependent capacity can be integrated in portfolios with assured capacity (KOPP et al. 2012), this in itself creates a need for such assured capacity. However, assured capacity is increasingly limited in an electricity supply system based largely on renewable energy. For example, generation from biomass provides assured renewable capacity. Assured capacity can also be indirectly derived from fluctuating energy, for example through pumped storage or through the power-to-gas technology. Furthermore, prices on the spot market will be more volatile than today, which might cause it to lose its signal function for futures transactions. The actors on the markets can nevertheless be expected to adapt to the new challenges and develop new strategies and products. It therefore seems likely that the market will see the entry of more intermediaries than at present, who will offer and control the renewable electricity produced on a decentralised basis by large numbers of households. Bundling decentralised electricity in this way makes it possible to offer a portfolio of weather-dependent and assured capacity on the market and to control its supply on the basis of price.

4.3 Financing

43. At present the energy-only market has not only the function of managing capacity deployment, but also a financing function. In other words, prices on the energy-only market must be high enough for power station capacity to make a sufficient contribution to covering fixed costs over and above the variable costs. They must also provide incentives to invest in new capacity.

The situation will be different when electricity supplies come largely from renewable energy sources. While one can expect the energy-only market to provide financing for the capacity that is regularly needed to cover the fluctuating residual load, there will be two other types of generating capacity that will in future require supplementary funding:

– In general, the fluctuating renewable capacity will have to finance itself.

– There will be a need for back-up capacity (gas power plants for reconversion) for the case that occurs every few years of a lengthy seasonal shortage of electricity from renewable energy sources. Renewable fuel must be kept in reserve for these back-up facilities. In addition, back-up capacity will be needed for the rare case of maximum residual load, when a shortage of electricity feed-in from fluctuating renewable energy installations coincides with heavy demand.

4.3.1 Renewable capacity

44. In general, the price level on the energy-only market must be sufficiently high to ensure that companies continue to invest in renewable energy several decades hence. Even if electricity supplies are based largely on renewable energy, the design of the market must offer sufficient financial incentives for both fluctuating and controllable renewable capacities and storage facilities, and also for infrastructures.

At present the price on the energy-only market is determined by the variable costs of the marginal generating capacity . In future we can expect prices on the energy-only market to be determined directly by demand, and also that they will be above the marginal costs of the marginal generating capacity. The short-term marginal costs of electricity production from wind and sun may be close to zero, but their generating capacity is technically limited and fluctuates considerably. If electricity customers' marginal willingness to pay on reaching the – fluctuating – maximum electricity supply is greater than zero (i.e. above the marginal costs of the most recently added generating capacity), then a positive market price in excess of marginal costs is needed to balance supply and demand. The resulting market price does not reflect the marginal costs of generation, but the scarcity of the good "electricity" and the marginal utility of the last kilowatt-hour generated. In situations dominated by such scarcity prices, all (renewable) generating capacity can generate a profit contribution (NICOLOSI 2012, p. 8 ff.). In view of the demand sector integration described in Chapter 3 (heat, transport, basic raw materials), the spatial integration (interconnection with load profiles in other countries) and time-shifting options (storage), demand will be considerably more price-elastic than in the past, with the result that positive prices can still be expected even at relatively high levels of renewable generation. Thus even in a supply system based largely on renewable energy, a situation in which there was no use for fluctuating electricity and the exchange price dropped to zero or in which curtailment of renewable generation was necessary would be a rare occurrence, as it would mean that throughout Europe there was no pumped-storage, compressed-air or gas-storage capacity available, and no demand for heating or refrigeration. In view of the large proportion of wind and solar energy with variable costs close to zero and sizeable fluctuations in supply, prices on the electricity market can nevertheless be expected to be lower and more volatile than at present in an electricity supply system based largely on renewable energy.

Investigation of this question with the aid of modelling has yielded divergent results. In a scenario analysis of this kind, HÖFLING (2013) examines the relative market values of fluctuating renewable resources. Although these values decrease as the market share increases, in most scenarios marketability of renewable generation shows a continuous improvement under the conditions assumed in the study (rise in emission prices and fuel prices; declining costs, increased system flexibility). In the medium to long term renewables might even be possible to cover fixed costs (op. cit.). Similar conclusions are reached by the comparable model-based scenario in the study by enervis and Büro für Energiewirtschaft und Technische Planung GmbH (BET) for the Association of Municipal Service Utilities (ECKE et al. 2013, p. 55–57). Their calculations indicate that in future large sections of the renewable energy sector will no longer need financial assistance. On balance, these studies come to the conclusion that, even if electricity supplies come largely from renewable sources, the energy-only market will be able to make a contribution to financing renewable energy. By contrast, another model-based study comes to the conclusion that financial contributions by the energy-only market will not be sufficient for the weather-dependent generating technologies (KOPP et al. 2012). This study, however, is based on current energy market prices, i.e. when estimating possible financial contributions it does not take account of the fact that increased demand from new, flexible consumers will support the price of electricity on the exchange.

On the whole it can be said that even if profit contributions are generated, there is at least some doubt as to whether these will be sufficient to finance renewable energy installations in full. The size of the trading contributions depends on the assumptions made about greater flexibility in the rest of the system, and hence about a reduction in the merit-order effect. A more flexible energy system with a less marked merit-order effect permits high financial contributions.

Special aspects of financing controllable capacity

45. In spite of the mechanisms mentioned above, the extent to which the individual generating and flexibility technologies will be able to pay for themselves on the market remains unclear. This is determined by the merit order, i.e. the deployment sequence, which results from the individual variable costs. Technologies with high variable costs will be used less frequently and will regularly generate lower trading contributions per deployment. In view of the merit order, technologies with low variable costs will be given preference even without feed-in priority.

Power plants based on solid biomass, and also combined cycle gas turbines and gas-fired power stations based on biogas or other renewable gases, have higher marginal costs than the other renewable technologies and are therefore used less frequently. The less often they are used, the more their average costs exceed their variable costs. For this reason these are the technologies where the greatest financial risks can be expected.

46. Storage facilities have both a demand and a supply function. The crucial factors for the profitability of storage facilities are the difference between the electricity price at the times of storage and retrieval (price spread) and the frequency of use. The resulting revenue contributes to financing investment and covering operating costs.

Storage facilities are particularly suitable for short-term load balancing and for providing control reserve (cf. Item 24 ff.). Thanks to the probable large number of discharge cycles, it seems likely that in the long term they can be financed via the market in view of the expected volatility of spot-market prices and the associated price spread.

Power-to-gas systems have high investment costs, but also additional financing opportunities, because in some cases they can make more revenue thanks to the varied uses to which the gas can be put. Thus it is not possible at present to assess what the financing situation for power-to-gas installations will be like in an electricity supply system based largely on renewable energy.

Prices for supply capacity

47. To the extent that gaps in financing have to be filled, it will be necessary to develop alternative financing options for the largely renewables-based electricity supply. On the supply side, the SRU advocates that in a renewables-based energy system a transitional phase should be followed in the long term – i.e. once financing is essentially taking place via the market – by a system of capacity prices for certain parts of the renewable capacity. Then the present phase of extending renewable capacity will give way to a phase of maintaining and ensuring capacity. In the long term the present growth-oriented system of price-setting approach of the feed-in tariff will be permanently replaced by a system of setting the quantity of renewable capacity. This applies particularly to large-scale technologies and installations (wind farms, large free-standing photovoltaic systems) and those which cannot pay for themselves on the energy-only market and appear to need capacity back-up for supply security reasons (cf. Item 44 f.). In parallel there can also be unsubsidised construction of those technologies that can pay for themselves. This must be strictly distinguished from the question of whether it is necessary *at present* to create capacity mechanisms for fossil capacities, which is discussed in Chapter 5.2..

On the whole the SRU takes the view that in future, once electricity supplies are largely based on renewable energy, the market will not be able to finance the necessary renewable energy installations completely. In the long term, therefore, it will make sense, on both the supply side and the demand side, to ensure a clearer distinction between service or capacity charges on the one hand and consumption charges on the other. On the supply side it will be task of the state to organise financing.

Demand-side cost allocation

48. In view of increasing share of fixed cost resulting from the infrastructure requirements described in Chapter 3.2, combined with less frequent use of such infrastructures, there will in future be a need to ensure better cost allocation to the demand side. In the long term, therefore, it will make sense to ensure a clearer distinction between capacity charges on the one hand and electricity consumption charges on the other. A cost allocation system based entirely on electrical work used – i.e. per kilowatt-hour – cannot generate an adequate contribution to finance. In view of high fixed cost components this applies in principle to all infrastructures with the exception of short-term storage facilities. However, the ones least frequently used are those most affected. In view of a greater degree of self-generation, service charges would ensure greater equity of financing in an electricity supply system based largely on renewable energy. Private operators of renewable energy installations (e.g. photovoltaic roof systems) who supply their own electricity to a large extent, are also dependent on the power grid. They use external electricity when their own supply is not sufficient, and at other times they feed surplus electricity into the system. On the whole, therefore, there is a need for a larger and at least partially flat payment for keeping these structures available for when they are needed (SVR 2012, Item 449).

By analogy with the grid fees paid by major consumers, a capacity-related component should in the long term be introduced for smaller consumers as well. At household level the consumption-independent “meter price” for example, could be developed into such a system. Such a combined model of capacity charges and consumption prices should be weighted to ensure that it covers those fixed costs of the electricity system that are not generated by trading contributions from the electricity system. The combined model would provide efficiency incentives for both components – capacity and consumption. It creates incentives to reduce overall consumption and maximum load by investing in energy efficiency and demand side management. That is why a combined model is preferable to a straight flat rate, to maintain the incentive to save on the part of the consumer.

4.3.2 Financing the back-up

49. For peak-load management, problems arise from the situation with maximum residual load that can occur, for example, on a cold winter’s evening with no wind, when only controllable renewable installations are feeding in electricity (Agora Energiewende 2012). Another critical situation is the rare case of a lengthy seasonal shortage of electricity from renewable sources. These situations call for back-up capacity (gas-fired power plants for reconversion of renewable gas) and fuel reserves, which also need to be financed. However, ensuring electricity supplies for Germany as an industrialised country and an attractive location for business is a task for the state. The state therefore has to ensure that this back-up capacity is available on an adequate scale. Such supply shortages can be offset by long-term storage facilities or by highly flexible gas turbines.

Long-term storage and flexible gas turbines

50. Even if the financing of storage facilities for regular short-term load balancing, as described, need not be a problem, the situation is different when the storage option is intended to perform an “insurance-like” function that has to offset large-scale or lengthy supply shortages due to weather conditions. A very large price spread would be necessary to ensure financing entirely via the market. Moreover, it is uncertain how much storage capacity would have to be kept available to ensure security of supply in a system based largely on renewable energy. It therefore seems doubtful whether sufficient incentives exist to invest in the large-scale storage capacity that is needed for such special cases, since their capacity is only used for a few cycles a year or even less. How long-term storage facilities can be financed is thus an unanswered question.

Furthermore, it seem likely that the potential in Germany is largely exhausted, especially for pumped-storage system, in view of nature conservation and environmental and landscape considerations and the lack of acceptance by local communities. Additional capacity can only be created by using or expanding existing pumped storage systems, especially in the Alps and Scandinavia (see also SRU 2011).

On the assumption that long-term storage facilities will only be necessary when electricity supplies are based almost entirely on weather-dependent renewable energy sources, renewable methane that is produced by a power-to-gas process and can be reconverted in gas-fired power stations is another possible alternative (cf. Item 21 – 23, 27).

Even if 100 per cent of capacity had to be kept available in the form of gas turbines to bridge long-lasting periods of calm in winter in an electricity supply system based on 100 per cent weather-dependent energy sources, this would only increase the price of electricity by about 0.5 ct/kWh. This calculation is based on gas turbine costs of 400 EUR/kW, a useful life of 25 years, an interest rate of 5% p.a., gross electricity generation of 509 TWh/a and an annual peak load of 85 GW. If this reserve capacity of 500 full-load hours per year were used at fuel costs of 0.035 EUR/kWh and an efficiency of 40 per cent, the electricity produced would cost around 9 ct/kWh. Spread over the annual quantity of electricity produced by the system as a whole, this would only amount to about 1 ct/kWh including capital costs.

Renewable gas

51. Assuming that storage of electricity in the form of synthetic methane will play an important role in a supply system largely based on renewable energy, there is no reason to expect that its long-term storage can be financed by the market, in spite of the expected fall in the cost of synthetic methane, especially with regard to its broad spectrum of possible uses.

It could therefore become necessary to introduce a renewable gas reserve to ensure operation of gas-fired power stations (reconversion). It would be deployed if electricity production from sun and wind was inadequate and if the other flexibility options described in Chapter 3.2 were unable to guarantee secure supplies. The existing infrastructure could be used to store the renewable gas reserve. The design of this system could be based on the strategy and experience of the petroleum reserve model introduced in 1966 (Erdölbevorratungsverband 2008).

4.4 Interim conclusions

52. Even under the conditions of a supply system largely based on renewable energy, the main functions of the energy-only market must be guaranteed, namely managing generation capacity deployment, sufficient flexibility to cover residual load and financing of capacity. The market structures must be adapted to the characteristics of the future lead technologies.

Capacity deployment will continue to be managed via the energy-only market. Moreover, to balance the fluctuations in electricity from renewable energy and the fact that they are more difficult to predict, adjustable capacities will also have to satisfy high flexibility requirements. What is more, the biggest challenge will be financing the capital cost of renewable energy installations and the supplementary infrastructure.

53. At present the price on the energy-only market is determined by the variable costs of the marginal generating capacity. In future we can expect an increasing number of instances where prices on the energy-only market are set by the demand above the marginal costs of the marginal generating capacity. In view of the demand sector integration (heat, transport, basic raw materials), the spatial integration (interconnection with load profiles in other countries) and time-shifting options (storage), demand will be considerably more price-elastic than in the past, with the result that positive prices can still be expected even at relatively high feed-in levels. Thus a situation in which there was no use at all for weather-dependent electricity and the exchange price fell to zero or curtailment became necessary would tend to be rare situation, even in a supply system based largely on renewable energy sources. In view of the large proportion of wind and solar energy with variable costs close to zero and sizeable fluctuations in supply, prices on the electricity market can nevertheless be expected to be lower and more volatile than at present in a supply system based largely on electricity from renewable sources. This will provide certain – albeit limited – financial opportunities.

To fill the finance gap on the supply side, the SRU advocates in the long term a system of capacity payments for the renewable capacity cost component that cannot be financed through the energy-only market. In a supply system based largely on renewable energy this would mean a transition from the present price-setting system to a system in which the quantity of renewable capacity is set. Considerable further research is needed to ascertain the implications for the design of this system. On the demand side, electricity customers should pay separate capacity charges to finance supply security. In view of rising fixed cost components, this will help to allocate costs better to those who cause them.

The situation with maximum residual load causes problems in peak-load balancing. Furthermore, there will be – albeit occasional – periods when there is not enough renewable energy being fed in, and these cannot be offset by short-term storage options. The market does not offer adequate financing opportunities for insurance-like solutions for these rare long periods. However, guaranteeing security of supply is a state function for which suitable solutions have yet to be found. The SRU therefore assumes that back-up capacity in the form of long-term storage facilities and highly flexible gas turbines will have to be available, and their financing will have to be ensured by the state. It could also become necessary to introduce a renewable gas reserve to ensure operation of gas-fired power stations.

5 Market design for the transition

54. The preceding sections have identified plausible characteristics of a future electricity market based on renewable energy. Starting from this vision of the future, which is primarily based on a large measure of integration of the various energy consumption sectors (heat, transport, industrial processes), first steps for the transition are suggested below. The central issue from the point of view of the SRU is, above all, to facilitate a more market-oriented but seamless transition that does not bring the further growth of renewable energy to an abrupt halt.

The following proposals therefore set out modifications to the existing electricity market and the existing promotion system that permit such a seamless transition to a largely renewable energy supply system. After a description of the existing problems in Chapter 5.1, Chapter 5.2 goes on to look at the two main options currently under discussion in Germany for supplementing the energy-only market: capacity market and strategic reserve. Chapter 5.3 examines the central importance of a sufficiently high carbon price and discusses means of ensuring it. The measures that make sense in any case ("no-regret measures" for the further development of the electricity market) are considered in Chapter 5.4. Finally, Chapter 5.5 discusses the future development of the Renewable Energy Source Act (EEG). This includes a proposal for possible further development of the variable market premium.

55. Any addition to the existing market design will have to meet a number of fundamental requirements. Firstly, proposals for reform should take the energy system of the future as a reference point to prevent the creation of permanent structures that impede the necessary change. The risks of every change in market design must be set against the expected benefits. After all, it is unlikely that such changes will succeed from a standing start and without interest-driven influence. Secondly, it also follows from this cost-benefit comparison that in view of the great uncertainties the electricity market design should be adaptable and open to learning. Thirdly, modifications to the market design must take account of the problems that are already occurring or can be expected to occur. When assessing present-day problems, however, it is important to take the long-term approach of the *Energiewende*, in order to look beyond the day-to-day political context when examining their actual importance and identifying their implications.

While satisfying the requirements mentioned, a reformed market design must also ensure that the three main functions of the energy-only market are preserved, namely deployment of the fleet of power stations, financing generation capacity and provision of flexibility. It is also necessary to take account of the framework conditions which influence the functioning of the transitional regime, e.g. climate policy. An aspect of central importance here is a sufficiently high carbon price, since this not only helps to achieve the climate objectives, but also induces the necessary structural change in the portfolio of fossil-fuel power stations. A sufficiently high carbon price would reduce the present financing problems of the necessary flexible capacity. This would be desirable in the interests of minimising the cost of structural change. Sufficiently high carbon prices must therefore be regarded as a precondition for each of the changes in market design discussed below (Item 72).

5.1 Present problems

56. In the public debate, people expect great things of a new market design. The projected reform is to address a large number of developments that are perceived to be current problems of the *Energiewende*. They include the profitability problems of flexible gas-fired power stations and pumped-storage systems, the financing of a back-up portfolio of fossil-fuel power stations which some consider to be necessary, the falling wholesale and rising household electricity prices, the incomplete market integration of renewable energy, a perceived over-subsidising of renewable energy sources, and the difficulty of steering renewable generation technologies and locations through the EEG. The following sections look into three issues which the SRU considers to be of central importance for the future development of the market design: the surplus capacity of non-flexible power stations, the task of ensuring security of supply, and the cost of expanding the renewable energy sector.

5.1.1 Non-flexible surplus capacity

57. In future the entire energy system will have to adapt to the large and rapid fluctuations in electricity fed in by weather-dependent sources. This makes it necessary to provide highly flexible capacity to cover the residual load, i.e. the electricity demand that remains to be met after deducting the feed-in from weather-dependent renewable energy sources. The necessary flexibility can be achieved by means of controllable generating capacity, demand side management or storage facilities. To maintain system reliability, flexibility becomes the central criterion in the future development of adjustable capacities (power stations, sheddable loads and storage facilities). In particular, rapid start-up and shut down of power stations must be possible (GOTTSTEIN and SKILLINGS 2013; HOGAN and GOTTSTEIN 2012; LEPRICH et al. 2012).

However, today's power plant portfolio is not compatible with the requirements mentioned. It is characterised by surplus capacity and non-flexible base-load power stations with low marginal costs (fuel costs, emission allowances and other variable costs). They are relatively early in the merit order and are therefore used frequently. Most of them are nuclear and coal-fired power stations, which in 2012 together accounted for one third of capacity and about 60 per cent of gross electricity generated. In 2012 the particularly non-flexible nuclear and lignite power stations made up 17 per cent of capacity and 42 per cent of gross electricity generated (Federal Network Agency 2013; AG Energiebilanzen 2013). Today, however, the conventional must-run (i.e. minimum generation by conventional electricity plants) is so large that at certain hours during the year it exceeds the residual load, thereby leading to negative prices and the curtailment of renewable energy. By contrast, flexible low-emission gas turbines and gas-and steam plants in the medium and peak-load sector have the greatest financing problems, because they have high marginal costs, are relatively late in the merit order and are therefore most infrequently used (cf. Fig. 2-2). The low price of emission allowances is a major factor responsible for the fact that coal-fired power stations are comparatively well utilised, whereas gas-fired power stations have become less profitable as a result of low prices and low operating hours (BDEW 2013b, p. 20).

5.1.2 Supply security

58. For some time now there has a been a controversial discussion about whether supply security is assured in the *Energiewende* (LEPRICH et al. 2012, p. 17; Agora Energiewende 2012; 2013b, p. 20; TIETJEN 2012; NICOLOSI 2012b; MATTHES et al. 2012; MÜSGENS and PEEK 2011; CRAMTON and OCKENFELS 2012; BMU 2013b). The final phasing out of nuclear power at the end of 2022 must be regarded as the crucial date here. By the end of 2022 some 12 GW of nuclear capacity will be taken off the grid – as much as 10 GW of this figure in the years 2019 to 2022 (13th Act amending the Nuclear Energy Act, 31 July 2011). This could give rise to shortages, especially of a regional nature. Regional shortages can best be countered by stepping up the expansion of the power grid. It remains to be seen whether the situation can be remedied effectively by the new planning of electricity grids under Section 12a ff. of the Energy Management Act (EnWG).

Financing conventional capacity

59. In the medium term there are also controversial discussions, under the heading of the "missing-money problem", about whether deregulated energy markets are in fact in a position to generate sufficient contributions to cover the costs of the necessary conventional generating capacity. It is not finally settled whether the energy-only market geared exclusively to the sale of electricity quantities can, on the marginal costs principle, perform the financing function ascribed to it and thus ensure security of supply (LEPRICH et al. 2012, p. 17; Agora Energiewende 2013b, p. 20; TIETJEN 2012; NICOLOSI 2012b; MATTHES et al. 2012; MÜSGENS and PEEK 2011; CRAMTON and OCKENFELS 2012). The missing-money problem is also being discussed for electricity markets based exclusively on conventional sources of energy. The growing share of renewable energy with low marginal costs – especially the photovoltaic feed-in at the time of the midday consumption peak – reduces wholesale electricity prices and exacerbates the problem.

In Germany certain fossil power plants have been suffering from profitability problems for some time now, because not only their revenue per kilowatt-hour, but also their utilisation are falling (BDEW 2013b). In some cases they are no longer making an adequate contribution to covering the capital costs of existing capacity. At present this problem primarily affects flexible gas-fired power stations, which have lower emission levels than coal-fired power stations. Some of these are only operating for very short periods. There is currently little incentive to invest in new generating capacity.

Assessments of the functioning of the energy-only market vary very widely. One opinion is that no empirical evidence exists as yet for market failure in the medium term, and that economic theory does not offer any cogent reasons for market failure either (NICOLOSI 2012a, p. 29). The other view submits that the theoretical and empirical findings show that basically the energy-only market will hardly be in a position to ensure security of supply, because of inherent limitations, regulatory uncertainties and risk-avoiding investment behaviour (MATTHES et al. 2012, p. 39). These very divergent assessments are based on different assumptions about the self-healing powers of markets. The question at issue is whether the players on the energy-only market can foresee potential capacity shortages in good time and will invest sufficiently far in advance to avoid such shortages from the outset.

Accordingly, opinions are divided on whether it is a temporary problem that can be solved within the market, or whether there is a need to correct or supplement the design of the market.

60. One argument for the idea of a temporary gap in finance is that today's power plant portfolio is dominated by surplus capacity dating from the time before deregulation (TIETJEN 2012, p. 9; WINKLER et al. 2013). For the market mechanism to create sufficient incentives for financing, there must first be a shortage. Analyses show that the energy-only market has behaved in line with theoretical expectations in recent years. The trend of prices over time has reflected the shortage situation. High-price phases arise from shortages. Low-price phases are due partly to surplus capacity, but also to failure to adapt the power plant portfolio fast enough to the expansion of renewable energy (NICOLOSI 2012b, p. 8 ff. and 20 ff. with further references). As a rule, studies which consider it necessary to introduce additional financing instruments work on the basis of certain assumptions, such as straight marginal cost pricing and fixed power plant lifetimes. However, these assumptions are disputed and may not necessarily apply (NICOLOSI 2012b, p. 5–7 with further references). The status quo, however, is claimed to be the result of the slow pace of structural change in the fossil power plant portfolio. It also results from the fact that the other energy consumption sectors (transport, heat, basic industries) have not yet adapted to a supply system based on electricity and there has yet to be adequate expansion of the power grids.

61. One argument against this theory is that a number of countries with deregulated energy markets – regardless of the expansion of renewable energy – have already introduced capacity markets. This can be taken as a sign that the energy-only market alone cannot ensure security of supply. This is accompanied by the observation that almost the entire power plant portfolio was built and financed before deregulation. The addition of new capacity since then is explained, at least in part, by special factors. Another objection is that the functioning of the energy-only market is linked to a number of preconditions that frequently do not exist in reality, such a flexible demand for electricity, or are not accepted by the public, such as high electricity prices (MATTHES et al. 2012, p. 36 ff. with further references).

Estimates of when capacity needs to be assured, and on what scale, diverge between various studies. A metastudy providing an overview of various studies narrows down the additional capacity requirement to between 4 and 15 GW in 2020 (LEPRICH et al. 2012, p. 28, footnote 5). In another metastudy, the figures for the same year range from 0 to 13 GW (WINKLER et al. 2013). The estimates are the net result of current, approved and planned new facilities and closures. The great divergence between the studies is due to the uncertainties affecting the information. Furthermore, all studies arrive at different assessments of other capacity options, such as demand management, and include them in different ways.

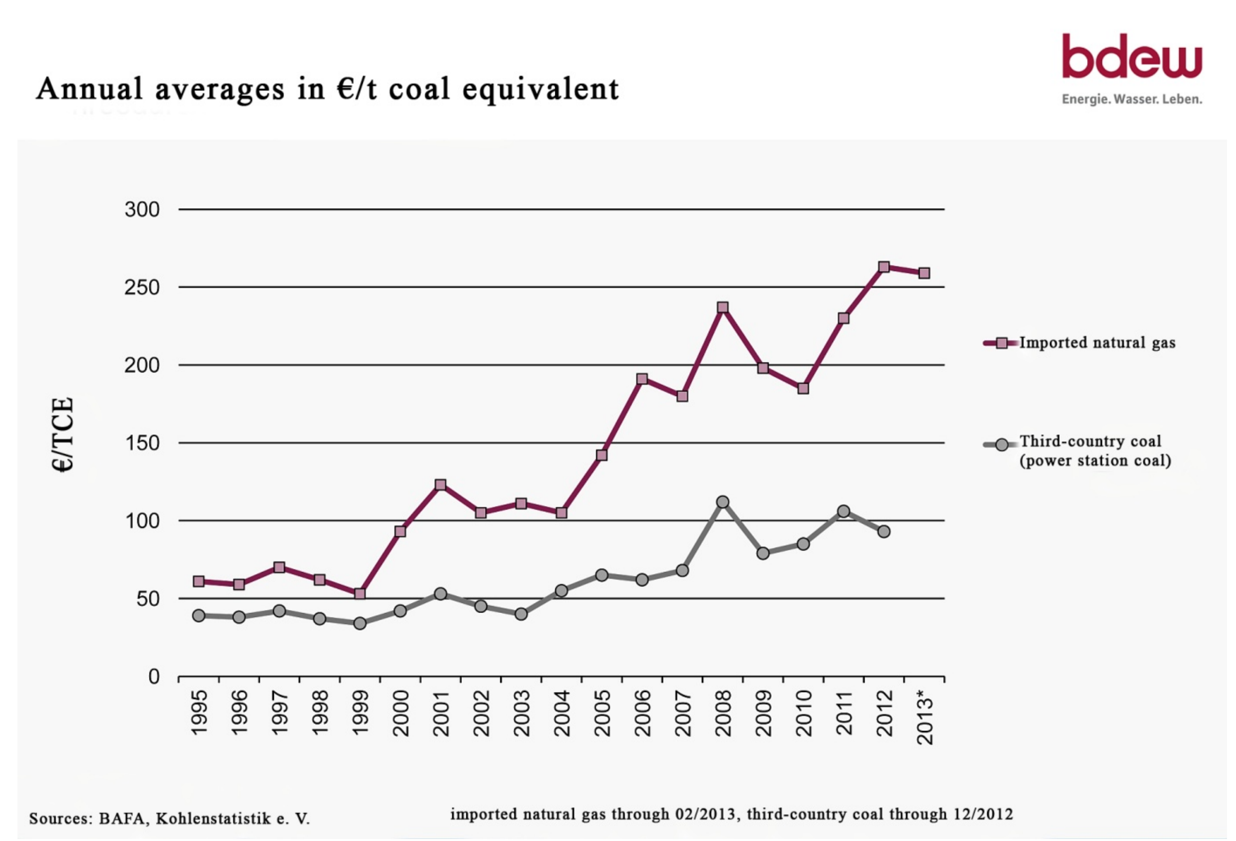
5.1.3 Costs

62. A central starting point in the discussion about reforming the EEG is the issue of electricity prices. The reform of the EEG should be based on indicators that systematically register the costs and benefits of the expansion of renewable energy. Here the focus should be on the efficiency of measures to promote renewable energy. The present debate, however, has an undue focus on electricity prices, and is based on incorrect assumptions. Firstly, it explains the increase in electricity prices in recent years as being due entirely to the expansion of renewable energy. Secondly, the dispute concentrates on the EEG surcharge, and thus on an indicator that is not suitable for determining the real costs of promotion. Thirdly, it exaggerates the resulting social problems and the overall importance of such developments for the economy as a whole. As a consequence there is a risk of short-term intervention by politicians which could jeopardise a smooth transition to renewable energy without actually increasing the efficiency of renewable energy promotion. The SRU therefore expressly warns against such misinterpretations of the trend in costs.

63. As recent analyses show, household electricity prices have more than doubled since the year 2000, to 28.5 ct/kWh (BDEW 2013a). Only about a third of this increase is due to renewable energy (WEBER et al. 2012; WEBER and HEY 2012b; LORECK et al. 2012). The costs of fossil generation and distribution have also risen substantially. The main reason for this is the rise in global trading prices for gas and coal (see Fig. 5-1). Moreover, the increase in value-added tax in proportion to the other electricity price components has also resulted in considerably more funds for the federal budget. Thus it is not correct to place undue emphasis on renewable energy sources as being responsible for the rise in costs.

Figure 5-1

Development of selected energy prices



Source: BDEW 2013c, adapted

According to forecasts by the International Energy Agency (IEA 2012), the price increase for fossil fuels will continue in the decades ahead despite the "shale gas revolution" in the USA. The analyses by the Energy Watch Group suggest that there will be an even more marked increase in prices for all fossil fuels (ZITTEL et al. 2013; also: GERBERT et al. 2013 for the BDI; SRU 2013b).

64. To systematically capture the costs and benefits of the further expansion of renewable energy, there is a need for suitable indicators. Cost estimates for the future which merely cumulate the total investment requirement for renewable energies without considering overall costs are inappropriate (cf. review in: acatech 2012, p. 15 f.). One economic characteristic of electricity generation from sun and wind is the fact that high initial investment is followed by low operating costs. If only investment costs are taken into account, this means that savings on operating costs, especially due to the phasing-out of fossil fuels, are overlooked.

A more appropriate indicator is differential cost estimates, which consider both capital costs and operating costs and compare a renewables expansion scenario with a reference scenario. The "Lead Study" conducted at the request of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) has been using such a differential costs estimate for years now. According to the Lead Study the cumulative differential costs for the expansion of renewable energy between 2011 and 2030, as approved in the *Energiewende* decisions, come to around 137 billion EUR. In the following decade, this amount will be completely offset by the fact that electricity supplies based on renewable energy will be cheaper than a conventional system because of their lower operating costs (NITSCH et al. 2012). If the external costs of electricity generation on the basis of fossil fuels were taken into account, the cumulative differential costs would become negative as early as 2030, in other words there would be a cost saving compared with the conventional pathway.

However, the costs taken as a basis for the Lead Study are incomplete in that they do not take account of the infrastructure and storage expansion necessary for the *Energiewende* (NITSCH et al. 2012). In fact, therefore, it will probably take a few years longer for the cumulative differential costs to become negative. It should be noted, for example, that a large proportion of the infrastructure costs estimated for grid expansion would, according to the Federal Network Agency, be incurred even without the *Energiewende* (GAWEL et al. 2012a, p. 279). Even if the full amount of infrastructure and storage expansion costs is included, the differential costs are well below the total investment requirement by 2030. According to a systematic calculation, single-digit billions of EUR will be incurred up to 2030 as realistic annual additional costs to society if renewable energy expansion proceeds so that it reaches a share of 63 per cent of electricity generation (NITSCH et al. 2012, p. 105).

The estimates of the Boston Consulting Group for the BDI lead to similar conclusions. For the years 2011 to 2030 they calculate a total investment requirement (including grid expansion) of 372 billion EUR for a target scenario that envisages a 69 per cent renewables share of electricity generation by 2030. For comparison, the study also calculates a fossil scenario based on stagnation of renewable energy at around 28 per cent and the replacement of electricity from nuclear power stations by gas-fired power stations. In this scenario there is an investment requirement of about 150 billion EUR for new conventional power stations (GERBERT et al. 2013, p. 37). If, as well as the differential investment costs calculated by Boston Consulting Group, one were to deduct the savings on current costs (fuels and CO_2 allowances), the magnitude of total differential costs would be similar to that in the BMU Lead Study.

The Energy Institute of the University of Cologne (EWI) has calculated for the BDI the costs that could be saved if the expansion of renewable energy were cancelled with immediate effect. In the next ten years up to 2022 this savings potential is around 58 billion EUR, or about 10 per cent of the total cumulative system costs of 556 billion EUR for the energy supply system (BERTSCH et al. 2013, p. 8). Because of the liabilities generated in the past, an immediate stop could at most save costs of less than 6 billion EUR per year – albeit at the cost of failing to achieve the climate and energy objectives.

The statement by the Expert Commission on the German Government's first monitoring report "Energy for the Future" arrives on balance at the conclusion that the share of gross domestic product accounted for by electricity is still within the historical corridor of fluctuations between 2.6 per cent (1991) and 1.7 per cent (2000) (LÖSCHEL et al. 2012, p. 101). Electricity costs account for a similar share of expenditure by private households. In 2013 this share was around 2.5 per cent. In the public debate, there is a much greater focus on the electricity price increases alleged to be due to renewable energy than on the price increases for other uses of energy, which also account for a large share of expenditure (motor fuels 3.45 per cent and heat 2.41 per cent). Nevertheless, the differences in the impact on different income groups must be taken seriously. Supplementary measures are needed to cushion these impacts (NEUHOFF et al. 2012).

On the whole, costs and prices can be expected to increase much less sharply than in the past decade. Such an increase can therefore be characterised as economically and socially acceptable.

EEG surcharge

65. The level of the EEG surcharge is usually taken as an indicator in the debate about the cost of the *Energiewende*. In 2013 the EEG surcharge rose from 3.59 to 5.3 ct/kWh. In 2014 it will reach 6.24 ct/kWh, and in the next few years it could increase to over 7 ct/kWh (GERBERT et al. 2013). But other studies forecast a stabilisation of the EEG surcharge as being more likely (NAGL et al. 2012).

On the whole, however, the EEG surcharge is not a suitable indicator of the cost of promoting renewable energy, especially for the following reasons:

– Because sections of industry are exempted from the surcharge, the number of end consumers liable to pay the surcharge decreases. Accordingly, the contribution payable by each non-exempted electricity customer increases.

– The growth of renewable energy sources with very low variable costs reduces the price of electricity on the exchange (merit-order effect). However, since the size of the surcharge is calculated from the difference between the feed-in payments for renewable energy and the exchange price, the surcharge automatically increases, even if technology costs remain constant.

– The merit-order effect tends to reduce the procurement costs of the electricity distribution companies. This benefits either the end customers (if the lower costs are passed on to the end customer) or the companies themselves (if they are not passed on, e.g. in the case of existing customers). These positive income effects are not taken into account in an exclusive focus on the EEG surcharge.

- The size of the EEG surcharge depends on the extent to which the costs on fossil and nuclear electricity generation are internalised (GAWEL et al. 2012b, p. 41 with further references). Because these external costs are not included in the price of electricity, the exchange price of electricity is lower. The low price of emission allowances currently has such an effect, tending to reduce exchange prices and increase the surcharge.
- The surcharge is also an unsuitable cost indicator in that it creates a relationship between two cost categories that cannot be compared. On the one hand the market price on the electricity exchange, which reflects the variable costs of electricity generation, and on the other, the payments for renewable energy, the size of which is determined by average generating costs. For a genuine consideration of differences, it would be necessary to compare the average costs of conventional electricity generation with those of renewable energy sources (NESTLE and REUSTER 2012).
- Another factor that is not taken into account is that the size of the EEG surcharge is also influenced by temporary effects. For example, liquidity reserves and compensating measures associated with overspending in recent years resulted in an extraordinary increase in 2013.

According to various estimates, the surcharge would be much lower if it could be corrected to eliminate these distorting factors (NESTLE and REUSTER 2012; LORECK et al. 2012; KÜCHLER and MEYER 2012; WEBER et al. 2012; HERMANN et al. 2012). Recommendations include a genuine net costs view (WEBER and HEY 2012b), an Energiewende cost index (HERMANN et al. 2012) or a modified return to a form of cost transfer of the kind practised before the introduction of the EEG surcharge in 2010 (HORST and HAUSER 2012). In any case, if the reform of the EEG is founded on an unsuitable knowledge base it could result in the *Energiewende* being thrown seriously off course. The development of a suitable indicator for the promotion costs and systemic costs and benefits of renewable energy expansion should therefore be given priority over hasty reforms.

66. One such indicator of promotion costs is the level of the average payment for renewable energy as a whole and for individual technologies. The advantage of this indicator is that it pin-points more precisely the problems of promotion efficiency. For renewable energy sources as a whole, the average payment for plant operators rose from 9.29 ct/kWh in 2004 to 17.94 ct/kWh in 2011 (BMU 2012, p. 45), although the opposite could have been expected in view of the decline in costs for each individual generating technology. However, this can be explained by the fact that in the past relatively expensive renewable energy sources such as photovoltaic and bioenergy grew much faster than the relatively inexpensive wind energy. For example, between 2009 and 2012 – partly as a result of political management errors – photovoltaic expanded by 20 GW (BMU 2013a, p. 13). As a result, more than half the EEG subsidies were paid out for a quarter of the quantity of the electricity generated (NESTLE and REUSTER 2012). In future, therefore, more attention must be paid to the costs of the renewable energy portfolio.

Moreover, there must be a greater focus on allocation of costs to those who have caused them. Electricity generated and used by the operator is largely exempted from the EEG surcharge and other charges (e.g. grid fees and electricity tax). The greater the burdens, the greater the incentive for industrial and private electricity customers to switch to using home-generated electricity. In this way, increasing numbers of customers are reducing their share of the financing of the overall system which provides supply security (see Item 48 and 108) and which they continue to take advantage of.

5.2 Safeguarding conventional capacity

67. Until the electricity supply system has been converted to renewable energy, flexible conventional capacity will be needed. Such capacity must be financed in the transition period, but is currently experiencing profitability problems (see Item 58 – 61). To address this, various payment models are being discussed under the heading of “capacity mechanism” (as a collective term for various financial support instruments for power stations): different types of capacity markets and the strategic reserve. Capacity mechanisms already exist in a number of European and non-European countries (Greece, Ireland, Lithuania, Spain, Portugal, East Coast of USA) or are going through the legislative process or at the planning stage (France, United Kingdom, Italy, Poland) (Agora Energiewende 2013c).

It should basically be noted that any change in the regulatory framework involves risks and calls for a learning process by all concerned. The market actors must adapt to the new conditions. New regulations are subject to political influence and may be faulty. These risks have to be weighed up against the expected benefits of the new regulation. The greater the intervention, the more this applies.

5.2.1 Capacity markets

68. Capacity markets area subcategory of volume-based capacity mechanisms (Süßenbacher et el. 2011). Various capacity market models are proposed for the German market. They vary in their target group and hence also in their distribution impacts, e.g. the question of inclusion of existing capacity. Whereas comprehensive capacity markets envisage payments for all power stations, there are selective capacity market models that finance those power plant capacities which are compatible with the framework of climate policy objectives (e.g. see overview in TIETJEN 2012). A distinction can also be made between centralised (MATTHES et al. 2012; ELBERG et al. 2012) and decentralised models (e.g. ECKE et al. 2013). Also under discussion are further design variants, such as the specification of energy sources and the inclusion of storage facilities and the demand side

(NICOLOSI 2012b; MATTHES et al. 2012; SCHLEMMERMEIER and DIERMANN 2011; HERRMANN and ECKE 2012; TIETJEN 2012).

On the basis of the overviews, especially by LEPRICH et al. (2012, Chapter 4.2), MATTHES et al. (2012, p. 44 ff.), TIETJEN (2012, p. 15 ff.) and Agora Energiewende (2013c) and the literature cited there, the one thing that all capacity mechanisms have in common is that only the provision of capacity is rewarded. In centralised models a regulator – for example the grid operator under the supervision of the Federal Network Agency – invites bids for a specific quantity of capacity for a defined period. Those plants which are awarded the contracts must remain available for operation throughout this period, which is guaranteed by a binding bid on the spot market (Monitoring Analytics 2012, p. 7). For this they receive a capacity payment. In decentralised models, the necessary capacity is determined on a decentralised basis by market actors through supply and demand (ECKE et al. 2013). The capacity payment – at least in the case of new installations – has the character of an investment grant, the costs of which are allocated among the electricity customers. A participation in the energy-only market generates a second revenue stream for the plants.

Comprehensive capacity markets that include both existing and new capacity (e.g. supply security agreements model in ELBERG et al. 2012) are a serious intervention with a long-term character. Selective capacity markets (e.g. ACHNER et al. 2011) primarily address new plants, though in some cases they are also concerned with load management capacity and measures for upgrading power plants. The proposal for focused capacity markets (MATTHES et al. 2012) is an intermediate solution, since it defines separate market segments for new power stations (5 GW by 2020 and a further 15 – 20 GW by 2030) and for existing capacity under threat of closure (17 – 20 GW) with different operating periods, and explicitly addresses load management and storage capacity.

69. All approaches have specific advantages and disadvantages. In the context of the German *Energiewende*, providing highly flexible capacity during the transition from nuclear phase-out to a largely renewable electricity supply system is an important objective (MATTHES et al. 2012; NICOLOSI 2012a; CRAMTON and OCKENFELS 2011). If it proves necessary to introduce a capacity mechanism, this should above all be geared to the requirement of flexible capacity. It would also have to be consistent with the climate objectives. This involves not only activating available flexibility potential in the existing portfolio, but also creating new flexibility potential (cf. also GOTTSTEIN and SKILLINGS 2013). On the supply side this means mainly gas turbine and combined cycle gas turbines. Emission-intensive and inflexible capacity – especially lignite power stations – should be successively removed from the market. The necessary capacity must be determined so as to include cross-border movements to and from neighbouring countries.

To take account of the fact that fossil capacity will only be needed for a transition period, some experts suggest designing the mechanism so that it is reversible and flexible. This would avoid setting the system in stone for decades to come. One such possibility would be to hold regular auctions in small tranches on a rolling basis and for specific purposes, such as highly flexible capacity for short-term deployment, flexible capacity for daily ramps, and normal capacity (HOGAN and GOTTSTEIN 2012). Gas turbine and combined cycle gas turbines are of special relevance to the system, since as bivalent systems they can be run both on fossil natural and on renewable gas (biogas) as well as synthetic fuels (power-to-gas). This means that they can be run as fossil back-up capacity during the transition period and also in a largely renewable electricity supply system.

Another important flexibility option is the inclusion of sheddable loads on the demand side and of storage facilities (GOTTSTEIN and SKILLINGS 2013). For long-term, high-volume storage capacity in particular, the introduction of a capacity mechanism could become more important, as they are rarely used and therefore have more of an insurance character.

However, nearly all models are criticised for favouring market power and windfall profits. In the event of capacity payments to new plants, there is thought to be a risk that no more new plants will be built without this incentive once the mechanism is introduced. This applies particularly to the selective approaches mentioned above, which are designed to promote new capacity. Their introduction should therefore be carefully considered (TIETJEN 2012; WINKLER et al. 2013). If they are not correctly designed, there is a risk that capacity payments, while ensuring the maintenance of existing capacity or the creation of new capacity, may not make any contribution to reducing the inflexible and in some cases CO_2-intensive surplus capacity. Capacity mechanisms tend to have a damping effect on electricity prices. This would reduce the profitability of the unsubsidised power stations, which would no longer be able to cover their capital costs. What was profitable without a capacity market, is no longer profitable with one. If the market actors believe there is a good probability that such mechanisms will be introduced, they could already start holding back on their investments.

70. The flexibility requirements mentioned above have not played any significant role in the introduction of capacity markets in other countries. Capacity mechanisms have been introduced as an “insurance” against short-term supply shortages, or represent de facto compensation payments for energy-policy disadvantages (BRUNEKREEFT et al. 2011). They are also suspected of being misused by market actors and particularly of generating windfall profits, while their potential for controlling the availability of capacity is the subject of controversial discussion (NICOLOSI 2012a; MEULMAN and MÉRAY 2012).

Moreover, most of the capacity mechanisms currently planned in other countries are not geared to an electricity supply system with a large share of renewable energy. Thus although experience in other countries can be examined to avoid repeating errors in Germany, there is on the whole little to be learned of relevance to the German context. A capacity market for fossil power stations that met the requirements of the *Energiewende* would be breaking new ground (WINKLER et al. 2013, p. 20).

5.2.2 Strategic reserve

71. The strategic reserve is a price-based capacity mechanism (SÜßENBACHER et al. 2011). Its advocates have more faith in the energy-only market itself, and regard the introduction of a strategic reserve as an adequate temporary safeguard for the energy-only market (e.g. NICOLOSI 2012a; Consentec 2012a; 2012b; r2b energy consulting 2012). It is a tender system for providing reserve capacity. Those plants whose bids are successful receive a capacity payment. Unlike capacity markets, they do not regularly take part in the energy-only market, but are only used if it is not possible to meet demand. In such situations of shortage, they are brought into the spot market by means of a second auction. Thus, unlike all other capacity mechanisms, the strategic reserve normally leaves the energy-only market unaffected; it has the character of an insurance policy. On the one hand variants are under discussion that are aimed at capacity under threat of closure, which for reasons of supply security are only to be kept in reserve as a transitional solution until a final decision is taken on the design of the market. On the other hand variants are being discussed which bring new power stations into the strategic reserve or even focus specifically on new power stations. The report on the results of the BMU's "Strategic Reserve" expert dialogue of May 2013 envisages the licensing of new power stations (BMU 2013b). The advocates of the strategic reserve also recommend measures to increase the flexibility of the system on both the supply and demand side.

On the whole, the SRU considers it difficult to assess whether capacity markets will be necessary. It therefore recommends a cautious attitude to measures associated with the introduction of a capacity market, which could constitute substantial and potentially irreversible intervention. On the whole, the SRU considers the strategic reserve to be the more suitable instrument in the first instance, since this represents the smallest intervention in the energy market. It provides an opportunity to press ahead with the necessary measures mentioned above, which are described in greater detail below, and thereby improving the earnings opportunities of the energy-only market. On this basis, a decision can be taken later on the possible introduction of a capacity market, with the aid of sound analyses.

5.3 The strategic importance of the carbon price

72. As already explained, there is a need for inflexible fossil power stations to gradually disappear from the market so that the further expansion of renewable energy can go ahead successfully and cost-effectively. A sufficiently high carbon price will increase the marginal costs of emission-intensive and inflexible coal-fired power stations, i.e. especially lignite power stations, more than those of gas-fired power stations. Thus the carbon price has a direct influence on the order in which the power stations are deployed on the energy-only market. This distinguishes the carbon price from capacity mechanisms: although the latter generate income, they do not result in more frequent use of gas-fired power stations on the energy-only market.

Making undifferentiated capacity payments would therefore hardly be sufficient to drive the necessary structural change. In relation to the instrument of the strategic reserve, a high carbon price would tend to encourage coal-fired rather than gas-fired power stations to drop out of the market and join the reserve. However, detailed estimates of the necessary carbon price level show relatively large differences, and are also specific to fuels and technologies. On the whole this climate-oriented correction of marginal costs would produce a reduction in base-load capacity in the course of time. Increasing the carbon price can therefore be described as a no-regret measure.

5.3.1 Role of the European emissions trading scheme

73. Thus a sufficiently high carbon price which increases the frequency of deployment of gas-fired power stations and improves their cost-covering situation must form the starting point for further reform measures. At present the carbon price is determined by the European emissions trading scheme, which lays down a Europe-wide emission budget for fossil energy generation plants and certain energy-intensive production industries (SRU 2006, Item 8; 2008, Item 165 and 185). Owing to a number of factors, there is currently a surplus of about two billion allowances (corresponding to 2 billion t CO_2) in the budget. If no countermeasures are taken, this will probably persist until 2020. This is more than the annual emission quantity of all stationary installations covered by the scheme (European Commission 2012a; “Emissions trading: 2012 saw continuing decline in emissions but growing surplus of allowances”, European Commission press release of 16 May 2013).

The primary and preferable instrument for restoring a sufficient level of carbon prices is therefore the European emissions trading scheme. A rise in the price of allowances can be achieved by reducing the budget. As a framework-defining instrument of climate policy, the emissions trading scheme would provide cost-minimising incentives specifically for the structural changes in the fossil power plant portfolio that are needed for the *Energiewende*. However, with the present low level of prices for allowances it is *de facto* non-existent. All political endeavours should therefore be aimed at revitalising the emissions trading scheme.

Since the problem is a European one, the European Commission has proposed the temporary removal of 900 million allowances (“backloading”), plus structural reforms to be decided later (European Commission 2012a). Following initial resistance, the European Parliament agreed in July 2013 on a compromise which accepts the European Commission’s proposal subject to restrictive conditions (“Parliament agrees beefed up CO_2 backloading plan”, Ends Daily of 3 July 2013). At the same time the environment ministers of twelve EU states are backing the Commission’s proposal, so there are good prospects of agreement by the end of the year (“UK rallies 12 EU countries behind backloading twin track emissions trading system (ets) reform”, U.K. Government press release of 1 July 2013). Although this temporary withdrawal would not raise the carbon price to the necessary level, it would at least stabilise it slightly ("Carbon market intrigue after European Parliament vote cancelled", EurActiv, 26 February 2013).

The controversy about backloading goes hand in hand with the discussion about raising the EU climate target for 2020, with an increase in the greenhouse gas reduction from 20 per cent to 30 per cent compared with 1990, which would also involve a corresponding adjustment to the emissions budget in the emissions trading scheme (European Commission 2012a). Also related to this is the discussion of the Green Paper published at the end of March on the climate framework for 2030, which urges a 40-percent reduction in greenhouse gases compared with 1990 (European Commission 2013). The emission budget for 2030 must be consistent with the long-term climate targets for 2050 (European Commission 2011). To map out a continuous reduction path for the latter, the SRU considers that a reduction target of at least 45 per cent on 1990 is needed for 2030, and this should be achieved by means of emission reduction measures within the EU (SRU 2013a).

In this context it is also necessary to take account of the close interactions between climate action, renewable energy sources and energy efficiency. To create a climate of certainty about investment and planning, and also to ensure continuity, the triad of energy and climate policy objectives needs to be extended to 2030. Moreover, agreed targets for reducing greenhouse gas emissions, expanding renewable energy and improving energy efficiency perform an important coordination function between generation, grid expansion and storage. They also promote convergence of the member states' policies. An independent EU renewable energies target provides legitimation for the promotion of renewable energy against objections from the point of view of competition law.

The SRU therefore advocates laying down binding and ambitious, mutually complementary targets for expanding renewable energy and improving energy efficiency. Bearing in mind the estimates of potential, the SRU recommends raising the renewables share of gross final energy consumption to at least 40 per cent by 2030 (HELLER et al. 2013; HOEFNAGELS et al. 2011; EREC 2012; SRU 2013a). In the field of energy efficiency as well, the existing reduction potential, should be exploited to the full by setting European targets. Recent studies put these potentials at up to 50 per cent of primary energy consumption compared with 2010 (BOßMANN et al. 2012a; 2012b; Fraunhofer ISI 2009).

74. In the context of this triad of objectives, strengthening the climate action incentives of the emissions trading scheme should be given priority over the introduction of capacity markets. Not least in view of the long learning process and the gradual improvements since the introduction of the EU emissions trading scheme, it would seem more sensible to take an existing instrument and systematically develop it than to run the risk of introducing a new instrument. It cannot be assumed that a complex instrument like a capacity market, which potentially has allocation effects, will be free from design faults right from the start. What is far more likely is a lengthy learning process lasting several years, as also indicated by experience in other countries (WINKLER et al. 2013, p. 15 ff.). If a capacity market is nevertheless introduced at a later stage, strengthening the emissions trading scheme is an effective means of avoiding some of the risks of this instrument, such as that of creating new dependent paths by subsidising CO_2-intensive generation.

5.3.2 National alternatives

75. If efforts to revitalise the emissions trading scheme at European level are unsuccessful, it would be necessary to consider national measures, possibly in conjunction with other member states. One option would be to adjust the Energy Tax. Existing exemptions from the Energy Tax Act (“eco tax”) for electricity generating facilities could be abolished. Under Section 53 of the Energy Tax Act, energy products for electricity generation are generally exempted from energy taxation on the input side. Since 1 August 2006 this tax concession, which previously applied only to highly efficient CHP and combined-cycle plants, has basically applied to all electricity generation facilities. The level of taxation should be adjusted and based on the specific carbon content of fossil fuels, in order to achieve the policy target of reducing CO_2 emissions.

A similar abolition of exemptions took place recently in the United Kingdom, where the “carbon price floor” has been in force since 1 April 2013. For years there has been a Climate Change Levy (CCL) on fossil fuels. Now the CCL is to be levied on electricity generation plants as well. It is intended to supplement the expected emission allowance price such that the total results in a steadily rising path for carbon pricing. The carbon price paid by electricity producers in the UK is to show a linear rise from the present price level of GBP 15.70/t CO_2 (approx. 18.4 EUR) to GBP 30/t CO_2 (35 EUR at current exchange rate) in 2020 and to GBP 70/t CO_2 (nearly 82 EUR at current exchange rate) in 2030 (MHRC 2013).

Compared with the structural reforms of the emissions trading system mentioned above, higher national carbon prices have the disadvantage that they leave unsolved the basic problem: the excessive size of the emission allowances budget at EU level. The higher carbon prices mean that a country with a minimum price saves allowances and provides incentives for investment. At the same time, however, the price of allowances falls throughout the EU and the certificates are available to other EU countries (SANDBAG 2013). On the other hand, national advances can make a valuable contribution to the dynamics of negotiations in the current discussions on the European climate targets for 2020/2030. A form of burden sharing in which individual countries assume more extensive reduction obligations may increase the readiness of hesitant or sceptical states to adopt ambitious European climate targets, since it reduces the cost of climate action by the latter countries. This can be taken into account in the European Commission’s estimates of the cost of achieving the European climate objectives for 2030, which were drawn up in advance in the context of impact assessment.

As well as the instruments mentioned, regulatory options at national level are also conceivable, but it would be necessary to look more closely at the question of whether they are legally permissible. Such options include a ban on the construction of new coal-fired power stations, the introduction of minimum efficiency levels for conventional power stations, mandatory use of CHP, CO_2 emission limits (SRU 2011, Item 445 ff.; ZIEHM and WEGENER 2013) and flexibility requirements for power station operation (for all options see VERHEYEN 2013).

5.4 Other no-regret measures

76. In addition to the above-mentioned measures for promoting structural change in the fossil power plant portfolio, it is possible to identify other measures that ought to be taken in any case because they strengthen the financing capacity of the energy-only market and thus make sense both for the transitional regime and for a largely renewables-based electricity supply system. They have a synergistic character, because they address many of the above criteria and involve comparatively small regulatory risks. These measures include adapting the electricity market to the characteristics of weather-dependent renewable energy sources, promoting demand side management and encouraging European market integration. These steps are part of a bundle of measures which, taken as a whole, improve the framework of incentives for the flexibility improvements described in Chapter 3. They also include increasing the flexibility of generation and storage, which in turn involves a large number of individual measures (Plattform Erneuerbare Energien 2012; KRZIKALLA et al. 2013).

5.4.1 Measures to increase the flexibility of the electricity market

77. Trading activities should be better adapted to the characteristics of weather-dependent renewable energy sources. Here the focus is on making market structures more flexible and giving more emphasis to short-term trading. These are tasks that can be implemented today.

The extent to which weather-dependent generation plants can react to day-to-day events on the energy exchange is limited, e.g. curtailing output or scheduling service intervals (LEPRICH et al. 2012). The availability of sun and wind can only be predicted in the short term. To take advantage of the better quality of short-term forecasts, there is a need to strengthen the intraday market compared with the day-ahead market. Some authors advise shortening the time between close of business and supply time, which may still be up to 36 hours (LEPRICH et al. 2012). Other authors stress the need for short-term (floor and bilateral) trading to take better account of the grid operator’s responsibilities, as is usually the case in North American market designs (BORGGREFE and NEUHOFF 2011). Another issue to be clarified is whether it would make sense to bring the exchange trading periods laid down by the Federal Network Agency (at present hourly) into line with the accounting periods

(15-minute intervals), because this would cater better for the capacity gradients of the weather-dependent energy sources and the operating modes of conventional power stations (LEPRICH et al. 2012, p. 26 f.; Consentec et al. 2011, p. 129; WINKLER 2011; WINKLER and ALTMANN 2012). An alternative proposal is the development of complex bids that directly offer the entire electricity production profile of conventional power plants, including start-up and shutdown times and the associated costs. By means of such complex bids, the trade could then find optimum market solutions in the course of time (BORGGREFE and NEUHOFF 2011).

On the balancing power market, flexibility products must be defined individually and in neutral terms, to create competition between different technologies and also allow the demand side to take part. There should also be a reduction in bid sizes and periods (WINKLER et al. 2013; Agora Energiewende 2013b, p. 27 f.; BARITAUD 2012, p. 68 and 71). Here there are close links with exploiting demand side management potential in industry. The less successful efforts are to strengthen the intraday market requirements, the greater the requirements for the balancing power market. In other words, if the intraday market cannot perform its balancing function in the short term, i.e. adapting to the actual supply of renewable energy, this must be offset by the balancing power market (WINKLER and ALTMANN 2012). In general, one can expect to see greater merging of the balancing power and intraday markets. The integration of grid operators in trading activities as mentioned above could be a first step. The more weather-dependent renewable energy can replace fossil capacity on the balancing power market by providing system services, the lower the must-run of fossil-fuel electricity needs to be and the more scope there is for feeding in renewable energy. Measures should therefore be taken to improve the ability of weather-dependent renewable energy sources to provide balancing power.

5.4.2 Demand side management

78. Improving demand-side flexibility is often another no-regret measure. In economic terms it means increasing the price elasticity of demand. If the demand side were more flexible, scarcity prices would not be so high. According to economic assumptions, one of the preconditions for the functioning of the energy-only market is that certain customers (are able to) forgo their demand for electricity. The cost of reducing demand is often lower than the cost of providing additional supply capacity.

Load shifting, however, is not suitable for shifting large quantities of energy for lengthy periods (SRU 2011, Item 510). Its potential is seen rather in balancing short-term load peaks. Demand side management can be practised both in the industrial and commercial sectors and in the household sector. New demand side management options will come into being as sectoral and EU integration progresses.

79. In the industrial sector, demand side management can take the form of increased integration of major industrial consumers into the existing electricity balancing market, and can be seen as part of the greater short-term orientation of the energy-only market which is any case necessary. Here consumers receive a payment for reducing their contractually guaranteed electricity consumption. The technical potential – at least for short periods – is regarded as considerable, and can often be exploited at low capital cost and by making organisational changes to operating procedures. To some extent, demand side management is already being practised today, but it is still associated with counter-productive incentives and regulations – such as contracts lasting several years or loss of exemption from grid fees – which raise obstacles to participation by industry (Agora Energiewende 2013b, p. 27 f.; APEL et al. 2012; KLOBASA et al. 2013b). The necessary corrections to incentives should be undertaken as soon as possible, to make it possible to exploit the technical potential. At present the requirements for participation in the electricity balancing market are geared to generators. They should be reformulated to allow the demand side to participate as well.

The technical demand side management potential in the household sector and in the small-scale industries, trade and services sector (GHD) is smaller than in the industrial sector and at the same time more widely distributed. Exploiting it therefore calls for the IT-based infrastructures (smart grids) mentioned in Section 3.2.3. There is also a need for load-dependent tariffs, to create incentives to shift demand for electricity into low-load times and vice versa. All in all it is not yet clear whether demand side management measures can be used in the near future to exploit appreciable potential in private households. It is basically necessary to clarify whether the repeatedly voiced political demand for constant availability of inexpensive electricity is compatible with the idea of increasing demand elasticity, since the latter would mean temporary – though contractually agreed – rationing or interruption of supplies.

5.4.3 European market integration

80. Greater European market integration and cross-border grid expansion are measures which should be taken in any case. This will permit better integration of different load and supply profiles in the member states, making for more efficient use of existing grid, generation and storage capacities. Short, medium and long-term options are available.

Short-term options

81. In the short term, closer integration of the existing European markets could make a significant contribution to demand side management and supply security. Even today, Germany has interconnections with neighbouring countries, with import capacities of around 17.3 GW and export capacities of around 14.9 GW (NICOLOSI 2012b, p. 32; BMU 2012, p. 9). This must be seen in relation to an annual peak load of approximately 80 GW. In 2011 electricity quantities totalling some 74 TWh changed hands in cross-border trading. Of this, 38.5 TWh was exported and 35.5 TWh imported (Federal Network Agency and Federal Cartel Office 2012, p. 71). Net electricity consumption in 2011 came to 524 TWh (BMWi and BMU 2012).

Generation and load profiles in Germany and its neighbouring countries are not identical. Cross-border electricity trading therefore helps to make efficient use of capacity reserves and surplus electricity from renewable energy sources. The crucial factor for the direction of flow is the price difference between Germany and its neighbours. For example, if demand is low, resulting in a surplus of electricity at low prices in Germany, it pays to export to neighbouring countries. If demand in Germany is high, electricity prices rise and it is worth importing electricity from neighbouring countries.

Various options are under discussion to substantially increase the capacity of existing interconnectors. These include more flexible models for capacity calculation and shorter-term market transactions in cross-border trading that meet the requirements of weather-dependent renewable energy sources (EWEA 2012; EURELECTRIC 2010). Work is currently in progress on appropriate network codes for integrating the European spot markets and on other issues relating to standardisation of market rules for cross-border grids (for the status of relevant grid codes, see: ESTERMANN et al. 2012; FISCHERAUER 2012). However, grid codes are developed by the transmission system operators themselves. This means there is a risk that the “regulated self-regulation” takes undue account of the interests of the rule-setting transmission system operators or might result in highly elastic drafting compromises (ZACHMANN 2013; FISCHERAUER 2012). In general, the potential and implementation prospects of measures to improve the utilisation of existing interconnectors between Germany and its neighbours should be further investigate, quantified and given active political support.

Medium-term options

82. In the short to medium term, implementation of the grid expansion plans of European grid operators could substantially increase the available transmission capacity. The relevant plans between Germany and its neighbours are ambitious (TEUSCH et al. 2012, p. 22; Prognos AG 2012, p. 46 f.). In the next two decades, transmission capacity could increase by a factor of between 2 and 4 (BMU 2012, p. 9).

83. At present, however, there is reason to fear a substantial gap between the investment actually planned and the investment needed to fulfil the plans. Only about two thirds of the investment needed in this decade, amounting to more than 142 billion EUR, is actually planned in the EU (ZACHMANN 2013, p. 7). Consequently there are considerable deficits where the construction and expansion of interconnectors is concerned, and above all there is a need to clear up issues relating to allocation between the beneficiaries and the parties bearing the costs of cross-border connections (von HIRSCHHAUSEN et al. 2012).

In the revised version of the Regulation on guidelines for trans-European energy infrastructure (Regulation (EU) No 347/2013 of the European Parliament and of the Council of 17 April 2013), the EU addresses major obstacles to the expansion of cross-border connections (CALLIESS and HEY 2013, p. 129; von HIRSCHHAUSEN et al. 2012, p. 16). The regulation sets out a number of important instruments for improving coordination, increasing commitment and financing projects of Community interest. On the basis of standardised cost-benefit assessments, the aim is in particular to determine in advance the costs of new cross-border connections and allocate them to the participating grid operators in the ratio of their shares in the benefit. This will therefore settle the allocation issues. On the whole the proposals are regarded as a step forward, but there are still a number of legal, institutional and incentive-related questions to be clarified (von HIRSCHHAUSEN et al. 2012, p. 33 ff.).

84. However, the expansion of European infrastructure can only improve security of supply if it makes it possible to fall back on free generating capacity in neighbouring countries if necessary, i.e. as and when peak loads occur. Estimates of available capacity and coverage gaps in the European context differ widely (MATTHES et al. 2012, p. 32; European Commission 2012b, p. 5). The expert commission on the “Energy for the Future” monitoring process and the European Commission and other actors therefore recommend observing the adjustable loads and capacities in the neighbouring countries and thereby arriving at a coordinated estimate of capacity (LÖSCHEL et al. 2012, p. 119; European Commission 2012b; GROWITSCH et al. 2013, p. 49).

85. As at national level, an intensive European debate on capacity mechanisms is already in progress in view of the possible risks for security of supply. A number of EU countries are planning capacity mechanisms or have already introduced them (cf. SVR 2012, p. 268; KRANNER and SHARMA 2013; WINKLER et al. 2013). The European Commission (2012b) takes a critical view of these developments, especially since many capacity mechanisms are not geared to the flexibility requirements of renewable energy or unduly favour supply options instead of catering for demand-side management (cf. Item 69 f). In its discussion paper, the European Commission (op. cit.) therefore suggests giving consideration to a European regulatory framework that would check the necessity for and design of national capacity markets in accordance with certain criteria and ensure non-discriminatory coordination. Germany should emphatically strengthen this cautiously reserved attitude on the part of the European Commission and should give political support to priority for “no-regret” measures.

Long-term prospects

86. As shown by the SRU in its 2011 special report, a massive expansion of infrastructure throughout Europe by means of a supergrid and cross-border connections could make a very great contribution to load balancing (SRU 2011, Item 232 ff.; see also ECF 2010; Greenpeace 2011; von HIRSCHHAUSEN et al. 2012; PATT et al. 2011).

87. The greater the distances over which different wind farms are connected, for example, the better it is possible to compensate for differences in weather conditions. Where the distances are very great (> 2,000 km) it is even possible to balance the natural fluctuations over a month. This significantly increases the share of weather-dependent capacity that can be regarded as assured (EWEA 2012; CZISCH 2009). However, substantial increases in existing grid capacity and the development of a highly efficient overlay grid are technical preconditions for a pan-European scenario with complete market integration. Grid planning of this kind that is geared to the needs of renewable energy sources calls for a pan-European consensus on the further substantial expansion of renewable energy. At best, this is only conceivable as a gradual process (cf. SRU, 2011, Chapters 5 and 6). At present it is not possible to foresee whether such further development of European climate and energy policy is likely to succeed, and how fast, partly because of Germany’s cautious attitude to a system of energy and climate policy targets for 2030 (FISCHER and GEDEN 2013).

88. What is likely is that the complex multi-level system will become even more differentiated, with some decisions being strongly Europeanised (e.g. climate objectives, internal market), while other policies converge within a European framework, but remain under national control (Item 138 ff.). In such a scenario, which is politically more realistic, European grid expansion for the needs of renewable energy sources will in the long term remain well below the technical and economic potential.

89. In its 2011 special report, the SRU drew attention to the importance of the large pumped-storage capacity in Norway for load balancing in Europe. However, it will probably only be possible to realise part of this substantial hydro power and energy storage potential in Norway and other European mountain regions (SRU 2011; Prognos AG 2012; EURELECTRIC 2011). The reasons for this are current political, economic, environmental and social restrictions. The size of the share that can actually be mobilised in the course of time is therefore uncertain (cf. BRUNS et al. 2012; Prognos AG 2012; MIDTTUN et al. 2011; REICHERT 2013; OHLHORST et al. 2012; GULLBERG 2013). Moreover, the potential that can be mobilised under market conditions also depends heavily on the price spread between Germany and its neighbours and the degree of utilisation of the interconnectors. Since the price spread tends to decrease with every new line, it is possible that the expansion potential which can be mobilised under market conditions will fall far short of the technical possibilities and the level that is desirable from an energy policy point of view. Prognos AG (2012, p. 59) therefore estimates the new construction potential that can be economically exploited in the long term between Germany and Scandinavia at only 7 to 12 GW. Another factor is the very unequal allocation effects on producers, consumers and grid operators in the individual countries if Scandinavian storage capacity is connected to the central European market (EGERER et al. 2012).

To this end a decisive political approach to design and negotiation is needed to deal with the obstacles mentioned. The focus here should be on economic incentives for further connections, cooperation on energy policy, and concepts and balancing solutions for the allocation effects. At all events, a case study on the decision process for the NordLink connection between Germany and Norway has revealed that there was strong support from political circles and the energy industry in Germany and hardly any appreciable resistance, and that major Norwegian actors were successfully encouraged to change their opinion (REICHERT 2013). The overall aim should be to exploit as much as possible of the considerable potential for integrating the Scandinavian energy market in the central European energy market.

90. The developments in the Nordic market are playing a pioneering role. In the interests of integrating wind-power electricity, Denmark is actively propagating grid connections to Norway and Sweden – the relevant grid capacity is currently under construction (UHLEN and CIRIO 2012; TEUSCH et al. 2012; von LA CHEVALLERIE and SCHWEITZER 2012; Prognos AG 2012). This could also be the route to closer integration of the German energy system. Denmark has set itself the target of reaching a wind-power share of 50 per cent by 2020 and a completely renewables-based heat and power supply system by 2035 (NOTENBOOM et al. 2012, p. 12). Whereas market integration with Scandinavia is still the subject of sceptical discussion in Germany, it has already made substantial progress in Denmark. Denmark has drawn up a grid action plan for 2030 which plans over 5,000 km of new transmission lines both in the very high voltage and the high voltage sectors, including connections to Sweden, Norway, Germany and the Netherlands (UHLEN and CIRIO 2012, p. 38 f.).

91. To sum up, it can be said that even in the short and medium term European market integration is capable of mobilising considerable reserve for load balancing. This reduces the need for assured capacity compared with a purely national perspective. This should certainly be taken into account in the national discussion about supply security and – as far as possible – quantified over time. Considerably more efficient use can be made of existing interconnectors by employing improved methods of calculating capacity and making capacity deployment more flexible. Although fears about capacity shortages in neighbouring countries also need to be taken seriously, it is important to estimate them realistically. However, joint capacity planning at European level is neither meaningful nor realistic, because the energy supply structures and the energy-policy objectives of the member states will remain too divergent for the foreseeable future. European capacity planning would presuppose a common energy policy. Bilateral, market-based coordination is therefore adequate. However, this must include cross-border assessment of the necessary capacity, because security of supply can no longer be defined on a national basis in interconnected markets.

92. In the medium and long term a marked increase in grid integration is possible. On the one hand it increases the utilisation of low-cost pumped-storage potential in Scandinavia and the Alpine region, and on the other – by long-distance balancing of feed-in profiles – it increases the proportion of assured capacity that can be supplied by renewable energy. However, a prerequisite for this is a coordinated solution at European level for serious incentive and allocation problems that are slowing up cross-border and pan-European grid expansion. In the interests of low-cost supply security, these barriers deserve priority within energy policy.

5.5 Developing and improving the Renewable Energy Sources Act

93. The principal mechanism for promoting renewable energy in Germany is the Renewable Energy Sources Act (EEG), which consists of three main elements: a payment system with fixed feed-in tariffs for twenty years, feed-in priority for the electricity produced, and a guarantee of connection for the plant installed. A fundamentally different approach is the "quota system", under which the element fixed is not the price per kilowatt-hour of the electricity fed in from renewable sources, but the quantity of renewable energy or capacity (MATSCHOSS 2013; MITCHELL et al. 2012; RAGWITZ et al. 2012).

94. Originally designed as a technology and market launch instrument that creates an assured market and operating environment for new renewable energy technologies, the EEG has developed into a financing instrument which offers plant operators a relatively safe return. In this way it permits learning processes not only in technology development, but also, and above all, in real-life operation through the diffusion of these technologies. Thanks to this market penetration the EEG has made a decisive contribution to systemic learning by the energy system in using the new technologies and their characteristics. The rules of the EEG need to be adapted to the progress of technological development, and it must be remembered that different technologies have different learning curves. Regardless of whether the EEG achieves its expansion targets, the technical, institutional and economic structures of the energy system (especially the design of the market) need to be adapted to the growing proportion of renewable energy.

5.5.1 Critical assessment of the quota model

95. Quota models are often discussed as an alternative to the EEG. Quota models are instruments for controlling quantities. They lay down the share of renewables-based electricity or renewable capacity. Their advocates believe them to be more effective and efficient than the EEG, since quotas are keyed to a fixed capacity expansion target, and the amount of financial assistance is not fixed by the state, but is determined by market competition. Ideally, quota models are of technology-neutral design, so it is always the lowest-cost technologies that are used (Monopolkommission 2013).

96. However, justified doubts about the claimed superiority of the quota model have repeatedly been voiced in the literature (e.g. FOUQUET and JOHANSSON 2008; JACOBSSON et al. 2009; LAUBER 2007; LAFFERTY and RUUD 2008). On an international comparison, feed-in tariffs have generally proved more effective at lower cost than quotas, which is due to the lower risks for investors and the associated lower cost of financing (RAGWITZ et al. 2012; DIEKMANN et al. 2012). In quota models the financial risk rests solely with the investors, who cannot expect a fixed income as they can under the EEG feed-in tariff. Their income is made up of sales revenue on the electricity market, which is difficult to forecast and fluctuates over time, plus a certificate price. The variable income give rise to a risk, for which investors (and the lending banks) demand risk premiums. This increases the capital cost of constructing renewable electricity generation facilities. The risk premiums are a problem for small electricity generators in particular, who have much less equity capital available than the major energy suppliers. In Germany, however, it is the former who have so far been the main drivers of renewable energy expansion. The higher risk premiums, which also result in windfall profits for operators of mature technologies, are passed on to electricity customers via the price.

It is basically doubtful whether technology-neutral quota models offer greater funding efficiency: If the expansion target is set high enough to ensure that more expensive technologies have to be used as well, the level of certificate prices depends on the cost of these latest expensive technologies. This means that comparatively inexpensive technologies are considerably over-subsidised. This can only be prevented by gearing the size of the quota to the expansion potential of the cheapest technologies (WEBER and HEY 2012a).

In practice, quota models have resulted in lower growth rates. In countries with quota models the expansion targets have not always been achieved, which casts doubt on their actual effectiveness. This can, as in the United Kingdom, be attributed to inadequate sanction mechanisms for failure to achieve the quota, for example if the penalties are set too low and represent an incentive to “buy one’s freedom” (WEBER and HEY 2012a; DIEKMANN et al. 2012). Quota models may also lead to a concentration of generation sites and technologies. In particular, there are fears that in Germany only the technologically mature onshore wind power would profit, and especially sites with high generating capacity. By contrast, offshore wind energy in particular would not be able to survive on the market. Even if investments already made in wind farms were safeguarded by the EEG, the technology would not be developed any further and hence there would be no learning curves resulting in reduced costs. This also applies to technologies that are not yet mature enough for the market or have yet to be developed in the future. To reach market maturity they need differentiated promotion, as in the EEG. Research promotion cannot anywhere near achieve the cost reductions that result from market launches (BERGEK 2010). Thus the quota model fails to meet the criterion of dynamic efficiency (e.g. DIEKMANN et al. 2012). On the whole, differentiated promotion ensures a mix of different technologies and sites.

There are also fears that quota models give preference to suppliers who already have large market shares, leading to an oligopoly on the electricity market. Investments in individual installations, and also in farms financed by local citizens might not be made because of increasing risks. Feed-in tariffs, by contrast, have generated more dynamic competition and successfully brought new competitors into the market (MITCHELL et al. 2012, p. 903 f.; HEY and WEBER 2012; WEBER et al. 2012; HEY et al. 2011).

Both geographical concentration and the expected reduction in the numbers of investors and operators could reduce the acceptance of the *Energiewende* in Germany. On the basis of the experience described, there seems to be no reliable evidence that this effect can be offset by lower electricity costs – especially for household customers.

97. In the meantime, feed-in tariffs based on the German model have been adopted by numerous countries in Europe and elsewhere. The United Kingdom is also phasing out its quota system, now that the principle of technology neutrality has been abandoned in view of the need for market integration of offshore wind energy by means of technological differentiation (“banding”). Small photovoltaic systems are already receiving a feed-in payment, and from 2017 onwards a feed-in model will apply to all new installations (DIEKMANN et al. 2012; DECC 2010; JACOBS and MEZ 2012).

Although the EEG has had problems with steering issues and over-funding situations, these do not justify switching to a quota system. Even if a quota model were to be introduced, the obligations entered into under the EEG to make feed-in payments for existing installations would still exist. Thus changing the financing system would only partially – if at all – alleviate the cost problem currently under discussion. European harmonisation of promotion mechanisms, as envisaged by the German Monopolies Commission (Monopolkommission 2013), is unrealistic at the present time (CALLIESS and HEY 2013).

Any change of system involves a regulatory learning process and associated investor uncertainty, which have to be weighed against the hoped-for gains in efficiency. This is all the more important in view of the fact that the climate objectives call for rapid expansion of renewable energy. Instead of a change of system, therefore, a gradual reform should be targeted. In other words, the restructuring of the system needs a more differentiated approach than the present “EEG versus quota” rhetoric (SVR 2012; SCHMIDT 2013; acatech 2012; Monopolkommission 2013) would suggest, especially since the EEG pursues the goal of broader technology promotion above and beyond the directly binding climate objective. There is nevertheless a need for reforms, since several technologies have emerges from their niches and are presenting the promotion system with new challenges (MATSCHOSS

2013; MATTHES 2013a). On balance, changing to a quota model should be rejected, but a reform of the EEG basically seems desirable.

5.5.2 SRU proposal for developing the variable market premium

5.5.2.1 Initial situation

98. As already mentioned, it becomes more and more difficult to follow the load curve as the share due to wind and photovoltaic generation increases. Decoupling the renewables-based electricity supply from the demand for electricity results in greater flexibility requirements with regard to the capacity for meeting residual demand and the energy system as a whole. Performing the increasingly complex task of synchronising total electricity supply and demand involves rising costs. It is therefore expected that the renewable energy sources as well – in so far as is technically feasible – will in future adapt their feed-in profile more closely to the load curve.

To motivate plant operators to gear their feed-in behaviour better to demand, they should be exposed more to price signals from the market. It must however be remembered that in all probability the energy-only market can only finance part of the investment and maintenance costs of renewable energy. Further stable growth of renewable energy therefore requires a combined payment system consisting of a market element and a subsidised premium payment, plus a fair and economically sensible apportionment of the risks. In an electricity market increasingly dominated by weather-dependent renewable energy sources there is a need for a promotion regime which offers not only sufficient investment security for plant operators, but also greater market integration and demand orientation. This, however, leaves the fundamental conflict of objectives unresolved: on the one hand ensuring incentives to invest by creating certainty for investors, and on the other, creating incentives to react more flexibly to variable market signals (GAWEL and PURKUS 2013a; 2013b; KLOBASA et al. 2013a; 2013c; WINKLER and ALTMANN 2012). The task here is to find a suitable balance between the two objectives.

A step in this direction has already been taken with the introduction of the optional variable market premium under the EEG. To encourage more market-oriented feed-in behaviour, a premium is paid for directly marketed electricity on top of the market price obtained (market premium). The point of reference for calculating the market premium is the individual technology-specific fixed feed-in payment. Plant operators also have the option of returning to the fixed payment system.

In view of the closer market integration and the financing of the further expansion of renewable energy sources, the SRU sees a need to develop and improve the market premium. Based on the current model of the optional variable market premium, the SRU proposes the following central amendments to the present design:

- Introduce direct marketing as a binding requirement for all new renewable energy installations;
- Change the payment limit from a time limit to a maximum promoted quantity of electricity in the form of a capacity-specific kilowatt-hour contingent;
- Calculate the variable market premium using a site-specific and technology-specific virtual reference installation;
- Reduce political influence by setting the premium on the basis of a cost index.

This approach is explained below, drawing attention to the ways in which it differs from the present model of an optional variable market premium.

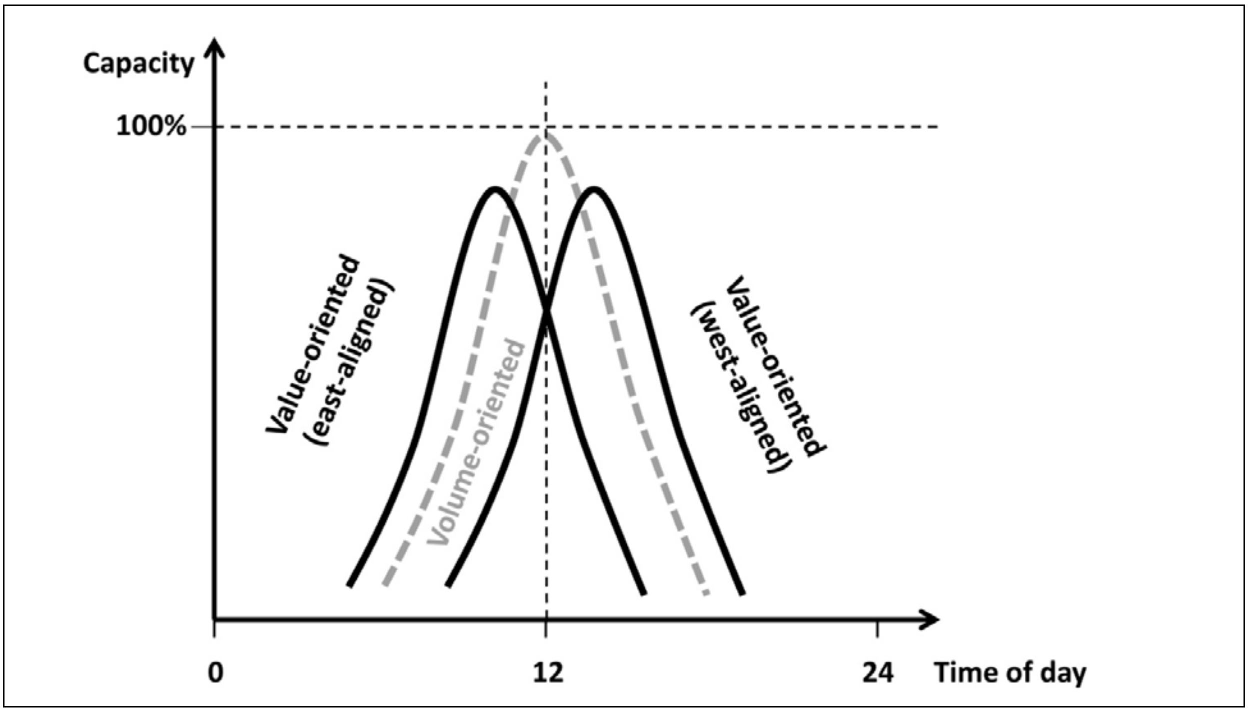
5.5.2.2 Volume orientation versus value orientation

99. Even if there are limits on the extent to which electricity from wind and photovoltaic sources can be controlled, it is nevertheless possible to strengthen their market orientation. Ways and means of gearing a wind energy or photovoltaic system more closely to demand exist during the investment decision phase in particular. During the design phase, photovoltaic and wind energy systems can essentially be trimmed to maximise either the volume of electricity (in kWh) or the market value (in EUR). A volume-oriented installation produces as much electricity as possible (e.g. south-aligned photovoltaic system). A value-oriented installation is designed to maximise the value of the electricity produced – the product of kWh generated and the average market price of the electricity fed in. A value-oriented installation will feed in particularly large amounts of electricity when market prices are high.

Appropriate alignment of value-optimised installations (e.g. east or west alignment of photovoltaic systems) results in the feed-in behaviour being more evenly distributed over the day, which means it is more demand oriented. This helps, for example, to smooth out the midday dip in prices where the proportion of photovoltaic systems is very large (see Fig. 5-2 and 5-3). By increasing the ratio of rotor area to nominal capacity, wind turbines can be designed to start producing electricity at very low wind speeds. This means they can feed in electricity even at times of very little wind, when units with higher-capacity generators designed for strong winds are not yet operating (Agora Energiewende 2013a).

Figure 5-2

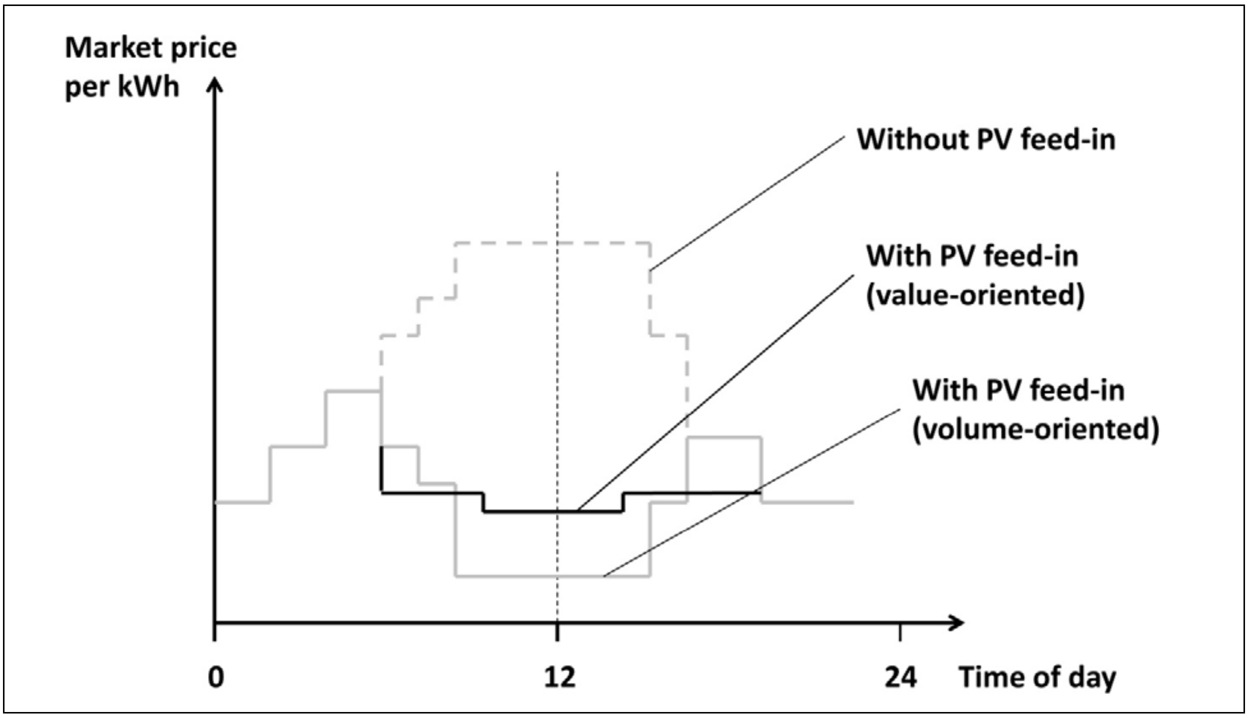
Capacity yield of volume-oriented and value-oriented photovoltaic systems during the day



SRU/SG 2013/Fig. 5-2

Figure 5-3

Development of spot market prices in the course of the day depending on photovoltaic feed-in (volume-oriented versus value-oriented)



SRU/SG 2013/Fig. 5-3

5.5.2.3 Present market premium model

100. The guaranteed fixed-price payment under the present EEG does not make use of market signals to encourage demand-oriented feed-in behaviour, and thereby creates an incentive to maximise the volume of electricity generated. However, as the proportion of renewable energy increases, feed-in behaviour that pays no regard to market and demand will give rise to high costs for the national economy, as it substantially increases the flexibility and capacity requirements for residual capacity generation and also the complexity of the system as a whole. This challenge was to be met at the beginning of 2012 by introducing the optional, variable market premium.

The variable market premium under Section 33 of the EEG is intended to create incentives for greater market orientation on a voluntary basis. On the one hand it serves to offset reductions in sales revenue due to lower prices on the electricity market – compared with the fixed feed-in payment –, and on the other hand, it compensates for the risks associated with entry into the market. These include the basic uncertainty about price trends on the electricity market. Especially for weather-dependent renewable energy sources, direct marketing creates other risks arising from the obligation to actually generate and feed in the predicted (and sold) quantity of electricity, or to buy shortfalls on the market (GAWEL and PURKUS 2013a; 2013b; KLOBASA et al. 2013a; 2013c; RAGWITZ and SENSFUß 2008).

Plant operators who switch to direct marketing receive the variable market premium – in addition to the market price – for every kWh sold. The variable market premium is calculated as the difference between the EEG payment set for the technology in question and the average monthly electricity exchange price that can be achieved with this technology. Thus the higher the average market price for a technology, the smaller the market premium, and vice versa. Continuous adjustment on a monthly basis makes it possible to smooth out electricity price fluctuations over the year. The problem of inadequate market forecasts with the danger of under- or over-subsidising ceases to exist (RAGWITZ and SENSFUß 2008). The attraction of direct marketing for plant operators lies in the fact that they can obtain higher market revenue than the average technology-specific exchange price, and receive – together with the market premium – higher total revenue than with the fixed EEG payment. Furthermore, a fixed management premium is paid for every directly marketed kWh. This is designed partly to compensate for the risks, especially with regard to forecasting errors for weather-dependent energy sources, and partly to cover the increased administrative work involved in direct marketing. It also enables direct marketers to give plant operators additional financial incentives to take part in direct marketing. In view of the rapidly improving quality of feed-in forecasts and the falling administrative costs of direct marketing in response to learning effects, the management premium was corrected downwards to prevent windfall-profit situations (ROSTANKOWSKI et al. 2012 on the Management Premium Ordinance).

If the change to direct marketing with a variable market premium and greater value orientation is actually to be worthwhile for a plant operator, the higher payment per kWh – consisting of the market premium and potentially higher market prices – needs to compensate for the likely drop in revenue due to the reduction in electricity feed-in; at the same time it must offset the costs of possible forecast errors and of the increased administrative input. A realistic prospect of achieving higher total revenue by direct marketing is essential to motivate investors to opt for value-oriented operation of their plants. Even with a variable market premium, plant operators are exposed to a greater economic risk if they take a value-oriented path than if the design of the plant is volume-oriented. The existing uncertainties, such as necessary maintenance costs and the weather during the planned useful life of the installation, are joined in direct marketing by further uncertainties, especially the price situation at different seasons and times of day. The higher risk and financing costs associated with this increased uncertainty have to be offset by a prospect of greater profits.

With the aid of the present optional model of the variable market premium – and especially the initially generous management premium – it would be possible to switch a large proportion of renewable energy sources, including weather-dependent sources, to direct marketing. Today more than half the electricity fed in from renewable sources is under the variable market premium, and in the case of wind energy the figure is as high as 80 per cent (KLOBASA et al. 2013a; GAWEL and PURKUS 2013a). However, there is also criticism of the present market premium model, especially with regard to its costs and effectiveness in the context of improving system integration of renewable energy (LÜDEMANN and ORTMANN 2012; GAWEL and PURKUS 2012).

5.5.2.4 SRU proposal for reforming the market premium model

101. The SRU proposes gradual development of the existing variable market premium, so as not to endanger the expansion of renewable energy by making a radical change in the system. Basically the SRU therefore takes the approach that the premium should be given as payment for the electricity fed in. In view of the fact that a large proportion of installations have already switched to direct marketing and the need to improve the demand orientation of increasing amounts of renewable energy in the electricity system, the SRU advocates making direct marketing compulsory for all newly constructed installations; only for the very smallest systems could exemptions from compulsory direct marketing be considered for a transitional period. The SRU's proposals for reform relate in particular to deciding the promotion period and calculating the site of the variable market premium. The introduction of a fixed kilowatt-hour contingent of eligible electricity per capacity unit will provide an incentive for greater market integration of renewable energy sources. A new method of calculating the variable market premium is intended to ensure that investors continue to find fairly safe financing conditions and that risk premiums therefore remain low. At the same time, steps must be taken to prevent site-specific under- or over-subsidisation and to steer the construction of new plants in the interests of portfolio optimisation for the entire system. Furthermore, the installation-specific promotion payments are in future to be more cost oriented less susceptible to political influence.

Fixed specific kilowatt-hour contingent per installation

102. A central change compared with the present promotion system is the switch from a limit on the promotion period (twenty years) to a limit of the quantity of electricity promoted per installation. The specific kilowatt-hour contingent for an installation is calculated using technology-oriented and site-oriented indicators. Setting a maximum number of eligible kilowatt-hours will create additional incentive to optimise plant orientation and feed-in behaviour from an economic point of view:

– Under the present system of a time limit, volume-oriented installations receive a larger absolute amount of financial assistance than value-oriented installations, because they produce a larger amount of electricity within the limited period. This is true whether they make use of the optional market premium or stay in the fixed feed-in payments system. Fixing a specific kilowatt-hour contingent ensures that value-oriented installations receive a similar absolute amount of promotion payments, albeit spread over a longer period. Limiting the electricity promoted rather than the promotion period thus increases the financial attractiveness of designing installations for value orientation at the investment stage.

– It gives plant operators an incentive to feed in electricity only at times when the market price – and hence the macroeconomic benefit – of the electricity is positive.

To be able to have this incentive effect, the specific kilowatt-hour contingent must be a binding restriction. The eligible specific kilowatt-hour contingent should be set, together with the specific payment per kilowatt-hour, so that the total revenue guaranteed in this way, consisting of premium payments and market revenues, ensures that capital and maintenance costs are covered and at the same time provides an incentive for long-term efficient operation of the installation. However, it is important to avoid over-subsidising particularly favourably sites, as this would unnecessarily increase the total promotion costs and thereby endanger the acceptance of subsidised renewable energy expansion. The maximum kilowatt-hour contingent, like the reference revenue explained in the next section, should be determined specifically for the technology and site in question. The calculation of the specific kilowatt-hour contingent for an installation will largely make use of capacity-related indicators; the greater the capacity of an installation, the more eligible kilowatt-hours its contingent will comprise. For photovoltaic systems one could conceivably use the nominal capacity (kW_p) in combination with the site-specific insolation, for example, or for wind turbines the wind energy impacting on the rotor surface could serve as an indicator for determining the kilowatt-hour contingent. The precise definition of the appropriate indicators and method of calculation for determining the eligible kilowatt-hour contingent requires further analyses, especially in the case of wind turbines. Care must be taken here to select suitable and objective indicators and a transparent method of calculation, to prevent windfall effects and create incentives to design and run renewable energy installations efficiently.

Calculating the market premium using a reference revenue model

103. The SRU also proposes a different method of calculating the size of the variable market premium. As in the present model, the reformed market premium suggested by the SRU serves to compensate for reduced revenue from direct marketing compared with the level of revenue needed to finance the project. The starting point for the calculation is that a volume-oriented installation which offers the energy it generates to the energy-only market should have total revenue similar to the present EEG promotion model with fixed feed-in payments. The sum of the market revenue and premium payments received over the probable useful life of the installation should ensure the financing of the installation with great certainty in order to avoid high risk premiums on the part of the investors. At the same time, care should be taken to avoid over-subsidising particularly favourable sites and under-subsidising sites which are less favourable from a meteorological point of view, but make sense in the context of the overall portfolio. This latter aspect is important, since a portfolio that is diversified in terms of technologies and sites and takes account of overall system aspects – such as grid expansion requirements or complementary feed-in profiles – can be more efficient from a macroeconomic point of view than one that focuses solely on minimising the levelised cost of energy.

Volume-oriented reference installations are differentiated by technology and site clusters. Under the model proposed here, a reference revenue per kilowatt-hour promoted is laid down for these volume-oriented reference installations. In its function and its necessary level, this reference revenue corresponds to the fixed feed-in payments in the present system, i.e. it is intended to ensure the safe financing of a (volume-oriented) installation. On similar lines to the present system, the variable market premium is calculated as the difference between the (technology-specific and site-specific) reference revenue and the average market revenue per kilowatt-hour that the relevant volume-oriented reference installation would have obtained on the market during the calculation period. Further studies are necessary to identify the suitable calculation period for determining the market premium. However, in order to ensure a sufficiently flexible response to changes in price levels on the electricity market, it should not be more than a year. If the average market price of the electricity generated by the reference installation exceeds the reference revenue per kilowatt-hour, no premium is paid, but the electricity supplied is still deducted from the eligible kilowatt-hour contingent to prevent over-subsidisation. When the volume of electricity reaches the figure laid down in the maximum kilowatt-hour contingent, and the total payments received per kilowatt-hour correspond to at least the reference revenue, the capital and maintenance costs of the plant should be largely paid for.

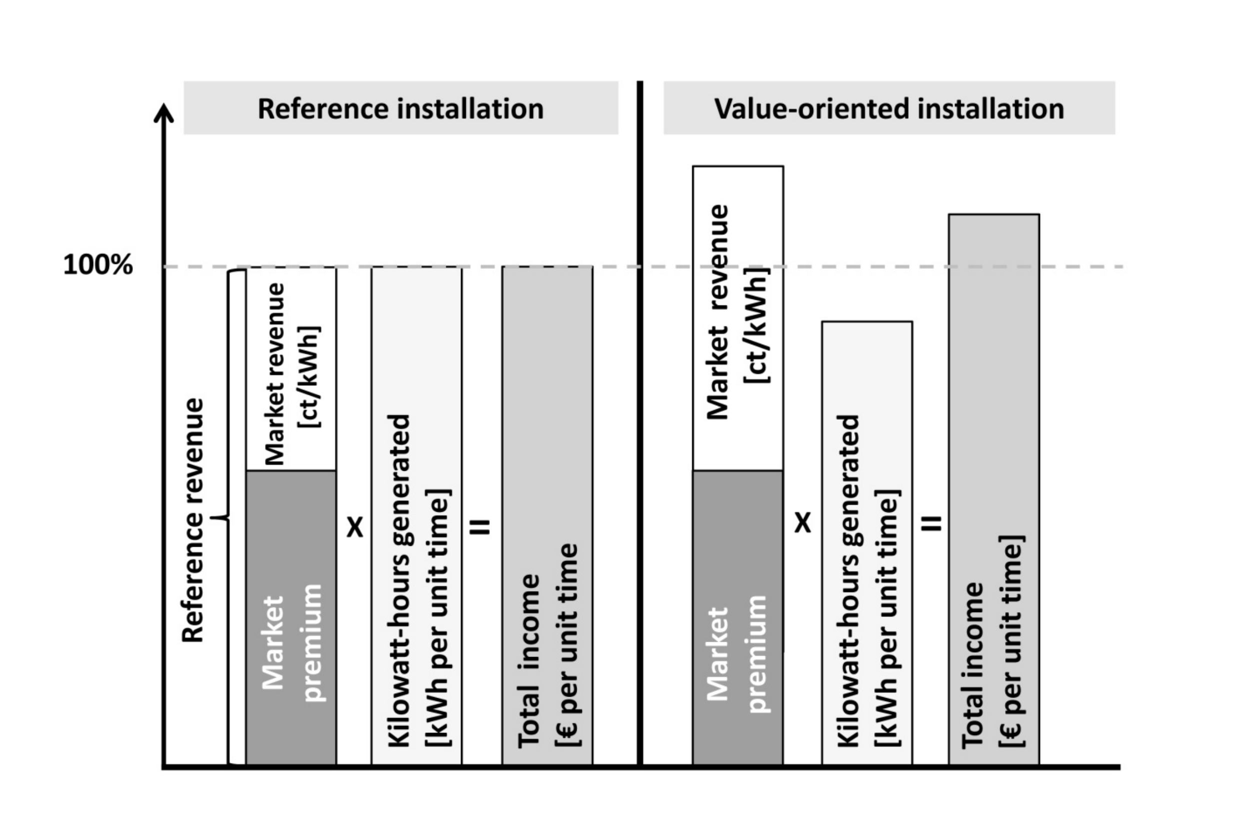
Unlike the present system, which makes use of real production portfolios to calculate the market premium, the volume-oriented reference installation is a virtual generating plant with feed-in quantities and electricity market revenue simulated hour by hour on the basis of weather and price data.

The proposed promotion structure can be illustrated by a simple example: A photovoltaic system on a very sunny site in the south would be assigned a higher specific kilowatt-hour contingent and a lower specific reference revenue than a system of identical type and capacity installed on a less sunny site. However, the total revenue of the volume-oriented reference installation, as guaranteed by the revised market premium model and calculated by multiplying the specific kilowatt-hour contingent by the specific reference revenue per kilowatt-hour, would be similar for both installations and would ensure financing of the capital and maintenance costs. It is not possible to determine *ex ante* what proportions of these costs will be covered by market revenue and market premium payments; this will depend on how market prices develop. The higher the market price, the lower the premium payments.

For a real volume-oriented installation with a feed-in profile largely corresponding to the reference installation, switching to the model proposed here will not result in any substantial changes from the present promotion system as far as expected revenue and economic risk are concerned. While value-oriented installations do not enjoy the same degree of certainty as regards the total revenue obtainable, the prospect of a possible higher total revenue offers an incentive to diverge from the feed-in profile of the volume-oriented reference installation. The market premium determined for the (virtual) volume-oriented reference installation will be paid out in full for every kilowatt-hour fed in by real installations. Thus higher prices obtainable on the electricity market are fully reflected in higher revenue per kilowatt-hour for value-oriented installations. If the (positive) revenue effect of higher total payments per kilowatt-hour exceeds the (negative) effect of a lower electricity yield for the value-oriented installation, the plant operator’s total revenue increases (cf. Fig. 5-4).

Figure 5-4

Schematic diagram of income situation of a value-oriented installation compared with a volume-oriented reference installation



SRU/SG 2013/Fig. 5-4

Declining scale of reference revenue using a cost index

104. A declining scale of promotion rates, similar to the system in the present EEG, should continue to be used in the model proposed here. At present the payment rates for new installations are reduced by a certain percentage every year on the assumption of falling capital costs – or in the case of photovoltaic systems depending on the volume of new installations completed – and then remain constant for twenty years for the installation in question. In the market premium model proposed here, the plant-specific reference revenue would remain constant for the entire kilowatt-hour contingent. In future, however, the pace of reduction (of the reference revenue) for new installations should be determined by an authority in a transparent procedure on the basis of a cost index, in order to obtain a picture of actual cost trends for such installations faster and without political influence (cf. Item 151 f.).

5.5.2.5 Alternative premium models with fixed payments

105. Alternative reform proposals currently under discussion, which are intended to provide incentives for greater market integration of renewable energy sources, envisage either a fixed market premium based on work (ct/kWh) or a fixed payment based on the installed capacity (€/kW). However, in promotion models with fixed payments, the market price risks would be borne entirely by the investors. The latter would react by holding back on investments or demanding considerably higher risk premiums, which would be reflected in higher electricity costs for the consumer. In the case of fixed premiums or capacity payments, there is not only a risk of under-subsidising, but also of over-subsidising, which could have adverse impacts on promotion efficiency (KOPP et al. 2013).

By contrast, the size of the subsidy in the variable market premium model is variable and depends on price developments on the electricity market, whereas the future revenue situation for investors remains calculable. The variable market premium absorbs a considerable proportion of the investor's market price risk, especially the long-term risk, and transfers this to society, which the SRU considers more efficient in terms of the national economy.

The distinguishing feature of the market premium model proposed here is variable contingents of eligible kilowatt-hours depending on the site and the capacity or size category of the installation. It thus creates incentives for high-quality investment and appropriate maintenance to permit long-term operation of the installation. With fixed capacity payments depending on installed capacity, these incentives, depending on individual design, would be less intensive and could result in macroeconomically suboptimal design and operating life of the installation and to sacrifices in quality and windfall effects. It is conceivable, for example, that operators of photovoltaic installations might minimise their investment costs by using inexpensive and inefficient inverters, to maximise the overall return on their installation. In the case of wind turbines there is a risk of misguided incentives, especially if the fixed capacity payment is based on generator output, as this can be increased at lower cost than rotor area: Operators could increase their capacity-based premium and their overall return at the expense of the macroeconomic efficiency of system operation, by choosing a very large generator-rotor ratio (KOPP et al. 2013). Problems such as these become increasingly relevant when the investor's private return is largely determined by the installed capacity and to a lesser extent by the electricity actually fed in. Such incentive structures can reduce the overall economic value of the individual installation.

5.5.2.6 Contribution to the transformation of the energy system

106. The model of an improved variable market premium suggested here can help to reduce costs during the energy system transformation phase, without impeding the expansion of renewable energy by an unbalanced allocation of risks. First of all, there is a general increase in the national economic value of the electricity fed in, as part of a greater demand orientation of renewable energy. Since value-oriented installations earn more revenue on the electricity market than volume-oriented installations, and since the electricity prices on the exchange will probably fluctuate less because of the more demand-oriented feed-in, the additional promotion is likely to decline in the medium term compared with the present EEG system. This would also relieve the burden on electricity customers. The costs to the national economy are also reduced by the fact that greater market integration reduces the need for flexible residual capacity and storage facilities. Furthermore, easier access to the electricity balancing market for directly marketed renewable energies can have positive economic and environmental effects within the system as a whole, for example through a reduction in conventional must-run (KRZIKALLA et al. 2013; KLOBASA et al. 2013a; 2013c).

To some extent, the site-specific and technology-specific differentiation of promotion permits targeted management of the regional and technological allocation of renewable generation capacity. This is done by means of the control variable “kilowatt-hour contingent” and the reference revenue in particular, and should take account of overall system aspects such as grid expansion requirements, the complementary nature of regional feed-in profiles or the geological availability of storage facilities. Inevitably there will be conflicts between minimising the straight generation costs per kilowatt-hour and optimising portfolio management in the interests of the system as a whole. In the final analysis, the crucial factor for renewable energy expansion must be transformation to a reliable and largely renewable electricity supply system which takes place at the lowest possible cost to the national economy, enjoys a high degree of public acceptance and takes account of all components of the transformation process.

5.5.3 Design issues

107. The fixed-payments system of the EEG in its present form guarantees a feed-in payment per unit of work that is differentiated by technology, mostly guaranteed for twenty years and lies above the market price. The differential costs between feed-in payment and renewable electricity revenue on the energy-only market are borne by the non-privileged electricity consumers in the form of the EEG surcharge on the price of electricity. In recent times the focus has been on the extent to which the promotion system can be financed, to some extent with inappropriate arguments. To ensure more equitable allocation the exemptions should first be reduced or abolished. Moreover, it would be possible to reduce costs if the payments were adapted better to the development status of the individual technologies.

5.5.3.1 Preferential treatment with regard to the EEG surcharge

108. The EEG in its present form provides for extensive exemptions from the EEG surcharge for energy-intensive companies in the manufacturing industry (POPPE 2012; KACHEL 2012; ISMER and KARCH 2013). These are to be granted on application (Sections 40 to 44 EEG). These exemptions are at the expense of non-privileged electricity consumers, since the costs to be apportioned remain constant and thus increase the surcharge per kilowatt-hour. The exemptions have now become so generous that in 2012 they applied to nearly 20 per cent of electricity consumed. Without this preferential treatment the EEG surcharge would be about 20 per cent lower. As well as the increasing total payment, the exemptions are thus a major cost driver for the EEG surcharge (NESTLE and REUSTER 2012). The exemptions were extended even further in 2013. The resulting burdens on the remaining consumers are not the only reason why the exemptions from the EEG surcharge are criticised. Their compatibility with higher-ranking law is also the subject of controversial discussion (ISMER and KARCH 2013; for conformity with European law: SCHLACKE and KRÖGER 2013; undecided GERMELMANN 2013; for a breach of European law, but still relating to the old legal situation: FRICKE 2010). The European Commission has initiated a preliminary state-aid investigation against various aspects of the EEG, and in December 2012 it also announced the initiation of a formal state-aid investigation, though this has not yet taken place. It remains to be seen what consequences the initiation of a formal investigation would have for the special compensation provisions. Basically the initiation of such an investigation puts an end to trust in the certainty of the regulation, and normally the state is no longer allowed to pay the aid in question – which in this case would mean not only the exemptions, but the entire EEG payment. In parallel, the EU legal framework for state aid in the environmental sector is being revised. In future, the result could be that under the new EU framework the EEG in its current form can no longer permit exemptions.

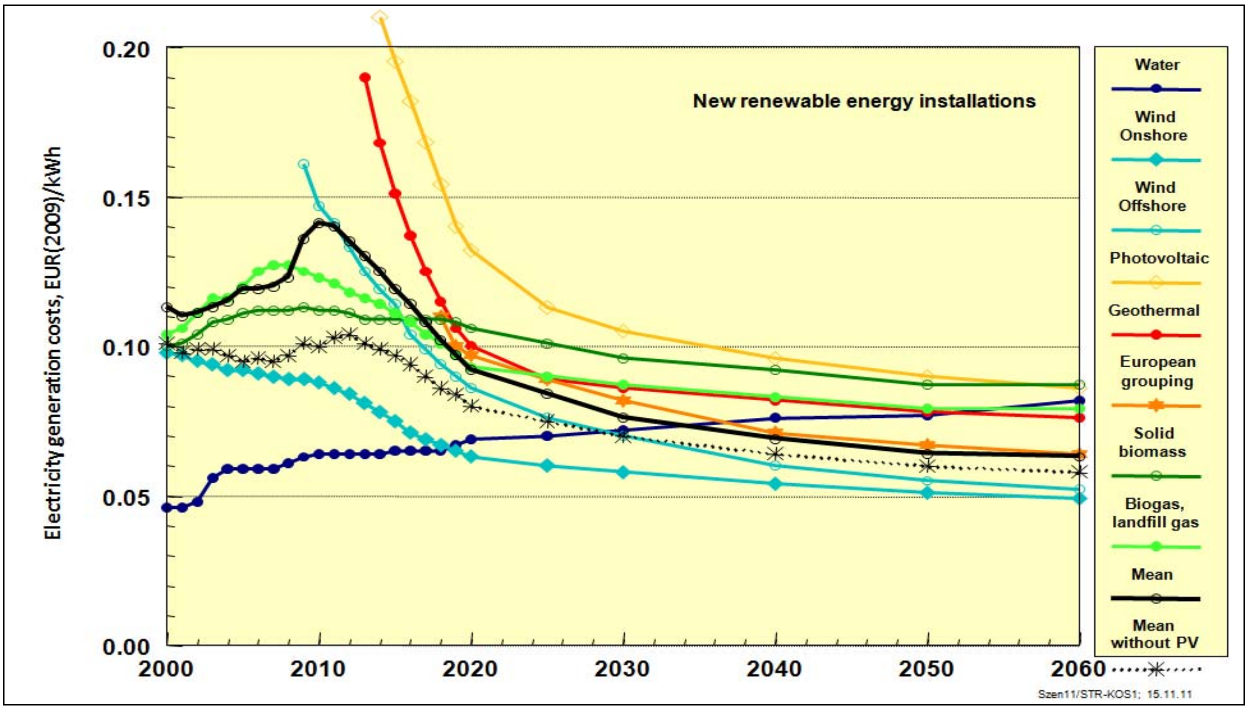
Site decisions are basically taken in the light of many factors. Even for energy-intensive companies, other factors such as product differentiation, integrated value chains, proximity to raw materials and sales markets or wages costs often play a greater role than energy price rises. The issue of energy price related company relocation has already been at the focus of the discussion on carbon leakage and needs-oriented allocation in the context of the European emissions trading scheme (SRU 2008, Item 170–1). Regardless of the legal investigation by the European Commission, the exemptions under the EEG should for economic reasons be cut back on the same lines as the rules for emissions trading. This would not only achieve the politically announced objective of relieving the burden on the energy-intensive companies exposed to international competition, but would also relieve the burden on non-privileged consumers.

5.5.3.2 Portfolio optimisation

109. By optimising the future promotion portfolio it is possible to achieve a better balance between expensive and less expensive technologies. Here the development status and potential of a technology are assessed on the basis of the empirical (past) and predicted (future) development of levelized costs of electricity, the “learning curve”. Figure 5-5 shows the levelized costs of electricity calculated using learning curves for various renewable technologies.

Figure 5-5

Future development of costs for electricity-generating renewable energy technologies up to 2050
Renewable energy mixes in Lead Study Scenario 2011 A



Source: NITSCH et al. 2012, p. 212, Fig. 7.3

The learning curves can be used to draw conclusions about the need for various promotion arrangements and payments. Special mention must be made of offshore wind energy, which is at the beginning of its learning curve, onshore wind energy and photovoltaic, which are well advanced along their learning curves, and biomass and hydro power, for which little or no learning curve effects can be identified (MATTHES 2013b). The first two represent weather-dependent technologies at different stages of development, which under the model proposed by the SRU should receive a variable market premium.

When optimising the portfolio, it should be remembered that technology promotion is an explicit objective of the EEG. Broader systemic advantages, such as the reduced need for expensive storage facilities for offshore wind energy compared with onshore, should be taken into account in optimisation. Another approach to optimisation is to gear the portfolio to the complementary nature of the technologies. This too can reduce the need for backup and/or storage capacity (MATTHES 2012; 2013a; MATSCHOSS 2013).

5.5.3.3 Technology-specific issues

110. It is clear from the example of photovoltaic subsidising that political control can fail when it comes to ending obvious over-subsidising in good time. In the case of photovoltaic systems, the legislature made corrections by establishing an annual corridor for the construction of new installations and decided to discontinue the payment when total installed capacity exceeds 52 GW (Sections 20a and 20b EEG). However, these measures came too late to prevent the market overheating and the persistent cost burdens for consumers.

It may make sense to define such a corridor for new facilities in order to prevent over-rapid growth. Nevertheless, the question of the necessary photovoltaic volume needs to be reviewed regularly against the background of a future electricity-based energy system. Experts expect (small-scale) use of photovoltaic systems on owner-occupied homes for self-consumption to be competitive from 2013 onwards independently of promotion instruments (SCHLEICHER-TAPPESER 2012). It should however be noted that users of photovoltaic systems should in future bear a larger share of financing the infrastructures (cf. Item 48). Larger installations, e.g. ground-mounted systems, to not benefit from the preferential treatment described above. Basically photovoltaic systems should also enjoy the benefits of the SRU's improved model of the variable market premium (Item 101 ff.). The declining scale should be coupled to an objective yardstick, e.g. an indicator of investment costs, to remove the determination process from political influence (SRU 2011, Item 486; IASS 2012).

111. Biomass is a basically controllable renewable energy source that is capable of providing feed-in appropriate to demand, enabling it to supply important system services such as balancing energy. At 5.5 GW the biomass capacity installed is already considerable (Federal Network Agency 2013). Consideration should therefore be given to incentives for converting existing installations. As a rule, however, the existing power stations cannot ensure demand-appropriate feed-in because of the small biogas storage capacity. In view of serious environmental impacts and undesirable relocation effects, consideration should definitely be given to discontinuing the promotion of cultivated biomass (PETERS et al. 2010).

For offshore wind power the SRU (2011) has proposed replacing the fixed feed-in payment with a tender model in the long term. Under this model, the best price is awarded the contract for the investment, but receives the second-best price (second price auction) (op. cit., p. 468). Experience with this instrument in other countries is varied and not always promising, though it is questionable how far it can be transferred to the German situation in the individual case. The opportunities for controlling the construction of offshore wind farms have increased considerably, thanks to the introduction of three instruments. These are firstly, the newly created "Federal Sectoral Plan Offshore North Sea" of the Federal Institute for Navigation and Hydrography (BSH); secondly, the offshore grid development plan of the transmission system operators; and thirdly, the fact that approval for the construction of an offshore wind farm is now given under a plan approval procedure instead of a strict authorisation (see Section 2 of the Offshore Installations Ordinance (Seeanlagenverordnung)). Recent studies indicate, however, that the very rapid pace of development urged by the SRU is not absolutely essential, and that slower expansion could be more cost-effective (Agora Energiewende 2013d). The SRU therefore continues to recommend that tender models only be considered in the long term.

5.5.3.4 Feed-in priority

112. It is frequently argued that feed-in priority is obsolete, because electricity from wind and sun is always used on a priority basis because of their low marginal costs. However, there are various barriers and disadvantages affecting the use of renewable energy on the electricity markets, which make it necessary to keep the feed-in priority system for the foreseeable future. Since suppliers of wind and solar energy can only make short-term forecasts about generation, they can only take part in the futures market to a limited extent. Balancing power markets are traditionally tailored to conventional power stations, which means that renewable energy sources cannot participate on a non-discriminatory basis. On the energy-only market, the plant operators' calculations also take account of the sometimes high costs of transport to and from fossil power stations. As a result, fossil power stations may produce electricity even at negative prices, whereas renewable energy installations partially curtail their output. Furthermore, the shut-down sequence associated with feed-in priority in the event of grid problems needs to be retained, because it ensures that conventional power stations are shed before renewable energy sources.

5.5.3.5 Guaranteed grid access

113. Guaranteed grid access for renewable energy sources is currently being called into question, although this was never the case in the days when fossil and nuclear capacity had a monopoly. For example, the expansion of nuclear capacity in the 1970s and 1980s led to massive grid expansion within a relatively short time. As explained above, grid expansion is the most important and lowest-cost flexibility option, even if it is not a self-contained process and will accompany the *Energiewende* until its final phase. Grid access must therefore continue to be guaranteed.

From an economic point of view, the decentralised distribution and fluctuating feed-in of electricity from renewable installations raise the question of the optimum degree of grid expansion. It is generally argued in the literature that it is more efficient to curtail renewable energy than to take away the "last kilowatt-hour "(for one of many examples: RAGWITZ et al. 2012, p. 63). On the other hand, cost accounting has to take account of the above-mentioned systemic advantages of grid connection. It must also be borne in mind that 80 per cent of weather-dependent capacity is connected to the grid (BRUNS et al. 2012, p. 345) and that large sections of the distribution systems are in any case in need of replacement (Deutscher Bundestag 2012). Further expected expansion of renewable energy can be taken into account in the course of this renewal, thereby reducing the additional costs (cf. Item 64).

Future grid expansion requirements are subject to uncertainty, partly because future technological development can result in changing needs. For example, breakthroughs in local storage technology (batteries) could lead to an energy system with a stronger local focus. However, a study on this subject comes to the conclusion that the cost of decentralised photovoltaic battery storage systems would have to be reduced by 80 per cent over the next twenty years to make decentralised expansion the optimum cost strategy (Agora Energiewende 2013d).

5.6 Interim conclusions

114. In the transition to an electricity supply system based on renewable energy there are currently three major challenges: security of supply with regard to fossil back-up capacity and the final phase-out of nuclear energy; great flexibility of the market for fossil and renewable energy production; and the demand for and costs of renewable energy expansion.

Topics under discussion for ensuring security of supply include the introduction of a strategic reserve and various models of capacity markets. The various proposals for capacity markets represent substantial interventions in the electricity market, and the relevant risks should be carefully considered in advance. Existing capacity markets in other countries have had the task of providing long-term support for fossil power stations. Also, they are not relevant to the context of an extensive transition to renewable energy, as would be the case in Germany. Moreover, there are hardly any quantitative analyses of the long-term effects on the market. These complex funding instruments could nevertheless prove to be necessary in future to provide temporary support for fossil capacity. In that case, however, it would be necessary to ensure that the capacity is only maintained or expanded long enough to allow previously completed gas power stations to pay for themselves. If the political level does not make it absolutely clear that it is only prepared to introduce capacity markets on this condition, the mere discussion about capacity markets will make these necessary as a self-fulfilling prophecy, because the discussion itself will put unfunded investments at risk.

The strategic reserve, by contrast, places greater faith in the incentive potential of the energy-only market itself and therefore represents a less serious intervention. The SRU therefore considers it preferable. The strategic reserve only comes into use if there are signs of a supply shortage. It consists of power stations that are not – or no longer – on the market. It can focus on capacities at the end of their economic life , or it may also permit flexible new power stations.

Regardless of any decision between these two hotly debated alternatives, there is fundamental need for greater flexibility of generation and demand. The greater the success in making the underlying structures more flexible, the less invasive any intervention in the market has to be to ensure security of supply. After all, every capacity mechanism merely compensates for the fact that the income streams generated for the plant operators by the energy-only market are not sufficient.

In the case of the fossil power plant capacity needed during the transition, lack of flexibility is the central problem in adapting to the large and rapid fluctuations in residual load. The power plant portfolio is characterised by a surplus of relatively inflexible power stations. It is therefore necessary in the near future to maintain and build more gas-fired power stations and to remove lignite power stations from the market. This can be encouraged by a sufficiently high carbon price. Revitalisation of the European emissions trading scheme is the instrument of choice for this purpose.

For this reason, ambitious European climate and energy targets for 2030 are of vital interest to the *Energiewende*. The SRU therefore considers there is a need for a European climate target for 2030 that aims to achieve at least a 45-percent reduction in greenhouse gas emissions compared with the reference figure for 1990 by means of measures within the EU.

If revitalisation of the emissions trading scheme – for which the temporary withdrawal of emission allowances in the current trading period (backloading) is a first step – is not successful, economic or regulatory measures should be taken at national level. In that case the existing exemptions for electricity generating plants in the Energy Tax Act should be abolished and the amount of taxation should be adjusted and geared to the specific carbon content of the fossil fuels. At national level there are also numerous regulatory options for reducing CO_2 emissions, and these should be investigated further as appropriate.

In addition to increasing carbon prices, a number of other measures are also needed. Trading activities should be better adapted to the characteristics of weather-dependent renewable energy sources. Here the focus is on making market structures more flexible and giving more emphasis to short-term trading. These are tasks that can be implemented today. Greater attention should be paid to the interests of the grid operator. This includes strengthening the intraday market over the day-ahead market, defining individual flexibility products on the electricity balancing market, and enabling weather-dependent energy sources to participate on the electricity balancing market. Secondly, it includes increasing the flexibility of the demand side, which is already practised to some extent in the industrial sector, but still suffers from counter-productive incentives and regulations. Thirdly, greater European market integration and pan-European grid expansion are absolutely essential.

115. The EEG has proved to be a very effective subsidising instrument in the renewable energy sector, especially since feed-in tariffs are, empirically speaking, generally more efficient than quota models. Hence the control and over-subsidising problems associated with the EEG do not justify a change of system to a quota model.

116. The SRU takes the view that the current debate on costs in connection with the EEG is based on incorrect assumptions. On the one hand, it explains the increase in electricity prices in recent years as being due entirely to the expansion of renewable energy. On the other, the discussion about the EEG surcharge focuses on an indicator that is unsuitable for determining the actual cost of promoting renewable energy. Even if the costs situation undoubtedly indicates a need for reform, such a reform should not be a response to current developments that are held to be undesirable, but should be basically geared to requirements for the transformation of the energy system.

117. In the context of the present discussion about a reform of the EEG, the SRU advocates developing and refining the variable market premium. To motivate plant operators to adopt a more demand-oriented feed-in behaviour, they should be given greater exposure to price signals. It must however be borne in mind that in all probability the energy-only market can only finance part of the capital and maintenance costs of renewable energy. Further stable growth of renewable energy therefore requires a combined payment system consisting of a market element and a subsidised premium payment, plus a fair and economically sensible apportionment of the risks. In future there is a need for a promotion regime that provides sufficient certainty for investment by plant operators and at the same time offers incentives for greater market integration and demand orientation.

Based on the current model of the optional variable market premium, the SRU proposes the following central amendments to the present design:

- Direct marketing as a binding requirement for all new renewable energy installations,
- Change the payment limit from a time limit to a maximum subsidised quantity of electricity in the form of a capacity-specific kilowatt-hour contingent,
- Calculate the variable market premium using a site-specific and technology-specific virtual reference installation,
- Reduce political influence by setting the premium on the basis of a cost index.

The model of an improved variable market premium suggested here can help to reduce costs during the energy system transformation phase, without impeding the expansion of renewable energy by an unbalanced allocation of risks. First of all, there is a general increase in the national economic value of the electricity fed in, as part of a greater demand orientation of renewable energy. Since demand-oriented installations earn more revenue on the electricity market, and since electricity prices on the exchange will probably fluctuate less because of the more demand-oriented feed-in, the additional promotion is likely to decline in the medium term compared with the present EEG system, which will also relieve the burden on electricity customers. The costs to the national economy are also reduced by the fact that greater market integration reduces the need for flexible capacity and storage facilities. Furthermore, easier access to the electricity balancing market for directly marketed renewable energy can have positive economic and environmental effects within the entire system, for example through a reduction in conventional must-run.

6 Energiewende as a challenge for state and society

118. The reform of the market system for renewable energy will be discussed, decided and implemented in a political and institutional setting that has grown historically and is constantly changing. Decisions on this reform involve various political levels – from European to local –, all of which have different competencies and pursue different interests, but cannot achieve these without cooperating with the other levels. The same applies to the various ministries with their sectoral interests. This raises questions of horizontal and vertical coordination in a polycentric and fragmented system of federal states. These decision processes involve civil, economic and scientific actors with their respective expertise and their various means of exerting influence and mobilising developments. Participation also takes place at a wide variety of levels, from "summits" in the Federal Chancellery to discussion of technical details in various expert committees. This raises the question of suitable forms of participation and fair allocation of opportunity in the various public arenas and expert bodies. The transformation of the energy supply system is not only the result of numerous bottom-up processes – whether new corporate concepts, innovative technology development or political initiatives, like the many 100 per cent renewable energy regions – but at the same time of central, political decisions and regulatory intervention in the market. Linking these processes in a meaningful way is a challenge. It is therefore necessary to clarify the relations between hierarchical control, negotiation and self-management at the various levels.

119. Issues like these are the subject of governance research. This is generally concerned with the rules, institutions and processes of public activity (SCHUPPERT 2010). Governance research analyses not only the structures involved in coordinating the actions of governmental and non-governmental actors, but also the mode of action (hierarchy, market, negotiation and self-management), their structural institutionalisation and the processes they set in motion (BENZ et al. 2007). This is a matter of rules and decision structures which, for example, determine the allocation of opportunities for influence, veto positions or resources of governmental and non-governmental actors, thereby influencing the prospects of various reform options. Governance research may be conducted on a purely analytical basis, but it usually has a bearing on problem solving: How, despite different or conflicting interests and fragmented institutions, can one succeed in making public goods available and thereby producing "good political results" in the interests of the common good (SCHUPPERT 2010)? This normative issue is examined below.

120. The proposals outlined by the SRU for reforming the organisation of the electricity market cannot be seen in isolation from the institutions, standards, rules and decision systems – the governance system of the *Energiewende*. The governance of the *Energiewende* is regarded as a part of the reform process. This being so, there is a need for closer analysis of the following questions about the governance of the *Energiewende*:

- What changes have taken place in the constellations of actors since the decisions on the *Energiewende*, and what new basic challenges arise in a more complex, multi-stage decision system (Chapter 6.1)?
- How important is participation for the success of the reform process (Chapter 6.2)?
- How is it possible to find better solutions to the horizontal and vertical coordination problems (Chapter 6.3)?
- How can political decisions be separated better from technical decisions on the *Energiewende*, thereby making for more effective implementation of the *Energiewende* (Chapter 6.4)?

6.1 Changing basic conditions

121. The constellation of energy-policy actors has been changing since the *Energiewende* decisions: New coalitions and new institutions have been formed, and different forms of political and technical participation are emerging. Section 6.1.1 first describes this structural change, then goes on to look at the opportunities and risks it creates for a reform of the market organisation. These give rise to new challenges for the various levels of the decision systems: hierarchical control of the *Energiewende* soon comes up against its limits (Section 6.1.2).

6.1.1 Innovation opportunities through consensus on Energiewende

122. In Germany, the accident at the Fukushima nuclear power station in March 2011 was followed by the first multi-party consensus on phasing out nuclear power and transforming the energy system into one based on renewable energy sources as its lead technologies. In particular, this was manifested in the Bundestag decisions of June 2011 on phasing out nuclear energy. Moreover, the Ethics Commission for a Safe Energy Supply set up by the Federal Chancellor also succeeded in integrating actors in the "Community Endeavour *Energiewende"* who had previously taken a critical attitude to the *Energiewende* (Ethikkommission Sichere Energieversorgung 2011). Since that time, a large number of governmental and non-governmental platforms, working groups and initiatives have been formed, and new strategic alliances are emerging between them.

A change can be observed from coalitions of either advocates or opponents of renewable or conventional energy (HIRSCHL 2008; SRU 2011) towards a more diverse constellation of actors. New actors come into being, old actors open up to new alliances, and coalitions show movement.

On the government side, the existing formal decision structures at ministerial level have been joined by coordination platforms on central reform issues designed to ensure involvement of the relevant stakeholders. The "Plattform Erneuerbare Energien", lead managed by the BMU, is responsible above all for the further development of the EEG and makes the technical preparations for it (Plattform Erneuerbare Energien 2012). There are also the “Plattform Zukunftsfähige Energienetze” and the “Kraftwerksforum” lead-managed by the Federal Ministry of Economics and Technology (BMWi). Finally, in the context of the *Energiewende* the Federal Government has re-established a number of actors such as the expert committee on *Energiewende* monitoring, and has transferred new responsibilities to other actors such as the Federal Network Agency.

123. The last two years have seen the emergence not only of governmental platforms, but also of non-governmental initiatives which have since concerned themselves with questions relating to redesigning the energy supply system and hence the design of the electricity market. These include scientific initiatives such as the Renewable Energy Research Alliance (ForschungsVerbund Erneuerbare Energien – FVEE), the Helmholtz Alliance Energy-Trans or the German Academy for Technical Sciences (acatech). Hybrid structures located between the political and academic worlds are increasingly looking into the reform of the energy supply structure as well: e.g. the Agora *Energiewende*, the Transdisciplinary Panel on Energy Change of the Institute for Advanced Sustainability Studies (IASS) or the trialogue series *“Energiewende”* of the Humboldt Viadrina School of Governance. A characteristic of these initiatives is their transdisciplinary, solution-oriented approach to the various fields of the *Energiewende*. They commission studies and organise discussion and coordination between different political and social actors. To some extent these new actors are also supported by the German Government, which thereby indicates that the plurality of ideas is desirable and necessary for putting the *Energiewende* into practice.

Old energy policy actors such as the German Energy Agency (Deutsche Energieagentur – dena), the industrial and environmental associations and other stakeholders such as the “Forum für Zukunftsenergien” also need to reposition themselves in the light of the *Energiewende* consensus. For example, the Federation of German Industry (BDI) has founded an “Energy Competence Initiative”. The “Forum für Zukunftsenergien”, which originally took a critical view of the nuclear power phase-out, is now taking a closer interest in the problems of implementing the *Energiewende*.

New alliances have emerged such as the “Nationale Forum Energiewende” initiated by the Federal Association of the Energy and Water Industries (BDEW) and the World Wide Fund for Nature (WWF) (Günther und Hildegard Müller: Rettet die Wende! Wie die neue Politik zu einem Erfolg werden kann: Ein Aufruf von WWF und Energiewirtschaft, Zeit Online, 6 December 2012.).

Not only the new strategic alliances are remarkable. Another new aspect is that issues which had polarised energy policy for decades, such as attitudes to nuclear power, are now regarded as settled, with the result that it is now possible to concentrate on issues concerning the implementation of an *Energiewende* that is least superficially accepted. Even fundamental critics of the EEG do not openly cast doubt on the *Energiewende* as an overall course (acatech 2012b; SVR 2012). This means there is at least superficially a substantive convergence of many actors who are calling for a system perspective for the integration of renewable energy. They basically agree that there is a need for a reform of the EEG that will have to address issues relating to greater flexibility, grid expansion, storage facilities, demand side management and safeguards for long-term investment incentives (e.g. The Federation of German Industries (BDI), German Renewable Energy Foundation (BEE), German Association of Energy and Water Industries (BDEW), Institute for Applied Ecology (Öko-Institut), Agora Energiewende, Verband Kommunaler Unternehmen (VKU), Verband der Industriellen Energie- und Kraftwirtschaft (VIK)). As a result, however, the debate is shifting away from a political discussion that the general public can understand and moving in the direction of a highly specialised technical discussion. Differences in interests are being translated into competing opinions on questions of detail. Positioning in this new interconnected situation presupposes suitably extensive detailed knowledge and is increasingly becoming an exclusive discussion between experts.

Even within the group of actors who traditionally call for a pro-active renewal of the energy industry in the direction of renewable energy, more climate action and the end of nuclear-generated electricity, the spectrum of opinions is becoming more differentiated (REST 2011). For example, the Institute for Applied Ecology and the Green Party in Baden-Württemberg are advocating early adoption of a capacity market model (MATTHES et al. 2012), whereas the UBA has taken up an opposing position, and the focus of a BMU research project is essentially on developing proposals for a strategic reserve model (BMU 2013; NICOLOSI 2012).

124. This constellation of basic consensus on the *Energiewende* plus competition on opinions about various topical solutions is capable of having innovative effects. Nevertheless, there is still the problem of how to ensure feedback between this debate and a public discussion that is increasingly being dominated by an over-simplified debate about costs (cf. Item 62).

Pluralistic participation of interests in opinion forming and decision-making processes is the precondition for a functioning democracy and the legitimation of decisions. The more diverse and complex the spectrum of actors, the more important it is to integrate the various initiatives in the democratically legitimised decision-making process. It is the task of the Federal Government to take advantage of this new actor structure. This includes establishing effective participation procedures and creating processes and arenas that permit learning effects and suitable corrective measures (LAFFERTY and MEADOWCROFT 1996; BÄCKSTRAND et al. 2010; Enquete-Kommission Wachstum Wohlstand Lebensqualität 2013, p. 475 f.).

6.1.2 Multi-stage decision systems

125. The change in the structure of the *Energiewende* actor networks also raises questions of governance. The transformation of the energy system requires regulatory and political decisions at a wide variety of levels and in many different fields of action. At the same time, these decisions must possess a certain minimum of consistency. In the expert discussions it was pointed out at an early stage that grid planning should be based on the requirements of renewable energy sources (dena 2005; SRU 2011, Chapter 9). This was taken up only partially and relatively late with the reform of federal grid planning (CALLIESS and DROSS 2012). There is also a need for more systematic coordination between federal grid planning and the expansion targets of the *Länder* (LUHMANN 2012). At the same time this transformation process will have to be capable of dealing with uncertainty and of integrating sudden and unforeseen events in the process.

The theoretical literature on governance considers that hierarchical control and planning of such a complex overall system is neither possible nor desirable (MAYNTZ 2005; JACOB et al. 2007; SRU 2012). The political system would be overwhelmed by the complexity of the issues from an information point of view, would not have the capacity to resolve all detailed conflicts on a central basis, and would consequently produce simplified and misguided solutions (SCHARPF et al. 1976). On the other hand, decentralised structures are also potentially spaces for innovation. Studies of social change and the management of complex systems show that innovations usually emerge in small, protected arenas with a limited number of niche players (ROTMANS and LOORBACH 2008, p. 25), which should be provided with space for designing and experimentation. At the same time, however, the parallel existence of uncoordinated self-regulated processes was said to result in inconsistency, inefficiency, and even to seriously endanger the project as a whole.

126. Recent literature on regime complexes, institutional diversity or “bound governance” seeks to bring together these contradictory profiles of decentralised self-management and hierarchical coordination (ZELLI and van ASSELT 2013; ZÜRN and FAUDE 2013). The concept of the overriding system of rules is important here. A system of rules is made up of standards, requirements, rules and procedures that the decentralised actors have to comply with. One everyday example is a football match: it follows its own course, but the teams still have to observe clear rules. The referee makes sure the players keep to the rules, but does not control the result of the game. The process is thus structured, but the outcome is open. Such systems of rules are a key success factor for the management of complex problems. However, there is no one specific set of rules that leads to success. The crucial thing is to find appropriate rules for each level of regulation, and to design systems as adaptable organisational units (OSTROM 2005, p. 254).

Multi-stage decision-making systems of this kind have efficiency and effectiveness advantages, because they permit learning processes and situation-appropriate adaptation strategies and offer all participating actors a fair allocation of opportunities (von PRITTWITZ 2012). The "constitutional" level lays down the rules of the game – especially the standards and overarching objectives, rights of participation, decision rules and procedures – in according with which the actors resolve their conflicts in the course of varied discussions and arrive at binding decisions. Public participation projects or the delegation of technical issues in self-managed expert bodies can be organised in this way. Markets too, like any other decision system, are embedded in a system of rules. This is particularly true of market-based instruments of environmental and climate policy, like the emissions trading scheme of the EEG. The market actors can react autonomously and in keeping with the situation to these politically established market and price signals. To this extent the outcome of the systems of rules is open. Von PRITTWITZ (2012) describes this as "bound governance".

The challenge for the governance of the *Energiewende* is to make the most of the positive elements of the emerging *Energiewende* regime – such as broad involvement and space for argumentative discussion of conflicts. Thus the emerging governance of the *Energiewende* should satisfy the principles of openness and access, transparency and plurality (KOOIMAN und JENTOFT 2009) and should thereby counteract the increasing lack of transparency of the matter in question for interested non-experts. This lack of transparency results from the large number of different interests and proposals for reforming the electricity market that are discussed in increasingly specialised expert discussions.

The various levels on which the *Energiewende* takes place should therefore be used as a space for innovation. If central decision processes are organised on an open-outcome basis for a sufficiently long time, and if there is sufficient coordination between the levels, it is possible to achieve learning effects. On the other hand it is also important to ensure that individual projects or even individual elements of the *Energiewende*, such as the highly decentralised expansion of renewable energy, do not endanger the success of the project as a whole. Below, the SRU elaborates proposals for increasing opportunities for participation, a Climate Change Act, closer coordination by the Federal Chancellery, or increased "outsourcing" of the implementation of reform elements to public authorities. They are in particular inspired by this basic idea of facilitating self-managing innovation spaces while providing these decentralised initiatives with common guidance and a clear system of rules.

6.2 Participation in multi-level systems

127. The process of transforming the electricity market is especially reliant on public exposure and the involvement of society and organised actors: as democratic participation, as a means of generating acceptance, and as an opportunity to present options that make up for the uncertainty and openness of the process. The German Government has catered for this by seeking, for example, to integrate the various groups of actors in the decision processes and thereby enabling them to participate. The Federal Environment Ministry's *Energiewende* platforms are an example of this, as is the support from interdisciplinary and transdisciplinary research platforms like the IASS (cf. Item 123). In addition to the integration of organised actors, there have been a variety of attempts in the past few years to strengthen new methods of public participation. This is to be welcomed, and can be seen as the start of a process which needs to be taken further.

128. A successful *Energiewende* is strengthened by broad societal participation. This can support acceptance and identification with political projects. Organised as an argumentative public discussion (deliberation), participation can set the tone of and carry the development of a vision by society (Item 143), make knowledge accessible and communicate common values (WBGU 2011; NANZ and FRITSCHE 2012; RWE 2012).

With regard to the present process of electricity market design it is particularly important that not only influential and short-term individual interests should make their way, but also that actors who have the long-term transformation tasks in view should play a part. Open and formal opportunities for participation that specifically open up offers to interests with fewer resources are also helpful in this context. For example, there should never again be an energy summit without the participation of environmental and consumer associations or without the renewable energy industries.

And participation has another important function: it can boost acceptance. Acceptance is a precondition for the success of the *Energiewende*, which is not merely a technical or economic task. If participation takes place at an early stage and is transparent and open, making it possible for the public to play their part in shaping the course of events, acceptance is more likely. As explained by the SRU (2011) in its special report “Pathways towards a 100% renewable energy system”, there is a need to differentiate between general and specific acceptance, so that both can be given targeted support. General acceptance of the expansion of renewable energy remains high (TNS Infratest 2013). To promote specific acceptance, such as local acceptance of individual projects, it is necessary to facilitate participation not only in the costs, but also in the benefits of projects, e.g. through financial participation in the case of cooperative projects (SRU 2011, Item 285, 489 and 505). One important factor for the acceptance of costs is their fair and just allocation (WUNDERLICH 2012).

129. Multi-level systems basically offer a wide variety of opportunities for participation, legitimation and acceptance. This is particularly significant in view of the fact that there are many system variables that cannot yet be reliably determined. Starting points for participation exist at all levels, providing many opportunities for feeding knowledge and new ideas into political processes. The dynamic developments with regard to actor constellations in the field of the *Energiewende* make it difficult for interested non-experts to find out about detailed aspects of the *Energiewende* of relevance to them. For these people, it is thus also difficult to placethese developments in the context of important political decisions and consequently identify suitable means of participation. It is a task of the state to strengthen such opportunities for participation, for example via formalised processes in public authorities that are involved in the *Energiewende* (Item 152). After all, it is part of the state's coordination task to ensure that the knowledge, values and joint findings are fed back into the decision process (Item 149).

130. In this connection a monitoring process covering a broader content gains in importance. The existing dual structure of *Energiewende* monitoring – an expert report and a joint report by the two ministries BMU and BMWi – serves the interests of transparency and quality control and is therefore basically to be welcomed. So that coordination can also be effective, there is a need not only to consolidate the monitoring process, but also to ensure the independence of inquiry and evaluation. The subject of monitoring is also relevant and should be expanded.

Monitoring should reflect both the state of development of technology and its implementation. On the other hand it should obtain information on cost-related and benefit-related allocation effects and permit conclusions about their causes – such as political measures or the general economic situation. Through these aspects which are already largely covered by the existing monitoring system, the *Energiewende* process should itself become the subject of monitoring. In concrete terms, that means extending the monitoring process to take in the decision processes and the existing opportunities for participations, and also an evaluation of coordination. Information should in particular be collected on the extent to which these processes satisfy transparency requirements and whether they ensure adequate participation and access by relevant actors.

If monitoring results in transparency about various reform activities and discussions, their authorship and their position in the *Energiewende* project as a whole, this makes it easier for all stakeholders to obtain information and participate on a targeted basis. For one thing, this would counteract frustration due to misinterpretation of the opportunities for exerting influence. For another, it would enable monitoring to perform a cardinal function between general political debates, e.g. on the cost of expanding renewable energy, and the expert discussions. And, not least, it is important to investigate the acceptance of reform decisions. This does not necessarily mean collecting data as part of the monitoring process. It is rather a matter of compiling and examining existing data, to obtain a valid overall picture of the acceptance and allocation impacts of the reforms under the *Energiewende*.

6.3 Coordination in a multi-level system

131. Energy and climate policy take place at European, federal, regional (*Länder*) and local level. In view of this multi-level interconnection of energy and climate policy, the task of coordinating, implementing and evaluating objectives, instruments and measures is an important element for efficient and effective process control (JACOBSSON and BERGEK 2004; BRUNNENGRÄBER 2013; KÖNNÖLÄ et al. 2009, p. 14). With its energy concept of

2010 and the corrections made in 2011, the German Government has already made a start on coordinating the individual *Energiewende* targets and raised awareness of the coordination tasks ahead. However, it is not clear how binding various governmental and non-governmental actors consider the different targets of the *Energiewende* to be. As the expansion of renewable energy goes ahead, therefore, it is necessary to develop the coordination mechanisms in the multi-level system and to overcome lock-in situations (e.g. the large portfolio of existing coal-fired power stations) (LOCKWOOD 2013, p. 35 and 41).

Successful coordination raises the prospects of better acceptance of the *Energiewende* projects and the resulting costs. The coordinating effect and also the acceptance of projects can be reinforced by agreement on common objectives in the context of drawing up a vision (SØRENSEN 2006). The coordination task is twofold: horizontal coordination of actors and the system on the one hand, and vertical coordination of interests and activities at EU, federal, regional and local level on the other. At all levels there are authorities concerned with implementing aspects of the *Energiewende*, ranging from political planning to authorisation of installations and power grids (OHLHORST and TEWS 2013).

6.3.1 Horizontal coordination of actors and system

132. The Energiewende is a cross-sectional topic and touches on the responsibilities of numerous sectoral ministries, especially those of the BMU and BMWi. The two ministries already cooperate in many ways, e.g. in the Power Plant Forum (*Kraftwerksforum)* or on *Energiewende* monitoring. However, they sometimes express fundamentally different views in public on time schedules and suitable instruments for implementing the reform of the electricity market, for example in their appraisal of the Monopoly Commission's proposals for a change of system in the funding models for renewable energy ("Rösler: Monopolkommission bestätigt Notwendigkeit eines Systemwechsels beim EEG", BMWi press release, 5 September 2013; "Altmaier: 'Erneuerbare-Energien-Gesetz braucht schnelle Reform'", BMU press release, 5 September 2013).

Whereas energy market regulation and grid expansion are the responsibility of the BMWi, the promotion of renewable energy has since 2002 been lead-managed by the BMU. The aim of this reorganisation was to strengthen and speed up the expansion of renewable energy. However, with the growing proportion of renewable energy sources on their way to becoming a lead technology, the need for coordination between the two ministries has increased considerably. This includes measures for ensuring supply security, speeding up grid expansion or reforming the EEG. These important elements of the *Energiewende* are so closely interconnected that at least the coordination processes between the ministries need to be intensified. This requires a jointly accepted guidance framework. At present there is no such framework with a sufficiently binding character.

The increasing complexity of the tasks connected with the *Energiewende* also means that not just two, but at least six ministries need to coordinate more closely in future to avoid conflicting political approaches. These include:

- BMU: Expansion of renewable energies,
- BMWi: Energy market regulation, grid regulation and planning, energy efficiency,
- BMVBS: Electromobility, building refurbishment, regional planning,
- BMF: Financing,
- BMBF: Promoting research,
- BMELV: Bioenergy and consumer protection.

133. The promotion of renewable energy sources has always been accompanied by disagreements on ministerial responsibility (DAGGER 2009). In view of the increasingly interconnected nature of the system, this affects an increasing number of ministries. This has various effects: on the one hand, it can be expected to result in the emergence of a greater diversity of ideas for reform. On the other hand, it also involves greater potential for conflicts. The resulting inefficiencies in decision processes can affect the entire spectrum of topics covered, such as emissions trading, EEG surcharge, or energy efficiency in the buildings or transport sector. Interministerial coordination is thus becoming even more important with the growing interconnections between the tasks involved.

The state is already making efforts to deal with these challenges. For example, the meetings at State Secretary level are partly an initiative aimed at improving interministerial coordination. On the other hand there is a need for a central instance that would at least perform conflict-resolution and guidance functions, where all *Energiewende* activities would come together.

6.3.2 Vertical coordination

134. Not only the horizontal interconnections between the reform processes for the *Energiewende* are increasing, but also the vertical connections in the multi-level system. In parallel with conflicts between objectives and measures of national and European energy policy, Germany's federal system pose the challenge of reconciling national measures and objectives to the extent that they do not obstruct each other and that they ensure the speed and efficiency of renewable energy expansion. For example, the renewable energy expansion targets of the *Länder* are not in line with the expansion targets of the federal government (LUHMANN 2012). Even if the federal system may at first appear to be a barrier, it offers great opportunities for the implementation of the *Energiewende*. Vertical coordination needs to be stepped up, not only between the federal and *Länder* authorities, but also between the national and European levels (OHLHORST and TEWS 2013).

Coordination between federal and regional level, and the role of local authorities

135. Thorough coordination of the interests of the federal and regional levels is essential for the efficient expansion of renewable energy and the necessary grid infrastructure. For example, incentives for site selection for the renewable energy expansion could be set at national level – e.g. under the EEG – or at the regulatory level of the federal *Länder*. The more closely not only the national level, but also decentralised regulatory levels are involved, the greater is the need for coordination of the various activities and decisions.

The *Länder* have considerable scope for helping to shape federal legislation. Although the EEG does not require the consent of the upper house, the latter is entitled to raise objections (ALTROCK/OSCHMANN/THEOBALD 2011, Section 64 marginal note 10). This means the Bundesrat can at least delay decisions by the federal government and force it to make concessions where speedy approval is wanted or in cases involving comprehensive policy packages that include elements requiring consent. For example, in the photovoltaic revision of 2012 the *Länder* were able to use their right of objection to first delay the planned restrictions in photovoltaic promotion and then considerably reduce them (Länder blockieren Kürzung der Solarstrom-Förderung, Zeit Online, 11 May 2012). The German Government could have anticipated such reactions by ensuring early participation in the reforms.

Apart from their influence on federal legislation, the *Länder* and local authorities have great freedom of action through their function of designating land for the expansion of renewable energy (building legislation, regional policy). Furthermore, the *Länder* are increasingly formulating their own expansion targets for renewable energy, not only in programmes, but also under their own climate change acts (North-Rhine/Westphalia Climate Change Act, Baden-Württemberg Act on Promotion of Climate Action). In this way they are underlining their strategic interest in exercising their competence in the field of promoting renewable energy sources.

The expansion of renewable energy installations and of distribution systems takes place on a decentralised basis in the local authorities. In addition to municipal energy supply companies, small municipalities in particular are relevant as *Energiewende* enterpreneurs, as the expansion of decentralised renewable energy installations is worthwhile for them to increase regional added value (HIRSCHL et al. 2011). An increase in decentralised feed-in to medium-voltage and low-voltage systems calls for corresponding grid expansion and coordination with higher levels, for example to weigh up options relating to the introduction of capacity payments to finance rarely used infrastructure (Chapter 4). Local authorities are also relevant actors when it comes to grid expansion. For one thing, grid expansion is frequently delayed by resistance at local level (BRUNS et al. 2012). This may not only delay the project or make it more expensive, but may also send out generally adverse signals.

Lack of local acceptance of renewable energy sources and the relevant infrastructure projects is a reputation risk for investors (GDV 2013).

On the other hand, grid expansion offers the possibility of taking part in the financing of the grid system – from extra-high voltage lines to the distribution system – and thereby creates opportunities for identifying with the *Energiewende* project and using influence to ensure fair and just allocation. However, this is to some extent the subject of controversy from a consumer protection point of view. One example of such an initiative is BürgerEnergie Berlin, which aims to enable citizens to buy the Berlin electricity system under a cooperative model (BürgerEnergie Berlin 2013).

136. The extent to which grid expansion is a critical limiting factor for the growth of renewable energy or whether it can be offset by more decentralised options for load management or curtailment of rare generation peaks (cf. Agora Energiewende 2013; Ecofys 2013), is the subject of controversial technical and economic discussion. From a governance perspective there is an argument in favour of not relying on only one of the two options: Complex transformation processes like the *Energiewende* which involve uncertainties are more resilient if they take place in parallel at many different places, because the partially redundant processes increase the performance capacity of the system as a whole by making it less prone to errors and increase the probability of solving the problem (ROTMANS and LOORBACH 2008; DOSI and NELSON 1994; OSTROM 2011, p. 41; 2005, p. 284). The local initiatives that can be observed worldwide are thus an important supporting and stabilising factor for climate action and the expansion of renewable energy (SCHREURS 2008). On the other hand, broad economic participation by local actors such as private individuals, cooperatives or farmers strengthens the political backing for the *Energiewende*, although this backing is not necessarily identical with support for a sustainable *Energiewende*, but occasionally results in support for non-sustainable structures, e.g. increased cultivation of biomass. Strengthening and consolidating networks while integrating civil society, and expanding communication paths between cities and regions are important steps to facilitate exchange of experience between the decentralised activities.

137. Governance systems based on a large number of decentralised control approaches require considerably greater coordination and transparency than less complex, centrally controlled systems. The governance of the *Energiewende* should take account of this finding, both in the long term and in the transitional regime. At national level the Federal Chancellor has attempted to play a mediating role by calling energy summits involving the *Länder* as well. Although six-monthly meeting can have a symbolic effect, detailed coordination of objectives, measures, implementation and evaluation require a more extensive reform of the governance structure. Section 6.3.3 sets out relevant policy recommendations.

Interaction of national and European energy policy

138. Coordination between the national and European policy levels is of strategic importance for the success of the *Energiewende* (BRUNNENGRÄBER and WALK 2007; SRU 2011; CALLIESS and HEY 2012). Today, important supporting aspects of the energy policy framework are decided at European level. In particular, these include:

– European climate policy, with the emissions trading scheme as its most important fully harmonised instrument,

– the design of competition legislation, and especially the framework for state environmental aid,

– European environmental legislation, especially relating to air quality control and nature conservation law,

– the further development of EU policies for renewable energy and efficiency measures,

– the design and further development of the single internal market for energy, and

– the development of the trans-European energy systems.

These fields of action can be designed so that they accompany and support the *Energiewende*. However, it is also possible for conflicts to arise which either increase the economic costs of the *Energiewende* or considerably restrict national freedom of action, especially from a legal point of view. Uncertainty has recently been created, especially by nuclear-friendly statements by the European Commission and by announcements about more restrictive application of the legislation on state aid. In recent years the EU has on the whole agreed on basic policy lines that tend to support the objectives of the *Energiewende*. These include the roadmap for a low-carbon economy in 2050, the Renewable Energy Directive 2009/28/EC, the energy policy targets for 2020 or the special arrangements for the expansion of renewable energy in the Third Deregulation Package (CALLIESS and HEY 2012; 2013; SRU 2011). For example, in its scenarios for its energy roadmap 2050, the European Commission shows that regardless of the member states' widely differing preferences in their choice of energy sources, it will not be possible to achieve the EU's climate objectives if the renewables-based share of electricity supply in 2050 is much below 60 percent (European Commission 2011). This percentage is therefore regarded as the renewable energy expansion target that must be achieved whatever happens. If this argument is accepted, all member states face the same challenge of having to adapt their energy systems to the needs of weather-dependent energy sources. It is still uncertain whether and to what extent a systematic pursuit of these approaches by means of an energy and climate system for 2030 will be successful. In a consultation on this topic held by the Commission, a very large number of member states expressed reservations or – like Germany – no views at all (European Commission 2013).

139. There is an inevitable conflict between a completely deregulated, non-discriminatory internal energy market – i.e. an energy-only market in which the choice of fuel is left to market forces and which is supposedly without distortion of competition between the member states – and active, national promotion of specific fuels, such as renewable energy sources. As shown by the analysis in Chapters 4 and 5 of the capabilities and limits of an energy-only market in transition to a largely renewables-based supply system, one-sided resolution of such a conflict in favour of the single market regime is not possible without endangering the renewable energy expansion targets and hence the national and European climate objectives. To date this conflict has been resolved by pragmatic solutions – sometimes after intense disputes. What has emerged in practice is a multidimensional European system of targets which takes balanced account of market deregulation, supply security and climate action, and which does not give the single market priority over all other objectives. This interconnection of targets and measures in European energy policy (CALLIESS 2008; CALLIESS and HEY 2012) should remain the basis for action in the future. The greater the success of political convergence (cf. HOLZINGER et al. 2008), the smaller the conflicts of objectives.

On the other hand, complete harmonisation of measures is not absolutely essential, and in view of divergent energy policy interests and visions of the future in the member states it is not always politically realistic either (MIDTTUN 2012, p. 30 f.; BERKHOUT et al. 2010; NILSSON 2011). Moreover, the initial conditions for a common climate policy have deteriorated considerably in the European financial and economic crisis (FISCHER and GEDEN 2013). For example, proposals that presuppose centralisation of European energy policy, such as a European quota system (acatech 2012a; SVR 2012; EFI 2013), appear to have little political prospect of success. Harmonisation of the promotion of renewable energy is not desirable, simply because of the widely differing background situations and energy policy objectives of the member states.

140. Convergence can come about through many other mechanisms, ranging from imitation of innovative solutions (emulation) to harmonised negotiated solutions that give the member states different degrees of freedom (HOLZINGER et al. 2008). For example, coordination, communication, regulatory competition and independent problem solving have, as voluntary mechanisms, contributed to the convergence of renewable energy promotion within the EU, without having to enforce this by means of harmonisation (JACOBS 2012). One example of such a non-centrally controlled diffusion of innovative solutions is the spread of feed-in tariffs for renewable energy within the EU (JACOBS and MEZ 2012; RAGWITZ and HELD 2012). The autonomy-friendly flexible arrangements (MIDTTUN 2012) include the European directives on energy efficiency and renewable energy: By contrast, the emissions trading scheme is a highly centralised solution (BERKHOUT et al. 2010, p. 149; van ASSELT 2010).

More recent literature gives reason for optimism that climate policy and renewable energy expansion may gain momentum despite a not very binding start (JÄNICKE 2012; MIDTTUN 2012). These authors believe in the positive feedback effects of political measures (policy feedback). For example, observations have shown that many European measures have developed growing ambitions and attracted increasing commitment in the course of time (JORDAN et al. 2010, p. 46). This can be seen, among other things, from the European requirements for efficiency and renewable energy (cf. SRU 2011, Chapter 5). It involves a process of learning and adaptation that arises from the contrast between great expectations of politicians and the initially inadequate solutions of the first generation of policy measures. One the one hand, first-generation measures create initial problem-solving capacities in the field of action, and on the other, under-management generates pressure to take action (von PRITTWITZ 1990). An aspect of strategic importance in this connection is a multi-dimensional approach based on a large number of coordinated measures and not on one single instrument that theoretically addresses all problems, like the emissions trading scheme (JÄNICKE 2012; MIDTTUN 2012; Enquete-Kommission Wachstum Wohlstand Lebensqualität 2013; Item 73; see also notes on the need for a differentiated target approach, SRU 2013). This multi-dimensional approach is much more resistant to political blockades and vetoes than a policy that only focuses on a single instrument.

In the long term this could give rise to a European energy policy that pushes ahead not only with the project of “negative integration” of the single energy market, but also with the project of “positive integration” (cf. SCHARPF 1999), thereby giving strength to a flexible regulatory framework for renewable energy, energy efficiency, grid integration and supply security.

These positive integration targets are interdependent, and their design and further development need to take account of this interdependence (cf. Projektgruppe 4 Enquete-Kommission Wachstum Wohlstand Lebensqualität 2013; EFI 2013; also SVR 2012; NOTENBOOM et al. 2012; FISCHER and GEDEN 2013). The Green Paper published by the European Commission in the spring of 2013 is intended to prepare a target structure for 2030 (European Commission 2013). In this context it is important for the success of the *Energiewende* that the EU should develop not only a binding climate target for 2030, but also an ambitious and highly committed target for renewable energy and energy efficiency (SRU 2013). Only with such a coherent system of targets will it be possible to justify further measures for promoting renewable energy as a contribution to climate action, and also to minimise competition risks and anticipate the interactions between emission trading, efficiency and the expansion of renewable energy. If the *Energiewende* is a strategic national objective, it follows that a suitably consistent European framework must be of vital national interest.

141. A constituent factor in the development of such a European system of objectives is thus the adoption of a committed position in the EU by the German Government. Numerous examples reveal a lack of such consistency in the recent past (HEY 2012; DUFFIELD and WESTPHAL 2011). Indeed, there has been and still is considerable resistance in Germany to more extensive initiatives by the European Commission to revitalise the European emissions trading scheme or on energy efficiency (ANCYGIER 2013). This positioning is not coherent with the *Energiewende* objectives pursued by the German Government. The establishment of an effective steering centre for the *Energiewende* could help to overcome this consistency problem.

6.3.3 Reform proposals for coordination

142. The governance challenges that are changing with the growing proportion of renewable energy in the electricity mix can only be met with a large number of interlocking reform steps. This need arises among other things from the increasing difficulty of controlling far-reaching changes in the energy system in a way that it is efficient, transparent and participatory. Various coordination options are available to government representatives and other governmental actors. They can design the framework for self-regulation, provide targeted support for initiatives and networks, or influence the position of political strategies by creating opportunities for interpretation and identification (story-telling) (SØRENSEN 2006; HAJER 1997). The following sections outline and discuss a number of possible approaches that the SRU considers important. Vision development as an important anchor point for all other processes should be complemented with a coordinating body at central level. However, a fully differentiated description of the reform needs is beyond the scope of this report.

Climate Change Act

143. It is important that the climate objectives be laid down in binding form to ensure that they are achieved. The same applies to the renewable energy expansion targets, which in turn give concrete shape to the climate objectives and translate them into action targets. This lends the necessary weight to the political and social importance of climate action and the *Energiewende*, and creates certainty for investors and planners. The SRU advocates enshrining the objectives in a Climate Change Act. If the actors to be coordinated in the multi-level system can be won over by the environmental guiding principle “climate protection”, the Act could also serve the interests of vision development. In view of the interactions between climate action, renewable energy and energy efficiency and other effects of renewable energy and efficiency (SRU 2013), however, the hierarchy of objectives frequently suggested in the literature (LÖSCHEL et al. 2012; SVR 2012; acatech 2012b) does not appear to make sense. This would once again consign political measures for renewable energy and efficiency to a less binding field of secondary importance.

Binding enshrinement of the climate objectives and the objectives of the *Energiewende* in a Climate Change Act would shift the decarbonisation of society into the focus of political discussion and support the strategic alignment of the coordination activities (for the significance of storytelling and image construction see KOOIMAN and JENTOFT 2009). A Climate Change Act can help to place climate action, the *Energiewende* and the relevant objectives above the political debate. The binding enshrinement of these objectives in a Climate Change Act could also be a strategic source of legitimation for the control and coordination of the electricity market reform and thereby reduce uncertainty about the reversibility of the *Energiewende* targets.

144. Climate Change Acts have been in place in a number of European countries for some years now, particularly in Switzerland (1999), France (2005) and the United Kingdom (2008); all three acts include concrete CO_2 reduction targets. These acts are described briefly below in order to assess possible design options from the spectrum of European models, even if they cannot be applied directly to Germany without checking legal aspects.

The Swiss CO_2 Act dates from 1999, but was revised at the beginning of 2013 (Bundesgesetz über die Reduktion der CO_2-Emissionen – CO_2-Gesetz). It contains an overall nationwide reduction target of 20 per cent compared with 1990 by the year 2020. The Swiss Bundesrat can increase this to up to 40 percent. It also includes sectoral requirements and a detailed CO_2 levy on fuels. The Act also contains requirements for technical measures in the fields of buildings and passenger vehicles. Chapter 4 of the CO_2 Act is concerned with emissions trading and compensation.

The preceding act laid down three levels (12, 24, 36 CHF/t CO_2) for the CO_2 levy on fuels, if the planned overall reduction in CO_2 emissions was not achieved. At present the highest level of 36 CHF/t CO_2 applies because the targets were not achieved. Following the revision of the Act, the Bundesrat can now increase the levy up to a maximum of 120 CHF/t CO_2 if the intermediate targets laid down for the fuels are not achieved.

The French Energy Programme Act (Loi n°2005-781 de programme fixant les orientations de la politique énergétique) of 13 July 2005, comparable to the German Energy Management Act, lays down an average annual reduction of greenhouse gases by 3 percent. To achieve this, a climate plan is drawn up and has to be updated every two years. The Act also contains final energy intensity reduction targets for the renewables-based share and for electricity consumption. Other French legislation also contains provisions on climate change mitigation.

The British Climate Change Act contains very detailed provisions. The Carbon Budgets embodied in the Act lay down for five years at a time where and how emission reductions are to be made. The first four Carbon Budget cover the period 2008 to 2027. The reduction obligations for the emissions trading sector are laid down separately from those for the other sectors (transport, agriculture and buildings). The budgets lay down the emission levels in the form of “orders” (e.g. Carbon Budgets Order 2011). The Carbon Plan sets out how the first four budgets are to be achieved. It lists the individual instruments per sector. The Climate Change Act was also the basis for establishing the Committee on Climate Change.

This gives the government independent advice on the Carbon Budgets and evaluates them. Before setting the emission level, the ministry has to note the advice of the Committee on Climate Change.

All three European acts contain a performance monitoring system that permits corrective action (for a comparison of the acts and their common features, see GROß 2011).

145. In Germany there are two climate acts at *Länder* level which have a number of features in common. Both North-Rhine/Westphalia (passed in January 2013) and Baden-Württemberg (passed in July 2013) have laid down binding climate targets for the years 2020 and 2050. Both *Länder* aim to make a 25-percent reduction in greenhouse gas emissions by 2020, compared with 1990. By 2050, emissions are to be reduced by at least 80 per cent in North-Rhine/Westphalia and by 90 per cent in Baden-Württemberg (Section 3 Klimaschutzgesetz NRW, Section 4 KSG BW). The climate acts also lay down that the measures, interim targets and targets necessary for their implementation, among other things for the expansion of renewable energy and the reduction contributions of the individual sectors, are to be developed in a follow-up process and enshrined in a climate action plan (North-Rhine/Westphalia) or an integrated energy and climate concept (Baden-Württemberg). Both acts also contain provisions on monitoring, the model function of the public administration and the establishment of an advisory council. In both *Länder* the individual processes for drawing up the implementation programmes are designed on a participatory basis from the outset, and offer a wide variety of participation opportunities for political, social and economic actors and for the general public. The process in North-Rhine/Westphalia is innovative in that development of measures does not take place in a linear feedback process, but in a continuous process with early involvement of all political, economic and social actors, by means of target group specific formats in a broadly based and relatively far-reaching programme. In the context of developing a vision for society, such an approach is notable in a densely populated and highly industrialised *Land* like North-Rhine/Westphalia, even if it is still too early to make a final assessment of this process. It could be informative for the federal level to keep the process in the two *Länder* under continuous observation, to assess the efficiency and effectiveness of the participatory, feedback-based procedures in the long term as well.

146. At federal level too, there have been several motions by the opposition to pass a Climate Change Act (Deutscher Bundestag 2013, p. 31298). Moreover, various studies have been carried out to investigate the proposals for concrete provisions and possibilities for legal enshrinement (MATTHES et al. 2010; SINA et al. 2009; WBGU 2011). An act of this kind would not prevent the passing of acts at *Länder* level, but would in fact reflect the obligation of all governmental levels to play an active part in climate action (GROß 2011, p. 177).

147. In summary, a Climate Change Act would be an important point of reference for the existing and future measures to implement the *Energiewende* and to reform the design of the electricity market. A Climate Change Act should also integrate other sectors that are not directly affected by the objectives of the *Energiewende*. As well as laying down targets phased over time, the Climate Change Act should provide for action programmes to be drawn up in follow-up steps. Detailed measures can then be specified in a next step, like the preparation of the climate action programmes for implementing the climate acts in the *Länder*. Furthermore, a Climate Change Act should bundle the relevant legislation, in particular the Greenhouse Gas Emissions Trading Act (TEHG), the Act concerning the National Allocation Plan for Greenhouse Gas Emission Allowances for the period 2008 to 2012 (Zuteilungsgesetz 2012 – ZuG 2012), and the Act of 11 December 1997 concerning the introduction of project mechanisms under the Kyoto Protocol to the United Nations Framework Convention on Climate Change (ProMechG).

Coordination centre

148. The larger the number of interconnected and interrelated *Energiewende* tasks, the greater will be the overlaps between ministerial responsibilities and the greater will be the need for a coordinating centre. Moreover, governance of the transition will be much more complex than the existing governance system, because of the number of action levels concerned. Especially because both interministerial coordination and coordination between the federal and *Länder* levels are perceived to be inadequate, repeated calls have been made in the public debate for the establishment of an energy ministry which would be responsible for central control and coordination of the *Energiewende* process (one example of many: Martin Greive, Matthias Kamann and Daniel Friedrich Sturm: Jetzt wollen alle die *Energiewende* für sich, Die Welt, 12 April 2013).

The main argument for setting up an energy ministry is to improve the efficiency of the coordination processes, because the final decision rests with only one minister (STIGSON et al. 2009; KEMFERT 2010, p. 154; RAVE et al. 2013, p. 264 f.).

However, on the basis of her theoretical analyses of the organisation of environmental policy, especially in its function as an interdisciplinary cross-sectional policy, MÜLLER (1995; 1999) comes to the conclusion that there is no one single organisational model in the abstract sense, but that different organisational models perform better depending on the development phase of a policy and the stage in the political cycle. She argues that during the phase where a policy is being newly designed, positive coordination – joint work on solutions to overarching problem complexes that are initially dealt with in parallel – is the best form of organisation, especially within an overarching ministry, but that programmes are best implemented on a shared basis. Since a ministry is always an “advocate” of specific interests, an environment ministry may be the best guarantee of that demands for deregulation will be warded off in phases when environmental policy is on the defensive. Such a constellation is basically conceivable in relation to renewable energy as well.

At any rate, merging ministries is no guarantee that there will be no conflicts of interests. They will merely shift to the interministerial level. As a result, they will be less perceptible to the public and thus solved at interministerial level in a less transparent process. In this respect different ministries are useful for identifying conflicts and resolving them in a transparent manner. In the past the conflicts between the Environment Ministry (BMU) and the Economics Ministry (BMWi) have led to inadequate solutions, because the interministerial conflicts were sometimes exaggerated by party-political differences (KAISER 2013).

For a number of reasons the SRU advises against introducing a separate energy ministry:

The coordination requirements far exceed the competence of a single ministry. Decisions concerning the *Energiewende* are taken not only at federal level, but in a complex multi-level system, and implemented on a centralised basis. There is thus a need for coordination not only between the federal ministries, but also between the federal and *Bundesland* level and between Germany and the EU.

The *Energiewende* is not merely the responsibility of the economics and environment ministries. Other ministries also play an important part, e.g. the ministries of transport, research or agriculture. It would be unrealistic to bundle all these tasks in a single ministry.

Each ministry acts as the point of contact for specific stakeholders. If these interests are spread among different ministries, there is competition between the ministries to innovate, and this can be seen as a driving force behind the *Energiewende*. With renewables-based electricity accounting for 25 per cent of electricity consumption, the electricity mix is still dominated by conventional energy, which means that producers of the latter would potentially be able to exert great influence in a newly created energy ministry. Special care must therefore be taken to cater for the interests of the renewable energy sector in the transitional period. The simplest solution is to leave responsibility for renewable energy in the Environment Ministry.

The establishment of an additional ministry could lead to individual issues being given greater priority, resulting in marginal topics becoming less important in the Cabinet (SCHAMBURECK 2010). Effects in two directions are conceivable here, neither of which represents any improvement on the status quo. Firstly, an energy ministry could result in energy topics being given priority over other important issues. In the event of conflicts of objectives, e.g. between renewable energy and nature conservation, this would not be in the interests of a balanced solution. Secondly, the relative weakening of the other ministries due to the Energy Ministry could also give rise to hostile reactions ranging up to a blockade mentality, because other ministries fear their issues could become less important.

Finally, outsourcing energy topics to an *Energiewende* ministry would also fail to do justice to the cross-sectional character of the *Energiewende* and would not solve the problem that a number of ministries were affected. On the other hand, synergies with other topics within a ministry, e.g. technology policy, would be lost (KAISER 2013). MÜLLER (1995, p. 518) advocates that topics with explicitly cross-sectional functions should be integrated in different sectoral ministries rather than bundling them in a single ministry. STIGSON et al. (2009) also take the view that bundling energy policy issues in a single ministry is no substitute for much-needed improvements in interministerial coordination. In the current peer review of German sustainability policy, the experts – as in the past – advocate creating an officer for sustainable development, who should be based in the Federal Chancellery. This officer should be assigned an interface function not only for sustainability policy, but also for the *Energiewende* (STIGSON et al. 2013, p. 71).

Neither is it possible to conclude from empirical evidence that bundling energy competencies in a single ministry yields the hoped-for advantages. The British Energy and Climate Ministry was established in the interests of strategic positioning in international climate policy and is a comparatively small ministry performing mainly coordination functions, but other ministries are still integrated in interministerial coordination, which is not made superfluous by the creation of an energy ministry (RAVE et al. 2013, p. 267).

An analysis of the Danish example shows that bundling energy issues in a single ministry can have positive effects on coordination, whereas in the USA these effects were negative (RAVE et al. 2013). Frequent renaming and restructuring of ministries (e.g. in France) also indicates that a separate energy ministry has not proved superior and is heavily dependent on the context. Germany’s attempt in 1998 to bundle energy policy in one ministry – the Economic Ministry – was not successful. As a consequence, two divisions for renewable energy were created within the Environment Ministry (KAISER 2013). If it is not possible to ensure that an energy ministry is more effective and more efficient than a divided organisation, then such a ministry should not be created. Restructuring (within a ministry or between ministries) ties up resources and involves (transaction and search) costs, which means that creating an energy ministry will initially lead to delays in decisions.

Instead of creating a separate ministry it would make sense to optimise the coordination processes between ministries. A Climate Change Act would be an important connecting element here. In view of the innovative competition between ministries that can arise from allocating *Energiewende*-specific tasks to different ministries, the SRU recommends retaining the present ministerial competencies.

149. Having a central body to perform a primarily strategic coordination function is important for the bundling and coordinated interaction of activities in the multi-level system. The more diverse the actors are and the more is done to comply with demands for more opportunities for participation, including by civil society, the more important this becomes. The creation of such a body must however be seen in isolation from the establishment of a separate energy ministry, as its responsibilities lie mainly in the field of coordination and moderation. The task of working out the details of and implementing the individual objectives of the *Energiewende* continues to rest with the departments of the existing ministries and authorities. To enable the diverse coordination tasks to be performed as coherently and efficiently as possible, the SRU recommends the German Government to establish a central coordination unit in the Federal Chancellery and equip it with adequate decision powers and human resources. This would institutionally underpin the policy-making powers of the Federal Chancellor.

The unit should be integrated in the Federal Chancellery at the level of a minister of state. This would ensure direct access to the Federal Chancellor, since the minister of state would belong to the management of the Federal Chancellery (BUSSE and HOFMANN 2010) and would take part in Cabinet meetings (Section 23 of the Federal Government's Joint Rules of Procedure). The rank of a minister of state in the Federal Chancellery reflects the character of an interministerial integration task. The "Minister of State for the *Energiewende*" would sharpen the topic's profile and give it the necessary importance within the political decision structures and in the public eye. The minister of state would coordinate the *Energiewende* and would have a moderating function in cases of interministerial conflicts, especially at top level. The minister would also perform this function in consultations between the federal and *Länder* levels.

The Minister of State in the Federal Chancellery would formally be of equal rank with the parliamentary state secretaries in ministries. However, a crucial factor in the exercise of the relevant powers is that the minister of state is subject to the direct political responsibility of the Federal Chancellor (BUSSE and HOFMANN 2010). Furthermore, ministers of state do not have to be members of parliament (Section 1(1), second half sentence of the Act concerning the Legal Situation of Parliamentary Secretaries of State), but – like all members of the Federal Government and the Bundesrat – they are entitled to attend all sessions of the Bundestag and its committees, where they must also be heard (Art. 43(2) of the Basic Law).

To ensure technical support, the "Minister of State for the *Energiewende*" should have appropriate divisions, as is the case with the Officer for Culture and Media, for example. The divisions should reflect the core topic of energy policy. Central to the sphere of duties of the "Minister of State for the *Energiewende*" should be the consultation between the federal and *Länder* levels, which is crucial to the success of the energy-policy objectives. Decision-making on energy and climate policy at European and international level also represents important arenas for the contribution of German experience. It offers room to argue for needs, and thus influences the freedom of action of national policy. In this spirit the "Minister of State for the *Energiewende*" should also contribute to consistent positioning of energy and climate policy at the various levels.

Furthermore, preparing decisions on fundamental systemic issues should also belong to the functions of the minister of state, for example the question of whether and, if so, when additional investment incentives for generating capacity should be introduced in Germany. The minister's functions would also include discussing the essential design principles of such a mechanism, such as deciding on a central actor responsible for its implementation. Another central task is regular scrutiny of the independent monitoring reports (Item 130). The minister of state should facilitate and accelerate the establishment of a set of rules for implementing the *Energiewende*. The implementation and fine tuning of the set of rules should be the province of a subordinate level of regulation (Item 152).

6.4 Efficient implementation of the Energiewende

150. As well as coordination and participation, the governance of the *Energiewende* should ensure that the system of rules is efficiently designed for its implementation. Section 6.4.1 explains the need to select and assign functions for the official levels of regulation that go beyond political and strategic decisions and relate to the level of implementing reforms. Finally, Section 6.4.2 explains – with reference to the changes in electricity market design recommended by the SRU – the extent to which existing authority structures meet the reform requirements efficiently or are themselves in need of reform.

6.4.1 Stable and responsive systems of rules

151. Even when managing short-term problems, the governance of the *Energiewende* must be in a position to maintain dependable signals for investment decisions and not to block solutions that are viable in the long term. One means of speeding up political decisions and supporting their implementation is to delegate decision to another (official) level of regulation that has greater technical expertise (MAJONE 1997). Greater separation of the level of rule management from those decision levels that are more exposed to stakeholder influence can help to depoliticise issues and thus contribute to greater efficiency of the technical elements of the *Energiewende* (CHRISTENSEN 2011; Item 126). In an increasingly integrated energy system, efficient dovetailing and rapid response capacity of the individual implementation steps are a necessary precondition for reliable electricity supplies. This means that the authorities directly or indirectly concerned with the implementation of electricity market reforms (e.g. through targeted scientific expertise) will increasingly be reliant on cooperation.

Setting down a system of rules for this implementation – with clear official responsibilities and clear rules for interaction between authorities – can ensure skilled routine handling of even unknown variables such as the development of costs for storage technology or the changing face of European legislation. Fundamental decisions, such as decisions on the next steps in reforming the EEG or on any additions to the market design for the energy-only market, must – for constitutional reasons – continue to be taken in the parliamentary legislation process. There is however a need for control at an operational level that is technical and has to adapt more flexible to new situations. This applies, for example, to determining the size of the market premium or possibly in the long term to the administration of a model for guaranteeing prices for the replacement or construction of additional renewable energy installations. These tasks also include preparing and providing the necessary basis of information for such decisions, or collecting indicator information for monitoring, performing independent monitoring coordinated with the *Länder*, continuous development and updating of scenarios, and compiling assessments/reports on progress with the implementation of the *Energiewende*.

6.4.2 Proposals for reforming the implementing authorities

152. Today, two federal authorities which also possess considerable technical expertise – the Federal Environment Agency (UBA) and the Federal Network Agency (BNetzA) – already perform central tasks in the implementation of the *Energiewende*. Other authorities are also involved in matters relating to the implementation of the *Energiewende*. For example, the Federal Office of Economics and Export Control (BAFA) deals with applications for special compensation for electricity-intensive companies under the EEG. It is beyond the scope of this special report to list all the relevant tasks of all the authorities and describe their interconnections. The following remarks are therefore of a more general nature. The allocation of responsibilities to higher federal authorities should generally be in line with the subject area of the managing authority, in order to strengthen existing expertise. For the Federal Network Agency this currently means performing tasks in the field of grid expansion and supply security, while for the Federal Environment Agency it includes the promotion of renewable energy and climate action. A concrete example of a new task for the UBA in connection with electricity market design would be calculating the size of the variable market premium, as suggested by the SRU (cf. Item 103).

To ensure that the competencies of the authorities can be used efficiently, three aspects are of central importance: Firstly, the transparency of work processes and opportunities for participation, secondly a clearly defined relationship between the legislature and the implementing authority, and thirdly optimised coordination between the implementing authorities themselves.

Firstly, publicly transparent work processes in an authority are of central importance to make it easier to verify that its work is in line with the overarching objectives of the *Energiewende* and to counteract the risk that the authority may be “captured” by stakeholder influence (cf. CHRISTENSEN 2011). In any expansion or restructuring of authorities it is a matter of institutionalising and optimising sufficiently formalised opportunities for participation. Favourable mention must be made of the legislative design of public participation and consultation in grid planning (CALLIESS and DROSS 2012), though it remains to be seen how suitable the processes are in practice and it may be necessary to adjust the framework conditions accordingly (LUHMANN 2013). Moreover, the authorities must be provided with adequate human and financial resources to ensure transparent implementation of the *Energiewende*.

Secondly, any extension of the tasks of the implementing authorities must be accompanied by investigation and clarification of the relationship between the legislature, responsible ministries and implementing authority. Clear allocation of responsibilities and transparent presentation of this division of responsibilities is a precondition for cooperation between authorities and efficient use of their competencies.

Thirdly, cooperation between authorities should be strengthened by means of coordination mechanisms ranging up to rules of common agreement. Bringing all organisational sub-units together in an "*Energiewende*" department within the authority in question could be useful and should be investigated. Within the authorities, departments should be set up for federal/regional coordination (e.g. coordination of reports and monitoring processes), bilateral coordination (Germany with neighbours) and EU coordination.

6.5 Interim conclusions

153. Energy policy in Germany is going through a process of transformation. An electricity market based on largely renewables-based supply of electricity requires reforms that are increasingly having impacts on different sectors and hence different portfolios at all political levels. In the course of these changes, the spectrum of actors is also changing: new institutions and organisations are being set up, old actors are adapting their strategies, new alliances and arenas are forming. This results in an increased need for coordination and consultation. On the one hand it is important to take advantage of the diverse steering initiatives and a pluralistic actor structure as an opportunity. On the other hand, specific decisions require closer coordination at a central level. This applies, for example, to fundamental decisions on the reform of the EEG or the decision on introducing a supplementary financing mechanism for the construction of new capacity.

154. In answer to these challenges, the SRU considers the following elements of governance reform to be essential:

- ensuring forms of participation for less influential groups,
- creating a Climate Change Act,
- preserving the basic divisions between ministries and creating a central coordination unit in the Federal Chancellery with the rank of a minister of state for handling the transition to a largely renewables-based energy supply system, and
- outsourcing *Energiewende* implementation tasks to the UBA and the BNetzA and strengthening the binding nature of cooperation between authorities.

155. A major success factor in the reform process is participation in political decision processes, not merely in the costs, but also in the benefits of the *Energiewende*. In addition to the creation and institutionalisation of participation formats, the development of a vision for society could support acceptance of the reforms. The creation of a Climate Change Act is a suitable framework for developing this vision. It places climate change in the focus of the political debate. The binding objectives create a point of reference for individual aspects of *Energiewende* implementation – such as the further expansion of renewable energy and the redesigning of the electricity market.

The SRU takes a critical view of the proposals for creating a separate energy (or *Energiewende*) ministry. The coordination requirements far exceed the competence of a single ministry. Decisions concerning the *Energiewende* are taken not only at federal level, but in a complex multi-level system, and implemented on a centralised basis. There is thus a need for coordination not only between the federal ministries, but also between the federal and *Bundesland* level and between Germany and the EU. The *Energiewende* is not merely the responsibility of the Economics Ministry and the Environment Ministry. Other ministries also play an important part, e.g. the ministries of transport, research or agriculture. It would be unrealistic to bundle all these tasks in a single ministry.

The handling of cross-sectional tasks and interministerial control of stakeholder influence are essential for transparent, effective and efficient reform of the design of the electricity market. For this reason the SRU advocates retaining the present divisions between the ministries. The creation of a separate energy ministry would run the risk of losing a strategically important innovation driver for the transition.

Instead, the establishment of a central coordination unit is an important governance element. There is a need for a unit where all important information on the progress of and changes in technology development and the implementation of the *Energiewende* comes together, to enable decision makers to gain an overview of trends and obstacles and to feed the relevant information back into (decentralised) processes. This coordination unit should be located in the Federal Chancellery, at the level of a minister of state.

The control function at operational level should continue to be exercised by the existing authorities. In order to make efficient use of authorities' competencies, participation opportunities and transparency of work processes should be guaranteed, the relationship between the legislature and the implementing authority should be clearly defined, and coordination between the implementing authorities should be optimised.

7 Summary

156. Electricity generation in Germany is going through a process of transformation. This was set in motion by the far-reaching political decisions in favour of climate action, renewable energy expansion and the phasing-out of nuclear power by 2022. On the basis of a broad political consensus, the Federal Government made a commitment to climate action and thereby set the central framework of targets. By 2050 greenhouse gas emissions in Germany are to be reduced by 80 to 95 per cent compared with 1990. In the same year the renewables share of electricity supplies is to reach at least 80 percent. In line with numerous research studies, the German Advisory Council on the Environment (SRU) has shown that electricity supply based entirely on renewable energy is not only possible, but also essential for achieving the climate objectives. The present special report draws attention to central issues relating to the need to redesign the electricity market to handle electricity supplies largely based on renewable energy.

Technical characteristics of a flexible, electricity-based energy system

157. Transforming the energy system into a system where electricity is largely generated from fluctuating energy sources as lead technologies has very extensive implications going far beyond the mere substitution of fuels. What is in fact required is a fundamental restructuring of the entire energy system in which the focus is on the supply of electricity from wind energy and photovoltaic systems and all other system components have to be geared to the special features of these energy sources. All controllable capacity must serve to balance the supply of renewable energy.

There is basically a large portfolio of load balancing options. In the long term, this will have to be used to the full. What contribution the individual components make, and in what order they are used, depends on a large number of technical, economic and regulatory factors which will emerge as the transformation of the energy system progresses.

First of all, an energy system that draws its supplies largely from renewable energy means a supply system which is based much more on electricity and which breaks down the boundaries between the individual sectors. Other important features of this new system will be the possibility of converting between the various forms of energy (electricity, heat, fuels) and the interaction of the consumer sectors (buildings, transport, industry).

Grid optimisation and grid expansion in Germany are of special importance for load balancing. The grid is also a precondition for being able to take advantage of the options for more flexible supply and demand. Furthermore, there is a need for greater interconnection of the European power grids and markets, in order to balance rapid variations in electricity supply over as large an area as possible and cater for regional and timing differences.

Load management and storage facilities will play a major role in an energy supply system based largely on renewables. Their capacity to ensure secure supplies even in unfavourable meteorological situations by storing for long periods and shifting large quantities of energy is an important factor.

Designing the electricity market to handle largely renewable energy supplies

158. Even under the conditions of a supply system largely based on renewable energy, the main functions of the energy-only market must be guaranteed, namely managing generation capacity deployment, sufficient flexibility to cover residual load and financing of capacity. The market structures must be adapted to the characteristics of the future lead technologies.

Capacity deployment will continue to be managed via the energy-only market. Moreover, to balance the fluctuations in electricity from renewable energy and the fact that they are more difficult to predict, adjustable capacities will also have to satisfy high flexibility requirements. What is more, the biggest challenge will be financing the capital cost of renewable energy installations and the supplementary infrastructure.

159. At present the price on the energy-only market is determined by the variable costs of the generating capacity marginal generating capacity. In future we can expect an increasing number of instances where prices on the energy-only market are set by the demand, above the marginal costs of the marginal generating capacity. In view of the demand sector integration (heat, transport, basic raw materials), the spatial integration (interconnection with load profiles in other countries) and time-shifting options (storage), demand will be considerably more price-elastic than in the past, with the result that positive prices can still be expected even at relatively high in-feed levels. Thus a situation in which there was no use at all for weather-dependent electricity and the exchange price fell to zero or curtailment became necessary would tend to be rare situation, even in a supply system based largely on renewable energy sources. In view of the large proportion of wind and solar energy with variable costs close to zero and sizeable fluctuations in supply, prices on the electricity market can nevertheless be expected to be lower and more volatile than at present in a supply system based largely on electricity from renewable sources. This will provide certain – albeit limited – financial opportunities.

To fill the finance gap on the supply side, the SRU advocates in the long term a system of capacity payments for the renewable capacity cost component that cannot be financed through the energy-only market. In a supply system based largely on renewable energy this would mean a transition from the present price-setting system to a system in which the quantity of renewable capacity is set. Considerable further research is needed to ascertain the implications for the design of this system. On the demand side, electricity customers should pay separate capacity charges to finance supply security. In view of rising fixed cost components, this will help to allocate costs better to those who cause them.

The situation with maximum residual load causes problems in peak-load balancing. Furthermore, there will be – albeit occasional – periods when there is not enough renewable energy being fed in, and these cannot be offset by short-term storage options. The market does not offer adequate financing opportunities for insurance-like solutions for these rare long periods. However, guaranteeing security of supply is a state function for which suitable solutions have yet to be found. The SRU therefore assumes that back-up capacity in the form of long-term storage facilities and highly flexible gas turbines will have to be available, and their financing will have to be ensured by the state. It could also become necessary to introduce a renewable gas reserve to ensure operation of gas-fired power stations.

Designing the market for the transition

160. In the transition to an electricity supply system based on renewable energy there are currently three major challenges: security of supply with regard to fossil back-up capacity and the final phase-out of nuclear energy; great flexibility of the market for fossil and renewable energy production; and the demand for and costs of renewable energy expansion.

Topics under discussion for ensuring security of supply include the introduction of a strategic reserve and various models of capacity markets. The various proposals for capacity markets represent substantial interventions in the electricity market, and the relevant risks should be carefully considered in advance. Existing capacity markets in other countries have had the task of providing long-term support for fossil power stations. Also, they are not relevant to the context of an extensive transition to renewable energy, as would be the case in Germany. Moreover, there are hardly any quantitative analyses of the long-term effects on the market. These complex funding instruments could nevertheless prove to be necessary in future to provide temporary support for fossil capacity. In that case, however, it would be necessary to ensure that the capacity is only maintained or expanded long enough to allow previously completed gas power stations to pay for themselves. If the political level does not make it absolutely clear that it is only prepared to introduce capacity markets on this condition, the mere discussion about capacity markets will make these necessary as a self-fulfilling prophecy, because the discussion itself will put unfunded investments at risk.

The strategic reserve, by contrast, places greater faith in the incentive potential of the energy-only market itself and therefore represents a less serious intervention. The SRU therefore considers it preferable. The strategic reserve only comes into use if there are signs of a supply shortage. It consists of power stations that are not – or no longer – on the market. It can focus on capacities at the end of their economic life, or it may also permit flexible new power stations.

Regardless of any decision between these two hotly debated alternatives, there is fundamental need for greater flexibility of generation and demand. The greater the success in making the underlying structures more flexible, the less invasive any intervention in the market has to be to ensure security of supply. After all, every capacity mechanism merely compensates for the fact that the income streams generated for the plant operators by the energy-only market are not sufficient.

In the case of the fossil power plant capacity needed during the transition, lack of flexibility is the central problem in adapting to the large and rapid fluctuations in residual load. The power plant portfolio is characterised by a surplus of relatively inflexible power stations. It is therefore necessary in the near future to maintain and build more gas-fired power stations and to remove lignite power stations from the market. This can be encouraged by a sufficiently high carbon price. Revitalisation of the European emissions trading scheme is the instrument of choice for this purpose.

For this reason, ambitious European climate and energy targets for 2030 are of vital interest to the *Energiewende*. The SRU therefore considers there is a need for a European climate target for 2030 that aims to achieve at least a 45-percent reduction in greenhouse gas emissions compared with the reference figure for 1990 by means of measures within the EU.

If revitalisation of the emissions trading scheme – for which the temporary withdrawal of emission allowances in the current trading period (backloading) is a first step – is not successful, economic or regulatory measures should be taken at national level. In that case the existing exemptions for electricity generating plants in the Energy Tax Act should be abolished and the amount of taxation should be adjusted and geared to the specific carbon content of the fossil fuels. At national level there are also numerous regulatory options for reducing CO_2 emissions, and these should be investigated further as appropriate.

In addition to increasing carbon prices, a number of other measures are also needed. Trading activities should be better adapted to the characteristics of weather-dependent renewable energy sources. Here the focus is on making market structures more flexible and giving more emphasis to short-term trading. These are tasks that can be implemented today. Greater attention should be paid to the interests of the grid operator. This includes strengthening the intraday market over the day-ahead market, defining individual flexibility products on the electricity balancing market, and enabling weather-dependent energy sources to participate on the electricity balancing market. Secondly, it includes increasing the flexibility of the demand side, which is already practised to some extent in the industrial sector, but still suffers from counter-productive incentives and regulations. Thirdly, greater European market integration and pan-European grid expansion are absolutely essential.

161. The EEG has proved to be a very effective subsidising instrument in the renewable energy sector, especially since feed-in tariffs are, empirically speaking, generally more efficient than quota models. Hence the control and over-subsidising problems associated with the EEG do not justify a change of system to a quota model.

162. The SRU takes the view that the current debate on costs in connection with the EEG is based on incorrect assumptions. On the one hand, it explains the increase in electricity prices in recent years as being due entirely to the expansion of renewable energy. On the other, the discussion about the EEG surcharge focuses on an indicator that is unsuitable for determining the actual cost of promoting renewable energy. Even if the costs situation undoubtedly indicates a need for reform, such a reform should not be a response to current developments that are held to be undesirable, but should be basically geared to requirements for the transformation of the energy system.

163. In the context of the present discussion about a reform of the EEG, the SRU advocates developing and refining the variable market premium. To motivate plant operators to adopt a more demand-oriented feed-in behaviour, they should be given greater exposure to price signals. It must however be borne in mind that in all probability the energy-only market can only finance part of the capital and maintenance costs of renewable energy. Further stable growth of renewable energy therefore requires a combined payment system consisting of a market element and a subsidised premium payment, plus a fair and economically sensible apportionment of the risks. In future there is a need for a promotion regime that provides sufficient certainty for investment by plant operators and at the same time offers incentives for greater market integration and demand orientation.

Based on the current model of the optional variable market premium, the SRU proposes the following central amendments to the present design:

– Direct marketing as a binding requirement for all new renewable energy installations,

– Change the payment limit from a time limit to a maximum subsidised quantity of electricity in the form of a capacity-specific kilowatt-hour contingent,

– Calculate the variable market premium using a site-specific and technology-specific virtual reference installation,

– Reduce political influence by setting the premium on the basis of a cost index.

The model of an improved variable market premium suggested here can help to reduce costs during the energy system transformation phase, without impeding the expansion of renewable energy by an unbalanced allocation of risks. First of all, there is a general increase in the national economic value of the electricity fed in, as part of a greater demand orientation of renewable energy. Since demand-oriented installations earn more revenue on the electricity market, and since electricity prices on the exchange will probably fluctuate less because of the more demand-oriented feed-in, the additional promotion is likely to decline in the medium term compared with the present EEG system, which will also relieve the burden on electricity customers. The costs to the national economy are also reduced by the fact that greater market integration reduces the need for flexible capacity and storage facilities. Furthermore, easier access to the electricity balancing market for directly marketed renewable energy can have positive economic and environmental effects within the entire system, for example through a reduction in conventional must-run.

Energiewende as a challenge for coordination and decision systems

164. Energy policy in Germany is going through a process of transformation. A market based on largely renewables-based supply of electricity calls for reforms that are increasingly having impacts on different sectors and hence different portfolios at all political levels. In the course of these changes, the spectrum of actors is also changing: new institutions and organisations are being set up, old actors are adapting their strategies, new alliances and arenas are forming. This results in an increased need for coordination and consultation. On the one hand it is important to take advantage of the diverse steering initiatives and a pluralistic actor structure as an opportunity. On the other hand, specific decisions require closer coordination at a central level. This applies, for example, to fundamental decisions on the reform of the EEG or the decision on introducing a supplementary financing mechanism for the construction of new capacity.

165. In answer to these challenges, the SRU considers the following elements of governance reform to be essential:

– ensuring forms of participation for less influential groups,

– creating a Climate Change Act,

– preserving the basic divisions between ministries and creating a central coordination unit in the Federal Chancellery with the rank of a minister of state for handling the transition to a largely renewables-based energy supply system, and

– outsourcing *Energiewende* implementation tasks to the UBA and the BNetzA and strengthening the binding nature of cooperation between authorities.

166. A major success factor in the reform process is participation in political decision processes, not merely in the costs, but also in the benefits of the *Energiewende*. In addition to the creation and institutionalisation of participation formats, the development of a vision for society could support acceptance of the reforms. The creation of a Climate Change Act is a suitable framework for developing this vision. It places climate change in the focus of the political debate. The binding objectives create a point of reference for individual aspects of *Energiewende* implementation – such as the further expansion of renewable energy and the redesigning of the electricity market.

The SRU takes a critical view of the proposals for creating a separate energy (or *Energiewende*) ministry. The coordination requirements far exceed the competence of a single ministry. Decisions concerning the *Energiewende* are taken not only at federal level, but in a complex multi-level system, and implemented on a centralised basis. There is thus a need for coordination not only between the federal ministries, but also between the federal and *Bundesland* level and between Germany and the EU. The *Energiewende* is not merely the responsibility of the Economics Ministry and the Environment Ministry. Other ministries also play an important part, e.g. the ministries of transport, research or agriculture. It would be unrealistic to bundle all these tasks in a single ministry.

The handling of cross-sectional tasks and interministerial control of stakeholder influence are essential for transparent, effective and efficient reform of the design of the electricity market. For this reason the SRU advocates retaining the present divisions between the ministries. The creation of a separate energy ministry would run the risk of losing a strategically important innovation driver for the transition.

Instead, the establishment of a central coordination unit is an important governance element. There is a need for a unit where all important information on the progress of and changes in technology development and the implementation of the *Energiewende* comes together, to enable decision makers to gain an overview of trends and obstacles and to feed the relevant information back into (decentralised) processes. This coordination unit should be located in the Federal Chancellery, at the level of a minister of state.

The control function at operational level should continue to be exercised by the existing authorities. In order to make efficient use of authorities' competencies, participation opportunities and transparency of work processes should be guaranteed, the relationship between the legislature and the implementing authority should be clearly defined, and coordination between the implementing authorities should be optimised.

Bibliography

Chapter 1

BMU (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit) (2013): Entwicklung der erneuerbaren Energien im Jahr 2012. Graphiken und Tabellen. Unter Verwendung aktueller Daten der Arbeitsgruppe Erneuerbare Energien-Statistik (AGEE-Stat). Stand: März 2013. Berlin: BMU. http://www.erneuerbare-energien.de/ unser-service/mediathek/downloads/detailansicht/artikel/entwicklung-der-erneuerbaren-energien-in-deutschland-im-jahr-2011/?tx_ttnews[backPid]=253&cHash=6b2899004aa67c11352b5cb2082bf917 (16.05.2013).

SRU (Sachverständigenrat für Umweltfragen) (2011): Wege zur 100 % erneuerbaren Stromversorgung. Sondergutachten. Berlin: Erich Schmidt.

Chapter 2

BDEW (Bundesverband der Energie- und Wasserwirtschaft) (2012): Strompreisanalyse Mai 2012. Haushalte und Industrie. Berlin: BDEW. http://bdew.de/internet.nsf/id/0E5D39E2E798737FC1257A09002D8C9C/$file/120525%20BDEW-Strompreisanalyse%202012%20Chartsatz%20gesamt.pdf (17.04.2013).

Bode, S. (2008): Anreize für Investitionen in Anlagen zur Stromerzeugung aus erneuerbaren Energien im liberalisierten Strommarkt. Zeitschrift für Umweltpolitik & Umweltrecht 31 (4), S. 497–515.

Bundeskartellamt (2011): Sektoruntersuchung Stromerzeugung Stromgroßhandel. Bericht gemäß § 32e Abs. 3 GWB. Bonn: Bundeskartellamt.

Bundesnetzagentur, Bundeskartellamt (2012): Monitoringbericht 2012. Monitoringbericht gemäß § 63 Abs. 3 i.V.m. § 35 EnWG und § 48 Abs. 3 i.V.m. § 53 Abs. 3 GWB. Bonn: Bundesnetzagentur, Bundeskartellamt. http://www.bundesnetzagentur.de/SharedDocs/Downloads/DE/Allgemeines/Bundesnetzagentur/Publikationen/Berichte/2012/MonitoringBericht2012.pdf?__blob=publicationFile&v=2 (13.06.2013).

Ehlers, N. (2011): Strommarktdesign angesichts des Ausbaus fluktuierender Stromerzeugung. Berlin: dissertation.de. Beiträge zur Energiesystemforschung 7.

Konstantin, P. (2009): Praxisbuch Energiewirtschaft. Energieumwandlung, -transport und -beschaffung im liberalisierten Markt. 2., bearb. und aktualisierte Aufl. Berlin, Heidelberg, New York: Springer.

Leprich, U., Hauser, E., Grashof, K., Grote, L., Luxenburger, M., Sabatier, M., Zipp, A. (2012): Kompassstudie Marktdesign. Leitideen für ein Design eines Stromsystems mit hohem Anteil fluktuierender Erneuerbarer Energien. Bochum: Ponte Press.

Matthes, F. C., Schlemmermeier, B., Diermann, C., Hermann, H., Hammerstein, C. von (2012): Fokussierte Kapazitätsmärkte. Ein neues Marktdesign für den Übergang zu einem neuen Energiesystem. Berlin: Öko-Institut, LBD-Beratungsgesellschaft, Raue LLP.

Ockenfels, A., Grimm, V., Zoettl, G. (2008): Strommarktdesign. Preisbildungsmechanismus im Auktionsverfahren für Stromstundenkontrakte an der EEX. Gutachten im Auftrag der European Energy Exchange AG zur Vorlage an die Sächsische Börsenaufsicht. Köln: Universität.

Roon, S. von, Huck, M. (2010): Merit Order des Kraftwerksparks. München: Forschungsstelle für Energiewirtschaft. http://www.ffe. de/download/wissen/20100607_Merit_Order.pdf (17.04.2013).

SRU (Sachverständigenrat für Umweltfragen) (2011): Wege zur 100 % erneuerbaren Stromversorgung. Sondergutachten. Berlin: Erich Schmidt.

Chapter 3

Adamek, F., Aundrup, T., Glaunsinger, W., Kleimaier, M., Landinger, H., Leuthold, M., Lunz, B., Mose, A., Pape, C., Pluntke, H., Rotering, N., Sauer, U., Sterner, M., Wellßow, W. (2012): Energiespeicher für die Energiewende. Speicherungsbedarf und Auswirkungen auf das Übertragungsnetz für Szenarien bis 2050. Frankfurt am Main: Verband der Elektrotechnik Elektronik Informationstechnik, Energietechnische Gesellschaft.

Adelt, M., Altfeld, K., Graf, F., Henel, M., Hoppe, M., Höcher, T., Kaesler, H., Linke, G., Löffler, T., Mlaker, H., Marewski, U., Müller-Syring, G., Nitschke-Kowsky, P., Köppel, W., Oehsen, A. von, Reimann, T., Reinhold, M., Schley, P., Schllmeyer, H.-J., Steiner, K., Sterner, M., Trost, T., Zenner, M., Zschocke, A. (2013): Entwicklung von modularen Konzepten zur Erzeugung, Speicherung und Einspeisung von Wasserstoff und Methan ins Erdgasnetz. Studie. Abschlussbericht. Bonn: Deutscher Verein des Gas- und Wasserfaches.

Agora Energiewende (2013a): Entwicklung der Windenergie in Deutschland. Eine Beschreibung von aktuellen und zukünftigen Trends und Charakteristika der Einspeisung von Windenergieanlagen. Berlin: Agora Energiewende. Kurzstudie.

Agora Energiewende (2013b): Impulse. 12 Thesen zur Energiewende. Ein Diskussionsbeitrag zu den wichtigsten Herausforderungen im Strommarkt (Langfassung). Überarb. Nachdr. Berlin: Agora Energiewende.

Apel, R., Aundrup, T., Buchholz, B. M., Domels, H. P., Funke, S., Gesing, T., Glaunsinger, W., Gronstedt, P., Heins, F., Hösle, A., Knack, V., Küter, T., Stötzer, M., Struwe, C., Styczynski, Z. A., Scheven, A. von, Seidl, H. (2012): Demand Side Integration. Lastverschiebungspotenziale in Deutschland. Ein notwendiger Baustein der Energiewende. Frankfurt am Main: Verband der Elektrotechnik – Energietechnische Gesellschaft.

Arpe, H.-J. (2007): Industrielle organische Chemie. Bedeutende Vor- und Zwischenprodukte. 6., vollst. überarb. Aufl. Weinheim: Wiley-VCH.

Barzantny, K., Achner, S., Vomberg, S., Groscurth, H.-M., Böhling, A., Breuer, T. (2009): Klimaschutz: Plan B 2050. Energiekonzept für Deutschland. Hamburg: Greenpeace

BMWi (Bundesministerium für Wirtschaft und Technologie), BMU (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit) (2012): Erster Monitoring-Bericht "Energie der Zukunft". Berlin: BMWi, BMU.

Brooks, K. P., Hu, J., Zhu, H., Kee, R. J. (2007): Methanation of carbon dioxide by hydrogen reduction using the Sabatier process in microchannel reactors. Chemical Engineering Science 62 (4), S. 1161–1170.

Bruns, E., Futterlieb, M., Ohlhorst, D., Wenzel, B. (2012): Netze als Rückgrat der Energiewende. Hemmnisse für die Integration erneuerbarer Energien in Strom-, Gas- und Wärmenetze. Berlin: Universitätsverlag der TU Berlin. http://opus.kobv.de/tuberlin/volltexte/2012/3730/ (09.01.2012).

Consentec, r2b energy consulting, FGH (Forschungsgemeinschaft für elektrische Anlagen und Stromwirtschaft) (2011): Optimierung und Umstrukturierung der EEG-Förderung zur verbesserten Netz- und Marktintegration Erneuerbarer Energien (Projekt I C 4 – 51/10) für Bundesministerium für Wirtschaft und Technologie (BMWi). Aachen, Köln, Mannheim: Consentec, r2b energy consulting, FGH.

Czisch, G. (2009): Möglichkeiten des großräumigen (transeuropäischen) Ausgleichs von Schwankungen großer Teile intermittierender Elektrizitätseinspeisung aus regenerativen Energiequellen in Deutschland im Rahmen einer 100 % regenerativen Stromerzeugung mit dem Zeithorizont 2050. Berlin: Sachverständigenrat für Umweltfragen. Materialien zur Umweltforschung 40. http://www.umweltrat.de/SharedDocs/Downloads/DE/03_Materialien/2010_09_MAT40_Czisch.pdf?__blob=publicationFile (01.10.2010).

Deutscher Bundestag (2012): Bericht des Ausschusses für Bildung, Forschung und Technikfolgenabschätzung (18. Ausschuss) gemäß § 56a der Geschäftsordnung. Technikfolgenabschätzung (TA). Regenerative Energieträger zur Sicherung der Grundlast in der Stromversorgung. Berlin: Deutscher Bundestag. Bundestagsdrucksache 17/10579.

ECF (European Climate Foundation), E3G, The Energy Research Centre of the Netherlands (2010): Roadmap 2050: A practical guide to a prosperous, low-carbon Europe. Vol. 2: Policy recommendations. Den Haag: ECF. http://www.roadmap2050.eu/attachments/files/Volume2_Policy.pdf (20.04.2010).

efzn (Energie-Forschungszentrum Niedersachsen) (2013): Studie: Eignung von Speichertechnologien zum Erhalt der Systemsicherheit. Abschlussbericht. Goslar: efzn.

Egner, S., Krätschmer, W., Faulstich, M. (2012): Perspektiven der Energiewende. In: Lorber, K. E., Pomberger, R., Adam, J., Aldrian, A., Arnberger, A., Kreindl, G., Menapace, H., Sarc, R., Schwarz, T. (Hrsg.): DepoTech 2012. Abfallwirtschaft, Abfalltechnik, Deponietechnik und Altlasten. Tagungsband zur 11. DepoTech Konferenz, Montanuniversität Leoben/Österreich, 6.–9. November 2012. Leoben: Institut für Nachhaltige Abfallwirtschaft und Entsorgungstechnik, S. 49–56.

Ess, F., Haefke, L., Hobohm, J., Peter, F., Wünsch, M. (2012): Bedeutung der internationalen Wasserkraft-Speicherung für die Energiewende. Studie. Berlin: Weltenergierat – Deutschland.

EURELECTRIC (2011): Hydro in Europe: Powering Renewables. Full Report. Brussels: EURELECTRIC.

EY (Ernst & Young) (2013): Kosten-Nutzen-Analyse für einen flächendeckenden Einsatz intelligenter Zähler. Düsseldorf, München: EY.

Faulstich, M. (2011): Energiespeicher als notwendige Voraussetzung für die Integration der Erneuerbaren Energien ins Stromnetz. Vortrag, Kongress in der Meistersingerhalle, 30.06.2011, Nürnberg.

Frey, H. (2007): Entwicklungsstand stationärer Energiespeicher. 20 % Erneuerbare Energien – Moderne Speichertechnologien als Voraussetzung? Vortrag, Forum für Zukunftstechnologien, 05.07.2007, Berlin.

Fuchs, G., Lunz, B., Leuthold, M., Sauer, U. (2012): Technologischer Überblick zur Speicherung von Elektrizität. Überblick zum Potenzial und zu Perspektiven des Einsatzes elektrischer Speichertechnologien. Studie. Aachen: Institut für Stromrichtertechnik und Elektrische Antriebe, RWTH Aachen.

Gerbert, P., Herhold, P., Heuskel, D., Klose, F. (2013): Trendstudie 2030+. Kompetenzinitiative Energie des BDI. Berlin: The Boston Consulting Group.

Grünwald, R., Ragwitz, M., Sensfuß, F., Winkler, J. (2012): Regenerative Energieträger zur Sicherung der Grundlast in der Stromversorgung. Endbericht zum Monitoring. Berlin: Büro für Technikfolgen-Abschätzung beim Deutschen Bundestag. Arbeitsbericht 147.

Gullberg, A. T. (2013): The political feasibility of Norway as the 'green battery' of Europe. Energy Policy 57, S. 615–623.

Hartmann, N., Eltrop, L., Bauer, N., Salzer, J., Schwarz, S., Schmidt, M. (2012): Stromspeicherpotenziale für Deutschland. Stuttgart: Universität Stuttgart.

Henning, H.-M., Palzer, A. (2012): 100 % erneuerbare Energien für Strom und Wärme in Deutschland. Freiburg: Fraunhofer-Institut für Solare Energiesysteme ISE.

Höhlein, B., Grube, T., Biedermann, P., Bielawa, H., Erdmann, G., Schlecht, L., Isenberg, G., Edinger, R. (2003): Methanol als Energieträger. Jülich: Forschungszentrum Jülich. Schriften des Forschungszentrums Jülich – Reihe Energietechnik 28.

IPCC (Intergovernmental Panel on Climate Change) (2011): Renewable Energy Sources and Climate Change Mitigation. Special Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press.

Jering, A., Klatt, A., Seven, J., Ehlers, K., Günther, J., Ostermeier, A., Mönch, L. (2012): Globale Landflächen und Biomasse nachhaltig und ressourcenschonend nutzen. UBA-Positionspapier. Dessau-Roßlau: Umweltbundesamt.

Kausch, P., Bertau, M., Gutzmer, J., Matschullat, J. (Hrsg.) (2011): Energie und Rohstoffe. Gestaltung unserer nachhaltigen Zukunft. Heidelberg: Spektrum Akademischer Verlag.

Klaus, T., Vollmer, C., Werner, K., Lehmann, H., Müschen, K. (2010): Energieziel 2050: 100 % Strom aus erneuerbaren Quellen. Dessau-Roßlau: Umweltbundesamt.

Krzikalla, N., Achner, S., Brühl, S. (2013): Möglichkeiten zum Ausgleich fluktuierender Einspeisungen aus Erneuerbaren Energien. Aachen: Büro für Energiewirtschaft und technische Planung.

Leprich, U., Hauser, E., Grashof, K., Grote, L., Luxenburger, M., Sabatier, M., Zipp, A. (2012): Kompassstudie Marktdesign. Leitideen für ein Design eines Stromsystems mit hohem Anteil fluktuierender Erneuerbarer Energien. Bochum: Ponte Press.

Mahnke, E., Mühlenhoff, J. (2012): Strom speichern. Berlin: Agentur für Erneuerbare Energien. Renews Spezial 57.

Matschoss, P. (2012): Fighting climate change. A structural shift towards renewable energies requires concerted policy action. Helsinki: The Finnish Institute of International Affairs. FIIA Briefing Paper 100.

Niemann, A., Perau, E., Schreiber, U., Koch, M. K. (2012): Pumpspeicherkraftwerke in den heute noch aktiven Steinkohlebergwerken – Herausforderung für die Wasserwirtschaft im Ruhrgebiet? In: Pinnekamp, J. (Hrsg.): 45. Essener Tagung für Wasser- und Abfallwirtschaft: "Wasserwirtschaft und Energiewende", 14. bis 16. März 2012 in der Messe Essen Ost. Aachen: Gesellschaft zur Förderung der Siedlungswasserwirtschaft an der RWTH Aachen. Gewässerschutz, Wasser, Abwasser, S. 63/1–63/13.

Nitsch, J., Pregger, T., Naegler, T., Heide, D., Tena, D. L. de, Trieb, F., Scholz, Y., Nienhaus, K., Gerhardt, N., Sterner, M., Trost, T., Oehsen, A. von, Schwinn, R., Pape, C., Hahn, H., Wickert, M., Wenzel, B. (2012): Langfristszenarien und Strategien für den Ausbau der erneuerbaren Energien in Deutschland bei Berücksichtigung der Entwicklung in Europa und global. Schlussbericht. Stuttgart, Kassel, Teltow: Deutsches Zentrum für Luft- und Raumfahrt, Institut für Technische Thermodynamik, Abt. Systemanalyse und Technikbewertung, Fraunhofer Institut für Windenergie und Energiesystemtechnik, Ingenieurbüro für neue Energien.

Ohlhorst, D., Schreurs, M., Gullberg, A. T. (2012): Norwegen – “Batterie” der deutschen Energiewende? Unterschiedliche Länderinteressen in der Energiepolitik. GAIA 21 (4), S. 319–320.

Öko-Institut, Prognos AG (2009): Modell Deutschland – Klimaschutz bis 2050: Vom Ziel her denken. Endbericht. Basel, Freiburg: Prognos, Öko-Institut.

Plattform Erneuerbare Energien (2012): Bericht der AG 3 Interaktion an den Steuerungskreis der Plattform Erneuerbare Energien, die Bundeskanzlerin und die Ministerpräsidenteninnen und Ministerpräsidenten der Länder vom 15.10.2012. Berlin: Plattform Erneuerbare Energien. http://www.bmu.de/fileadmin/Daten_BMU/Bilder_Unterseiten/Themen/Klima_Energie/Energiewende/bericht_plattform_ee_bf.pdf (16.05.2013).

Schill, W.-P. (2013): Integration von Wind- und Solarenergie: Flexibles Stromsystem verringert Überschüsse. DIW-Wochenbericht 80 (34), S. 3–14.

Schulz, D. (2009): Speicherpotenziale von Pumpspeicherwerken in Tagebaurestlöchern ehemaliger Braunkohlereviere. Vortrag, Forum Netzintegration Deutsche Umwelthilfe (DUH), 30.09.2009, Berlin.

SRU (Sachverständigenrat für Umweltfragen) (2012): Umweltgutachten 2012. Verantwortung in einer begrenzten Welt. Berlin: Erich Schmidt.

SRU (2011): Wege zur 100 % erneuerbaren Stromversorgung. Sondergutachten. Berlin: Erich Schmidt.

SRU (2008): Umweltgutachten 2008. Umweltschutz im Zeichen des Klimawandels. Berlin: Erich Schmidt.

sunfire (2013): Power-to-Liquids. Kraftstoffe aus Sonnenenergie, CO2 und Wasser. Dresden: sunfire. http://www.sunfire.de/produkte/fuel/power-to-liquids (01.11.2013).

Tichler, R. (2011): Volkswirtschaftliche Relevanz von Power-to-Gas für das zukünftige Energiesystem. Linz: Energieinstitut an der Johannes Kepler Universität Linz. http://www.energieinstitut-linz.at/dokumente/upload/vortrag_Tichler-Power-to-Gas_31d13.pdf (16.05.2013).

UBA (Umweltbundesamt) (2012): Struktur der Energiebereitstellung aus erneuerbaren Energieträgern. Dessau-Roßlau: UBA. http://www.umweltbundesamt-daten-zur-umwelt.de/umweltdaten/public/theme.do?nodeIdent=5981 (15.03.2013).

UBA (Hrsg.) (2013): Treibhausgasneutrales Deutschland im Jahr 2050. Hintergrund. Dessau-Roßlau: UBA.

Winkler, J. (2011): Assessment of electricity market designs for a completely renewable electricity system: a case study for Germany. London, Imperial College, Faculty of Natural Sciences, Centre for Environmental Policy, Master thesis.

Chapter 4

Agora Energiewende (2012): Erneuerbare Energien und Stromnachfrage im Jahr 2022. Analyse. Berlin: Agora Energiewende. http://www.agora-energiewende.de/fileadmin/downloads/publikationen/Agora_Studie_Erneuerbare_Energien_und_Stromnachfrage_im_Jahr_2022.pdf (29.07.2013).

Ecke, J., Herrmann, N., Hilmes, U., Kremp, R., Macharey, U., Nolde, A., Wolter, H., Zander, W. (2013): Ein zukunftsfähiges Energiemarktdesign für Deutschland. Langfassung. Berlin, Aachen: enervis energy advisors, BET Büro für Energiewirtschaft und technische Planung.

Erdölbevorratungsverband (2008): Mineralölpflichtbevorratung in der Bundesrepublik Deutschland. Hamburg: Erdölbevorratungsverband. http://www.ebv-oil.de/cms/pdf/pflicht2008.pdf (09.09.2013).

Höfling, H. (2013): Investitionsanreize für neue Erzeugungskapazität unter wachsendem Einfluss erneuerbarer Stromerzeugung. Eine modellbasierte Szenarioanalyse des deutschen Strommarktes. Diskussionspapier. Stuttgart: Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg.

Kopp, O., Eßer-Frey, A., Engelhorn, T. (2012): Können sich erneuerbare Energien langfristig auf wettbewerblich organisierten Strommärkten finanzieren? Zeitschrift für Energiewirtschaft 36 (4), S. 243–255.

Leprich, U., Hauser, E., Grashof, K., Grote, L., Luxenburger, M., Sabatier, M., Zipp, A. (2012): Kompassstudie Marktdesign. Leitideen für ein Design eines Stromsystems mit hohem Anteil fluktuierender Erneuerbarer Energien. Bochum: Ponte Press.

Nicolosi, M. (2012): Notwendigkeit von Kapazitätsmechanismen. Endbericht. Berlin: Ecofys.

SRU (Sachverständigenrat für Umweltfragen) (2011): Wege zur 100 % erneuerbaren Stromversorgung. Sondergutachten. Berlin: Erich Schmidt.

SVR (Sachverständigenrat zur Begutachtung der Gesamtwirtschaftlichen Entwicklung) (2012): Stabile Architektur für Europa – Handlungsbedarf im Inland. Jahresgutachten 2012/2013. Wiesbaden: SVR.

Winkler, J. (2011): Assessment of electricity market designs for a completely renewable electricity system: a case study for Germany. London, Imperial College, Faculty of Natural Sciences, Centre for Environmental Policy, Master thesis.

Winkler, J., Altmann, M. (2012): Market Designs for a Completely Renewable Power Sector. Zeitschrift für Energiewirtschaft 77 (2), S. 77–92.

Chapter 5

acatech (Deutsche Akademie der Technikwissenschaften) (Hrsg.) (2012): Die Energiewende finanzierbar gestalten. Effiziente Ordnungspolitik für das Energiesystem der Zukunft. acatech Position München, Berlin, Brüssel: acatech.

Achner, S., Michels, A., Nailis, D., Ritzau, M., Schuffelen, L. (2011): Kapazitätsmarkt. Rahmenbedingungen, Notwendigkeit und Eckpunkte einer Ausgestaltung. Aachen, Leipzig, Hamm: Büro für Energiewirtschaft und technische Planung.

AG Energiebilanzen (2013): Bruttostromerzeugung in Deutschland nach Energieträgern von 1990 bis 2012 nach Energieträgern. Stand: 14. Februar 2013. Berlin: AG Energiebilanzen. http://www.ag-energiebilanzen.de/tools/pdf-icon.gif (16.05.2013).

Agora Energiewende (2013a): Entwicklung der Windenergie in Deutschland. Eine Beschreibung von aktuellen und zukünftigen Trends und Charakteristika der Einspeisung von Windenergieanlagen. Berlin: Agora Energiewende. Kurzstudie.

Agora Energiewende (2013b): Impulse. 12 Thesen zur Energiewende. Ein Diskussionsbeitrag zu den wichtigsten Herausforderungen im Strommarkt (Langfassung). Überarb. Nachdr. Berlin: Agora Energiewende.

Agora Energiewende (2013c): Kapazitätsmarkt oder strategische Reserve: Was ist der nächste Schritt? Eine Übersicht über die in der Diskussion befindlichen Modelle zur Gewährleistung der Versorgungssicherheit in Deutschland. Berlin: Agora Energiewende.

Agora Energiewende (2013d): Kostenoptimaler Ausbau der Erneuerbaren Energien in Deutschland. Ein Vergleich möglicher Strategien für den Ausbau von Wind- und Solarenergie in Deutschland bis 2033. Studie. Berlin: Agora Energiewende.

Agora Energiewende (2012): Erneuerbare Energien und Stromnachfrage im Jahr 2022. Analyse. Berlin: Agora Energiewende. http://www.agora-energiewende.de/fileadmin/downloads/publikationen/Agora_Studie_Erneuerbare_Energien_und_Stromnachfrage_im_Jahr_2022.pdf (29.07.2013).

Apel, R., Aundrup, T., Buchholz, B. M., Domels, H. P., Funke, S., Gesing, T., Glaunsinger, W., Gronstedt, P., Heins, F., Hösle, A., Knack, V., Küter, T., Stötzer, M., Struwe, C., Styczynski, Z. A., Scheven, A. von, Seidl, H. (2012): Demand Side Integration. Lastverschiebungspotenziale in Deutschland. Ein notwendiger Baustein der Energiewende. Frankfurt am Main: Verband der Elektrotechnik - Energietechnische Gesellschaft.

Baritaud, M. (2012): Securing Power during the Transition. Generation Investment and Operation Issues in Electricity Markets with Low Carbon Policies. 2nd ed. Paris: International Energy Agency Insights Series. http://www.iea.org/publications/insights/SecuringPowerTransition_Secondeedition_WEB.pdf (17.04.2013).

BDEW (Bundesverband der Energie- und Wasserwirtschaft) (2013a): Erneuerbare Energien und das EEG: Zahlen, Fakten, Grafiken. Anlagen, installierte Leistung, Stromerzeugung, EEG-Auszahlungen, Marktintegration der Erneuerbaren Energien und regionale Verteilung der EEG-induzierten Zahlungsströme. Berlin: BDEW. http://www.bdew.de/internet.nsf/id/17DF3FA36BF264EBC1257B0A003EE8B8/$file/Energieinfo_EE-und-das-EEG-Januar-2013.pdf (23.05.2013).

BDEW (2013b): Kraftwerksplanungen und aktuelle ökonomische Rahmenbedingungen für Kraftwerke in Deutschland. Kommentierte Auswertung der BDEW-Kraftwerksliste 2013. Energie-Info. Berlin: BDEW.

BDEW (2013c): Strompreisanalyse Mai 2013. Haushalte und Industrie. Berlin: BDEW. http://www.bdew.de/internet.nsf/id/123176ABDD9ECE5DC1257AA20040E368/$file/13%2005%2027%20BDEW_Strompreisanalyse_Mai%202013.pdf (14.10.2013).

Bergek, A. (2010): The pitfalls of green innovation policy: the case of green certificates. Discussion Paper for the 6CP Workshop: Exploring the green paradigm. Linköpnig: Linköping University, Department of Management and Engineering. http://liu.diva-portal.org/smash/get/diva2:400397/FULLTEXT01.pdf (17.10.2013).

Bertsch, J., Bettzüge, M., Growitsch, C., Hecking, H., Lorenczik, S., Liebenau, V., Rehtanz, C., Schwippe, J., Seack, A. (2013): Trendstudie Strom 2022. Belastungstest für die Energiewende. Endbericht. Köln: Energiewirtschaftliches Institut an der Universität zu Köln. www.energiewende-richtig.de/download/file/fid/294 (21.03.2013).

BMU (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit) (2013a): Entwicklung der erneuerbaren Energien im Jahr 2012. Graphiken und Tabellen. Unter Verwendung aktueller Daten der Arbeitsgruppe Erneuerbare Energien-Statistik (AGEE-Stat). Stand: März 2013. Berlin: BMU. http://www.erneuerbare-energien.de/unser-service/mediathek/downloads/detailansicht/artikel/entwicklung-der-erneuerbaren-energien-in-deutschland-im-jahr-2011/?tx_ttnews[backPid]=253&cHash=6b2899004aa67c11352b5cb2082bf917 (16.05.2013).

BMU (2013b): Märkte stärken, Versorgung sichern. Konzept für die Umsetzung einer Strategischen Reserve in Deutschland. Ergebnisbericht des Fachdialogs "Strategische Reserve". Berlin: BMU.

BMU (2012): Erneuerbare Energien in Zahlen. Nationale und internationale Entwicklung. Stand: Juli 2012. Berlin: BMU.

BMWi (Bundesministerium für Wirtschaft und Technologie), BMU (2012): Erster Monitoring-Bericht "Energie der Zukunft". Berlin: BMWi, BMU.

Borggrefe, F., Neuhoff, K. (2011): Balancing and Intraday Market Design: Options for Wind Integration. Berlin: Deutsches Institut für Wirtschaft. Discussion Papers 1162.

Boßmann, T., Eichhammer, W., Elsland, R. (2012a): Concrete Paths of the European Union to the 2°C Scenario: Achieving the Climate Protection Targets of the EU by 2050 through Structural Change, Energy Savings and Energy Efficiency Technologies. Accompanying scientific report – Contribution of energy efficiency measures to climate protection within the European Union until 2050 (Draft). Karlsruhe: Fraunhofer Institute for Systems and Innovation Research ISI.

Boßmann, T., Eichhammer, W., Elsland, R. (Hrsg.) (2012b): Contribution of Energy Efficiency Measures to Climate Protection within the European Union until 2050. Policy Report. Berlin, Karlsruhe: Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Fraunhofer Institute for Systems and Innovation Research ISI.

Brunekreeft, G., Damsgaard, N., Vries, L. de, Fritz, P., Meyer, R. (2011): A Raw Model for a North European Capacity Market. A Discussion Paper. Stockholm: Elforsk. Elforsk rapport 11:30.

Bruns, E., Futterlieb, M., Ohlhorst, D., Wenzel, B. (2012): Netze als Rückgrat der Energiewende. Hemmnisse für die Integration erneuerbarer Energien in Strom-, Gas- und Wärmenetze. Berlin: Universitätsverlag der TU Berlin. http://opus.kobv.de/tuberlin/volltexte/2012/3730/ (09.01.2012).

Bundesnetzagentur (2013): Kraftwerksliste Bundesnetzagentur. Stand: 22.07.2013. Bonn: Bundesnetzagentur. http://www.bundesnetzagentur.de/SharedDocs/Downloads/DE/Sachgebiete/Energie/Unternehmen_Institutionen/Versorgungssicherheit/Erzeugungskapazitaeten/Kraftwerksliste/Kraftwerksliste_2013.xlsx;jsessionid=6F2D1BDB8D5C64C9A19C86C73FC6695B?__blob=publicationFile&v=4 (29.07.2013).

Bundesnetzagentur, Bundeskartellamt (2012): Monitoringbericht 2012. Monitoringbericht gemäß § 63 Abs. 3 i.V.m. § 35 EnWG und § 48 Abs. 3 i.V.m. § 53 Abs. 3 GWB. Bonn: Bundesnetzagentur, Bundeskartellamt. http://www.bundesnetzagentur.de/SharedDocs/Downloads/DE/Allgemeines/Bundesnetzagentur/Publikationen/Berichte/2012/MonitoringBericht2012.pdf?__blob=publicationFile&v=2 (13.06.2013).

Calliess, C., Hey, C. (2013): Multilevel Energy Policy in the EU: Paving the Way for Renewables? Journal for European Environmental and Planning Law 10 (2), S. 87–131.

Consentec (2012a): Praktikabel umsetzbare Ausgestaltung einer Strategischen Reserve. Aachen: Consentec GmbH.

Consentec (2012b): Versorgungssicherheit effizient gestalten – Erforderlichkeit, mögliche Ausgestaltung und Bewertung von Kapazitätsmechanismen in Deutschland. Abschlussbericht. Aachen: Consentec GmbH.

Consentec, r2b energy consulting, FGH (Forschungsgemeinschaft für elektrische Anlagen und Stromwirtschaft) (2011): Optimierung und Umstrukturierung der EEG-Förderung zur verbesserten Netz- und Marktintegration Erneuerbarer Energien (Projekt I C 4 - 51/10) für Bundesministerium für Wirtschaft und Technologie (BMWi). Aachen, Köln, Mannheim: Consentec, r2b energy consulting, FGH.

Cramton, P., Ockenfels, A. (2012): Economics and Design of Capacity Markets for the Power Sector. Zeitschrift für Energiewirtschaft 36 (2), S. 113–134.

Cramton, P., Ockenfels, A. (2011): Ökonomik und Design von Kapazitätsmärkten im Stromsektor. Energiewirtschaftliche Tagesfragen 61 (9), S. 14–15.

Czisch, G. (2009): Möglichkeiten des großräumigen (transeuropäischen) Ausgleichs von Schwankungen großer Teile intermittierender Elektrizitätseinspeisung aus regenerativen Energiequellen in Deutschland im Rahmen einer 100% regenerativen Stromerzeugung mit dem Zeithorizont 2050. Berlin: Sachverständigenrat für Umweltfragen. Materialien zur Umweltforschung 40. http://www.umweltrat.de/SharedDocs/Downloads/DE/03_Materialien/2010_09_MAT40_Czisch.pdf?__blob=publicationFile (01.10.2010).

DECC (Department of Energy and Climate Change) (2010): National Renewable Energy Action Plan for the United Kingdom. Article 4 of the Renewable Energy Directive 2009/28/EC. London: DECC.

Deutscher Bundestag (2012): Bericht des Ausschusses für Bildung, Forschung und Technikfolgenabschätzung (18. Ausschuss) gemäß § 56a der Geschäftsordnung. Technikfolgenabschätzung (TA). Regenerative Energieträger zur Sicherung der Grundlast in der Stromversorgung. Berlin: Deutscher Bundestag. Bundestagsdrucksache 17/10579.

Diekmann, J., Kemfert, C., Neuhoff, K., Schill, W.-P., Traber, T. (2012): Erneuerbare Energien: Quotenmodell keine Alternative zum EEG. DIW Wochenbericht 79 (45), S. 15–20.

ECF (European Climate Foundation), McKinsey & Company, KEMA, The Energy Futures Lab at Imperial College London, Oxford Economics (2010): Roadmap 2050: A practical guide to a prosperous, low-carbon Europe. Vol. 1: Technical analysis. Den Haag: ECF. http://www.roadmap2050.eu/attachments/files/Volume1_fullreport_PressPack.pdf (20.04.2010).

Ecke, J., Herrmann, N., Hilmes, U., Kremp, R., Macharey, U., Nolde, A., Wolter, H., Zander, W. (2013): Ein zukunftsfähiges Energiemarktdesign für Deutschland. Langfassung. Berlin, Aachen: enervis energy advisors, BET Büro für Energiewirtschaft und technische Planung.

Egerer, J., Kunz, F., Hirschhausen, C. von (2012): Development Scenarios for the North and Baltic Sea Grid. A Welfare Economic Analysis. Berlin: Deutsches Institut für Wirtschaftsforschung. DIW Discussion Papers 1261.

Elberg, C., Growitsch, C., Höffler, F., Richter, J. (2012): Untersuchungen zu einem Zukunftsfähigen Strommarktdesign. Endbericht. Köln: Energiewirtschaftliches Institut an der Universität zu Köln.

EREC (European Renewable Energy Council), Greenpeace International (Hrsg.) (2012): Energy [R]evolution. A Sustainable EU 27 Energy Outlook. Brussels, Amsterdam: EREC, Greenpeace International.

Estermann, A., John, O., Wand, R., Weißbach, T. (2012): Der Network Code zur Integration der europäischen Spotmärkte. Energiewirtschaftliche Tagesfragen 62 (12), S. 58–62.

EURELECTRIC (2011): Hydro in Europe: Powering Renewables. Full Report. Brussels: EURELECTRIC.

EURELECTRIC (2010): Integrating intermittent renewables sources into the EU electricity system by 2020: challenges and solutions. Brussels: EURELECTRIC. www.eurelectric.org/PublicDoc.asp?ID=63539 (21.03.2013).

Europäische Kommission (2013): Grünbuch. Ein Rahmen für die Klima- und Energiepolitik bis 2030. COM(2013) 169 final. Brüssel: Europäische Kommission.

Europäische Kommission (2012a): Bericht der Kommission an das Europäische Parlament und den Rat. Die Lage des CO_2-Marktes in der EU im Jahr 2012. COM(2012) 652 final. Brüssel: Europäische Kommission.

Europäische Kommission (2012b): Consultation Paper on generation adequacy, capacity mechanisms and the internal market in electricity. Brüssel: Europäische Kommission. http://ec.europa.eu/energy/gas_electricity/consultations/doc/20130207_generation_adequacy_consultation_document.pdf (21.03.2013).

Europäische Kommission (2011): Mitteilung der Kommission an das Europäische Parlament, den Rat, den Europäischen Wirtschafts- und Sozialausschuss und den Ausschuss der Regionen. Fahrplan für den Übergang zu einer wettbewerbsfähigen CO_2-armen Wirtschaft bis 2050. KOM(2011) 112 endg. Brüssel: Europäische Kommission.

EWEA (European Wind Energy Association) (2012): Creating the Internal Energy Market. A Report. Brussels: EWEA.

Fischer, S., Geden, O. (2013): Strategiediskussion in der EU-Energie- und Klimapolitik. Neue Ziele für die Zeit nach 2020. Bonn: Friedrich-Ebert-Stiftung. Internationale Politikanalyse. http://library.fes.de/pdf-files/id/ipa/09599.pdf (11.02.2013).

Fischerauer, S. (2012): Zwischen Regulierung und Selbstregulierung – Zur Ausarbeitung europäischer Netzkodizes im Energiesektor. Zeitschrift für neues Energierecht 16 (5), S. 453–460.

Fouquet, D., Johansson, T. B. (2008): European renewable energy policy at crossroads. Focus on electricity support mechanisms. Energy Policy 36 (11), S. 4079–4092.

Fraunhofer ISI (Fraunhofer Institut Systemtechnik und Innovationsforschung), ENERDATA, Technical University Vienna, Wuppertal Institute for Climate Environment and Energy (2009): Study on the Energy Savings Potentials in EU Member States, Candidate Countries and EEA Countries. Final Report. Karlsruhe, Grenoble, Rome, Vienna, Wuppertal: Fraunhofer ISI, ENERDATA, ISIS, Technical University, Wuppertal Institute for Climate, Environment and Energy. TREN/D1/239-2006/S07.66640.

Fricke, H.-C. (2010): Die Privilegierung der stromintensiv arbeitenden Industrie im Rahmen des EEG-Belastungsausgleichs – eine verfassungs- und europarechtliche Bewertung. Recht der Energiewirtschaft 2010 (3), S. 83–92.

Gawel, E., Korte, K., Lehmann, P., Strunz, S. (2012a): Die deutsche Energiewende – ein Skandalon? Fehlalarm! Es drohen weder Planwirtschaft noch Kosten-Tsunami. GAIA 22 (4), S. 278–283.

Gawel, E., Korte, K., Lehmann, P., Strunz, S. (2012b): Kosten der Energiewende - Fakten und Mythen. Energiewirtschaftliche Tagesfragen 62 (11), S. 39–44.

Gawel, E., Purkus, A. (2013a): Die Marktprämie im EEG 2012: Ein sinnvoller Beitrag zur Markt- und Systemintegration erneuerbarer Energien? Zeitschrift für Energiewirtschaft 37 (1), S. 43–61.

Gawel, E., Purkus, A. (2013b): Promoting the market and system integration of renewable energies through premium schemes – A case study of the German market premium. Energy Policy 61, S. 599–609.

Gawel, E., Purkus, A. (2012): Markt- und Systemintegration erneuerbarer Energien: Probleme der Marktprämie nach EEG 2012. Zeitschrift für Umweltrecht 23 (11), S. 587–596.

Gerbert, P., Herhold, P., Heuskel, D., Klose, F. (2013): Trendstudie 2030+. Kompetenzinitiative Energie des BDI. Berlin: The Boston Consulting Group.

Germelmann, C. F. (2013): Beihilferechtliche Rahmenvorgaben für staatliche Umlagesysteme – Neue Korrekturen für das Kriterium der staatlichen Mittel? Europäisches Wirtschafts- und Steuerrecht 2013 (5), S. 161–169.

Gottstein, M., Skillings, S. (2013): Über Kapazitätsmärkte hinaus denken: Flexibilität als Kernelement. In: Agora Energiewende (Hrsg.): Kapazitätsmarkt oder strategische Reserve: Was ist der nächste Schritt? Eine Übersicht über die in der Diskussion befindlichen Modelle zur Gewährleistung der Versorgungssicherheit in Deutschland. Berlin: Agora Energiewende, S. 15–26.

Greenpeace (2011): Battle of the Grids. Report 2011. How Europe can go 100 % renewable and phase out dirty energy. Amsterdam: Greenpeace International. http://www.greenpeace.org/international/Global/international/publications/climate/2011/battle %20of%20the%20grids.pdf (21.03.2013).

Growitsch, C., Matthes, F. C., Ziesing, H.-J. (2013): Clearing-Studie Kapazitätsmärkte. Berlin, Köln: Öko-Institut, Ziesing, Energiewirtschaftliches Institut an der Universität zu Köln.

Gullberg, A. T. (2013): The political feasibility of Norway as the 'green battery' of Europe. Energy Policy 57, S. 615–623.

Heller, R., Deng, Y., Breevoort, P. van (2013): Renewable energy: a 2030 scenario for the EU. Update. Utrecht: Ecofys Netherlands.

Hermann, H., Matthes, F. C., Emele, L., Jung, F. (2012): Strompreisentwicklungen im Spannungsfeld von Energiewende, Energiemärkten und Industriepolitik. Der Energiewende-Kosten-Index (EKX). Kurzstudie. Berlin: Öko-Institut.

Herrmann, N., Ecke, J. (2012): Gewinner und Verlierer eines Kapazitätsmarktes – Verteilungwirkungen eines neuen Strommarktdesigns. Energiewirtschaftliche Tagesfragen 62 (1-2), S. 28–33

Hey, C., Holm-Müller, K., Weber, M. (2011): Vermeidung von Anpassung – große Möglichkeiten im Stromsektor. ifo Schnelldienst 64 (5), S. 16–20.

Hey, C., Weber, M. (2012): Erfolgsbedingungen des Ausbaus erneuerbarer Energien oder Kritik einer monoinstrumentellen Klimapolitik. In: Steinmüller, H., Hauer, A., Schneider, F. (Hrsg.): Energiewirtschaft. Jahrbuch 12. Wien: Neuer Wissenschaftlicher Verlag, S. 15–32.

Hirschhausen, C. von, Ruester, S., Marcantonini, C., He, X., Egerer, J., Glachant, J.-M. (2012): EU Involvement in Electricity and Natural Gas Transmission Grid Tarification. Final Report. Florence: European University Institute.

HMRC (Her Majesty's Revenue & Customs) (2013): Carbon price floor. London: HMRC. http://www.hmrc.gov.uk/climate-change-levy/carbon-pf.htm#3 (23.05.2013).

Hoefnagels, R., Junginger, M., Panzer, C., Resch, G., Held, A. (2011): Long Term Potentials and Costs of RES. Part I: Potentials, Diffusion and Technological learning. Karlsruhe, Wien, Utrecht, Berlin, Kaunas, Budapest, Arnhern, Milan: Fraunhofer Institute for Systems and Innovation Research, Energy Economics Group, Ecofys, Deutsches Institut für Wirtschaftsforschung, Lithuanian Energy Institute, Utrecht University, Energy Banking Advisory, KEMA, Bocconi University. RE-Shaping Report D10.

Hogan, M., Gottstein, M. (2012): What Lies “Beyond Capacity Markets”? Delivering Least-Cost Reliability Under the New Resource Paradigm. A “straw man” proposal for discussion. Berlin: The Regulatory Assistance Project. www.raponline.org/document/download/id/6041 (29.07.2013).

Horst, J., Hauser, E. (2012): Eruierung von Optionen zur Absenkung der EEG-Umlage. Kurzgutachten. Saarbrücken: Institut für ZukunftsEnergieSysteme.

IASS (Institute for Advanced Sustainability Studies) (2012): Fördersystem der erneuerbaren Energien weiterentwickeln. Potsdam: IASS, Plattform Energiewende. http://www.iass-potsdam.de/sites/default/files/files/foerdersystem_der_erneuerbaren.pdf (05.09.2013).

IEA (International Energy Agency) (2012): World Energy Outlook 2012. Paris: IEA.

Ismer, R., Karch, A. (2013): Das EEG im Konflikt mit dem Unionsrecht: Die Begünstigung der stromintensiven Industrie als unzulässige Beihilfe. Zeitschrift für Umweltrecht (10), S. 526–534?

Jacobs, D., Mez, L. (2012): Zur internationalen Vorbildfunktion von StrEG und EEG. In: Müller, T. (Hrsg.): 20 Jahre Recht der Erneuerbaren Energien. Baden-Baden: Nomos. Schriften zum Umweltenergierecht 10, S. 258–271.

Jacobsson, S., Bergek, A., Finon, D., Lauber, V., Michel, C., Toke, D., Verbruggen, A. (2009): EU renewable energy support policy: Faith or facts? Energy Policy 37 (6), S. 2143–2146.

Kachel, M. (2012): Die besondere Ausgleichsregelung im EEG als Instrument zur Entlastung der stromintensiven Industrie. Zeitschrift für Umweltrecht 23 (1), S. 32–39.

Klobasa, M., Ragwitz, M., Sensfuß, F., Rostankowski, A., Gerhardt, N., Holzhammer, U., Richts, C., Lehnert, W. (2013a): Nutzenwirkung der Marktprämie. Erste Ergebnisse im Rahmen des Projekts “Laufende Evaluierung der Direktvermarktung von Strom aus Erneuerbaren Energien”. Karlsruhe: Fraunhofer Institut für System- und Innovationsforschung. Working Paper Sustainability and Innovation S 1/2013.

Klobasa, M., Roon, S. von, Buber, T., Gruber, A. (2013b): Lastmanagement als Beitrag zur Deckung des Spitzenlastbedarfs in Süddeutschland. Zusammenfassung der Zwischenergebnisse einer Studie von Fraunhofer ISI und der Forschungsgesellschaft für Energiewirtschaft. Studie. Berlin: Agora Energiewende.

Klobasa, M., Winkler, J., Sensfuß, F., Ragwitz, M. (2013c): Market Integration of Renewable Electricity Generation – The German Market Premium Model. Energy & Environment 24 (1-2), S. 127–146.

Kopp, O., Bode, S., Groscurth, H.-M., Klessmann, C., Gebhart, M., Nabe, C., Grave, K., Engelhorn, T., Onischka, M., Ehrhart, K.-M., Pietrzyk, S. (2013): Wege in ein wettbewerbliches Strommarktdesign für erneuerbare Energien. Hamburg, Berlin, Mannheim, Bayreuth: Arrhenius Institut für Energie und Klimapolitik, Ecofys, MVV Energie AG, Takon – Spieltheoretische Beratung.

Kranner, K., Sharma, S. (2013): Das europäische Strommarktdesign der Zukunft. Energiewirtschaftliche Tagesfragen 63 (1–2), S. 62–65.

Krzikalla, N., Achner, S., Brühl, S. (2013): Möglichkeiten zum Ausgleich fluktuierender Einspeisungen aus Erneuerbaren Energien. Aachen: Büro für Energiewirtschaft und technische Planung.

Küchler, S., Meyer, B. (2012): Was Strom wirklich kostet. Vergleich der staatlichen Förderungen und gesamtgesellschaftlichen Kosten konventioneller und erneuerbarer Energien. Langfassung. überarb. und aktualisierte Aufl. Berlin: Forum Ökologisch-Soziale Marktwirtschaft. Studien 9/12.

La Chevallerie, A. von, Schweitzer, K. (2012): Gemeinsamer Handel mit Stromzertifikaten – Förderung Erneuerbarer in Schweden und Norwegen. Energiewirtschaftliche Tagesfragen 62 (3), S. 92–95.

Lafferty, W. M., Ruud, A. (2008): Introduction: Promoting green electricity in Europe: The challenge of integrating contextual factors. In: Lafferty, W. M., Ruud, A. (Hrsg.): Promoting Sustainable Electricity in Europe. Challenging the Path Dependence of Dominant Energy Systems. Cheltenham: Edward Elgar, S. 1–44.

Lauber, V. (2007): The Politics of European Union Policy on Support Schemes for Electrictiy from Renewable Energy Sources. In: Mez, L. (Hrsg.): Green Power Markets: Support Schemes, Case Studies and Perspectives. Brentwood: Multi-Science Publishing, S. 9–29.

Leprich, U., Hauser, E., Grashof, K., Grote, L., Luxenburger, M., Sabatier, M., Zipp, A. (2012): Kompassstudie Marktdesign. Leitideen für ein Design eines Stromsystems mit hohem Anteil fluktuierender Erneuerbarer Energien. Bochum: Ponte Press.

Loreck, C., Matthes, F. C., Hermann, H., Jung, F., Emele, L. (2012): Kurzanalyse des Anstiegs der EEG-Umlage 2013. Berlin: Öko-Institut.

Löschel, A., Erdmann, G., Staiß, F., Ziesing, H.-J. (2012): Stellungnahme zum ersten Monitoring-Bericht der Bundesregierung für das Berichtsjahr 2011 der Expertenkommission zum Monitoring-Prozess "Energie der Zukunft". Berlin, Mannheim, Stuttgart: Expertenkommission zum Monitoring-Prozess "Energie der Zukunft".

Lüdemann, V., Ortmann, M. (2012): Hält die Marktprämie, was sie verspricht? Eine Analyse anhand aktueller Zahlen. Zeitschrift für Neues Energierecht 16 (4), S. 325–334.

Matschoss, P. (2013): The German energy transition. Status, challenges and the Finnish perspective. Helsinki: The Finnish Institute of International Affairs. FIIA Briefing Paper 128.

Matthes, F. C. (2013a): Vision und Augenmaß. Zur Reform des Flankierungsrahmens für die Stromerzeugung aus Erneuerbaren Energien. In: Agora Energiewende (Hrsg.): Die Zukunft des EEG – Evolution oder Systemwechsel? Berlin: Agora Energiewende, S. 17–24.

Matthes, F. C. (2013b): Vision und Augenmaß. Zur Reform des Flankierungsrahmens für die Stromerzeugung aus erneuerbaren Energien. Vortrag, Fachgespräch von Agora Energiewende. “Die Zukunft des EEG – Evolution oder Systemwechsel?”, 13.02.2013, Berlin.

Matthes, F. C. (2012): Einordnung der Aktuellen Debatte um den Flankierungsrahmen für die Stromerzeugung aus Erneuerbaren Energien. Memo. Berlin: Öko-Institut. http://www.oeko.de/files/forschungsergebnisse/application/octet-stream/download.php?id=1545 (29.07.2013).

Matthes, F. C., Schlemmermeier, B., Diermann, C., Hermann, H., Hammerstein, C. von (2012): Fokussierte Kapazitätsmärkte. Ein neues Marktdesign für den Übergang zu einem neuen Energiesystem. Berlin: Öko-Institut, LBD-Beratungsgesellschaft, Raue LLP.

Meulman, L., Méray, N. (2012): Capacity Mechanisms in Northwest Europe. Between a Rock and a Hard Place? The Hague: Nederlands Instituut voor Internationale Betrekkingen. Clingendael Energy Paper 2012/3.

Midttun, A., Ruohonen, T., Piria, R. (2011): Norway and the North Sea Grid. Key Positions and Players in Norway, from a Norwegian Perspective. Berlin: Smart Energy for Europe Platform. SEFEP working paper 2012-1.

Mitchell, C., Sawin, J. L., Pokharel, G. R., Kammen, D., Wan, Z., Fifita, S., Jaccard, M., Langniss, O., Lucas, H., Nadai, A., Blanco, R. T., Usher, E., Verbruggen, A., Wüstenhagen, R., Yamaguchi, K. (2012): Policy, Financing and Implementation. In: Edenhofer, O., Pichs-Madruga, R., Sokona, Y., Seyboth, K., Matschoss, P., Kadner, S., Zwickel, T., Eickemeier, P., Hansen, G., Schlömer, S., Stechow, C. von (Hrsg.): Renewable Energy Sources and Climate Change Mitigation. Special Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press, S. 865–950.

Monitoring Analytics (2012): The Independent Market Monitor for PJM. Eagleville, Pa.: Monitoring Analytics. http://www.monitoringanalytics.com/reports/Reports/2012/IMM_And_PJM_Capacity_White_Papers_On_OPSI_Issues_20120820.pdf (15.07.2013).

Monopolkommission (2013): Energie 2013: Wettbewerb in Zeiten der Energiewende: Sondergutachten der Monopolkommission gemäß § 62 Abs. 1 EnWG. Bonn: Monopolkommission. Sondergutachten der Monopolkommission 65. http://www.monopolkommission.de/sg_65/s65_volltext.pdf (17.10.2013).

Müsgens, F., Peek, M. (2011): Sind Kapazitätsmärkte in Deutschland erforderlich? Eine kritische Analyse vor dem Hintergrund der ökonomischen Theorie. Zeitschrift für neues Energierecht 15 (6), S. 576–583.

Nagl, S., Paulus, S., Lindenberger, D. (2012): Mögliche Entwicklung der Umlage zur Förderung der Stormerzeugung aus erneuerbaren Energien durch das Erneuerbare-Energien-Gesetz bis 2018. Köln: Energiewirtschaftliches Institut an der Universität zu Köln.

Nestle, U., Reuster, L. (2012): Ausweisung der EEG-Umlage: eine kritische Analyse. Argumente zur Bewertung der Umlage des Erneuerbare-Energien-Gesetzes. Berlin: Forum Ökologisch-Soziale Marktwirtschaft. Studien 11/12.

Neuhoff, K., Bach, S., Diekmann, J., Beznoska, M., El-Laboudy, T. (2012): Steigende EEG-Umlage: Unerwünsche Verteilungseffekte können vermindert werden. DIW-Wochenbericht 79 (41), S. 3–12.

Nicolosi, M. (2012a): Notwendigkeit und Ausgestaltungsmöglichkeiten eines Kapazitätsmechanismus für Deutschland. Zwischenbericht. Dessau-Roßlau: Umweltbundesamt. Climate Change 12/12. http://www.uba.de/uba-info-medien/4221.html (22.03.2013).

Nicolosi, M. (2012b): Notwendigkeit von Kapazitätsmechanismen. Endbericht. Berlin: Ecofys.

Nitsch, J., Pregger, T., Naegler, T., Heide, D., Tena, D. L. de, Trieb, F., Scholz, Y., Nienhaus, K., Gerhardt, N., Sterner, M., Trost, T., Oehsen, A. von, Schwinn, R., Pape, C., Hahn, H., Wickert, M., Wenzel, B. (2012): Langfristszenarien und Strategien für den Ausbau der erneuerbaren Energien in Deutschland bei Berücksichtigung der Entwicklung in Europa und global. Schlussbericht. Stuttgart, Kassel, Teltow: Deutsches Zentrum für Luft- und Raumfahrt, Institut für Technische Thermodynamik, Abt. Systemanalyse und Technikbewertung, Fraunhofer Institut für Windenergie und Energiesystemtechnik, Ingenieurbüro für neue Energien.

Notenboom, J., Boot, P., Koelemeijer, R., Ros, J. (2012): Climate and Energy Roadmaps towards 2050 in north-western Europe. A concise overview of long-term climate and energy policies in Belgium, Denmark, France, Germany, the Netherlands and the United Kingdom. The Hague: PBL Netherlands Environmental Assessment Agency.

Ohlhorst, D., Schreurs, M., Gullberg, A. T. (2012): Norwegen – "Batterie" der deutschen Energiewende? Unterschiedliche Länderinteressen in der Energiepolitik. GAIA 21 (4), S. 319–320.

Patt, A., Komendantova, N., Battaglini, A., Lilliestam, J. (2011): Regional integration to support full renewable power deployment for Europe by 2050. Environmental Politics 20 (5), S. 727–742.

Peters, W., Schultze, C., Schümann, K., Stein, S. (2010): Bioenergie und Naturschutz. Synergien fördern, Risiken vermeiden. Bonn: Bundesamt für Naturschutz.

Plattform Erneuerbare Energien (2012): Bericht der AG 3 Interaktion an den Steuerungskreis der Plattform Erneuerbare Energien, die Bundeskanzlerin und die Ministerpräsidenteninnen und Ministerpräsidenten der Länder vom 15.10.2012. Berlin: Plattform Erneuerbare Energien.
http://www.bmu.de/fileadmin/Daten_BMU/Bilder_Unterseiten/Themen/Klima_Energie/Energiewende/bericht_plattform_ee_bf.pdf (16.05.2013).

Poppe, A.-K. (2012): Begrenzung der EEG-Umlage und Stromnetzentgeltbefreiung für Unternehmen des produzierenden Gewerbes. Zeitschrift für neues Energierecht 16 (1), S. 47–52.

Prognos AG (2012): Bedeutung der internationalen Wasserkraft-Speicherung für die Energiewende. Studie. Basel: Prognos AG.

r2b energy consulting (2012): Ziele und Ausgestaltung einer Strategischen Reserve. Eckpunktepapier. Köln: r2b energy consulting.

Ragwitz, M., Sensfuß, F. (2008): Stellungnahme des Fraunhofer Instituts für System- und Innovationsforschung zum Entwurf eines Gesetzes zur Neuregelung des Rechts der Erneuerbaren Energien im Strombereich und zur Änderung damit zusammenhängender

Vorschriften. Karlsruhe: Fraunhofer Institut für System- und Innovationsforschung. http://www.clearingstelle-eeg.de/files/11-Stn_Fraunhofer_ISI.pdf (28.08.2013).

Ragwitz, M., Steinhilber, S., Breitschopf, B., Resch, G., Panzer, C., Ortner, A., Busch, S., Rathmann, M., Klessmann, C., Nabe, C., Lovinfosse, I. de, Neuhoff, K., Boyd, R., Junginger, M., Hoefnagels, R., Cusumano, N., Lorenzoni, A., Burgers, J., Boots, M., Weöres, B. (2012): RE-Shaping: Shaping an effective and efficient European renewable energy market. Karlsruhe, Wien, Utrecht, Berlin, Kaunas, Budapest, Arnhern, Milan: Fraunhofer Institute for Systems and Innovation Research, Energy Economics Group, Ecofys, Deutsches Institut für Wirtschaftsforschung, Lithuanian Energy Institute, Utrecht University, Energy Banking Advisory, KEMA, Bocconi University. RE-Shaping Report D23 (Final report).

Rathmann, M., Jager, D. de, Lovinfosse, I. de, Breitschopf, B., Burgers, J., Weöres, B. (2011): Towards triple-A policies: More renewable energy at lower cost. Karlsruhe, Wien, Utrecht, Berlin, Kaunas, Budapest, Arnhern, Milan: Fraunhofer Institute for Systems and Innovation Research, Energy Economics Group, Ecofys, Deutsches Institut für Wirtschaftsforschung, Lithuanian Energy Institute, Utrecht University, Energy Banking Advisory, KEMA, Bocconi University. RE-Shaping Report D16.

Reichert, S. (2013): Erneuerbare Energie quer durch die Nordsee? Akteurs- und Interessenkonstellationen der geplanten Interkonnektoren NorGer und Nord.Link zwischen Deutschland und Norwegen. Stuttgart: ibidem. Ecological Energy Policy 14.

Rostankowski, A., Baier, A., Gerhardt, N., Holzhammer, U., Klobasa, M., Ragwitz, M., Sensfuß, F., Lehnert, W. (2012): Anpassungsbedarf bei den Parametern des gleitenden Marktprämienmodells im Hinblick auf aktuelle energiewirtschaftliche Entwicklungen. Kurzgutachten. Karlsruhe, Bremerhaven, Berlin, Greifswald: Fraunhofer ISI, Fraunhofer IWES, Becker Büttner Held, Institut für Klimaschutz, Energie und Mobilität.

Sandbag (2013): The UK Carbon Floor Price. Sandbag briefing. London: Sandbag. http://www.sandbag.org.uk/site_media/pdfs/reports/Sandbag_Carbon_Floor_Price_2013_final.pdf (28.05.2013).

Schlacke, S., Kröger, J. (2013): Die Privilegierung stromintensiver Unternehmen im EEG. Eine unionsrechtliche Bewertung der besonderen Ausgleichsregelung (§§ 40 ff. EEG). Neue Zeitschrift für Verwaltungsrecht 32 (6), S. 313–319.

Schleicher-Tappeser, R. (2012): How renewables will change electricity markets in the next five years. Energy Policy 48, S. 64–75.

Schlemmermeier, B., Diermann, C. (2011): Energiewirtschaftliche Erfordernisse zur Ausgestaltung des Marktdesigns für einen Kapazitätsmarkt Strom. Abschlussbericht. Berlin: LBD-Beratungsgesellschaft. http://www.lbd.de/cms/pdf-gutachten-und-studien/1201-LBD-Gutachten-LRBW_Kapazitaetsmarkt_Endbericht.pdf (24.04.2013).

Schmidt, C. M. (2013): Die Zukunft des EEG – Evolution oder Systemwechsel? In: Agora Energiewende (Hrsg.): Die Zukunft des EEG – Evolution oder Systemwechsel? Berlin: Agora Energiewende, S. 31–34.

SRU (Sachverständigenrat für Umweltfragen) (2013a): An Ambitious Triple Target for 2030. Comment to the Commission's Green Paper "A 2030 Framework for Climate and Energy Policies" (COM(2013) 169 final). Berlin: SRU. Comment on Environmental Policy 12.

SRU (2013b): Fracking zur Schiefergasgewinnung: Ein Beitrag zur energie- und umweltpolitischen Bewertung. Berlin: SRU. Stellungnahme 18.

SRU (2011): Wege zur 100 % erneuerbaren Stromversorgung. Sondergutachten. Berlin: Erich Schmidt.

SRU (2008): Umweltgutachten 2008. Umweltschutz im Zeichen des Klimawandels. Berlin: Erich Schmidt.

SRU (2006): Die nationale Umsetzung des europäischen Emissionshandels: Marktwirtschaftlicher Klimaschutz oder Fortsetzung der energiepolitischen Subventionspolitik mit anderen Mitteln? Berlin: SRU. Stellungnahme 11.

Süßenbacher, W., Schwaiger, M., Stigler, H. (2011): Kapazitätsmärkte und -mechanismen im internationalen Kontext. Graz: Technische Universität Graz, Institut für Elektrizitätswirtschaft und Energieinnovation. http://eeg.tuwien.ac.at/eeg.tuwien.ac.at_pages/events/iewt/iewt2011/uploads/plenarysessions_iewt2011/P_Suessenbacher.pdf (14.10.2013).

SVR (Sachverständigenrat zur Begutachtung der Gesamtwirtschaftlichen Entwicklung) (2012): Stabile Architektur für Europa – Handlungsbedarf im Inland. Jahresgutachten 2012/2013. Wiesbaden: SVR.

Teusch, J., Behrens, A., Egenhofer, C. (2012): The Benefits of Investing in Electricity Transmission. Lessons from Northern Europe. Brussels: Centre for European Policy Studies. CEPS Special Report 59. http://www.ceps.eu/ceps/dld/6542/pdf (21.03.2013).

Tietjen, O. (2012): Kapazitätsmärkte. Hintergründe und Varianten mit Fokus auf einen emissionsarmen deutschen Strommarkt. Bonn, Berlin: Germanwatch. http://germanwatch.org/de/download/3564.pdf (19.3.2013).

Uhlen, K., Cirio, D. (2012): IEA Implementing Agreement on Electricity Networks Analysis, Research & Development (ENARD). Annex IV: Transmission Systems. Final Report. Trondheim: SINTEF Energy Research.

Verheyen, R. (2013): Rechtliche Instrumente zur Verhinderung neuer Kohlekraftwerke und Braunkohletagebaue in Deutschland. Rechtsgutachten. Berlin: Bund für Umwelt und Naturschutz Deutschland, Deutsche Umwelthilfe. http://www.bund.net/fileadmin/bundnet/pdfs/klima_und_energie/130514_bund_klima_energie_rechtsgutachten_kohlekraftwerke.pdf (13.06.2013).

Weber, M., Hey, C. (2012a): Effektive und effiziente Klimapolitik: Instrumentenmix, EEG und Subsidiarität. Wirtschaftsdienst 92 (Sonderheft), S. 43–51.

Weber, M., Hey, C. (2012b): Energiewende: Kosten wirklich zu hoch? Wirtschaftsdienst 92 (6), S. 360.

Weber, M., Hey, C., Faulstich, M. (2012): Energiewende – A Pricey Challenge. CESifo DICE Report 10 (3), S. 1–8.

Winkler, J. (2011): Assessment of electricity market designs for a completely renewable electricity system: a case study for Germany. London, Imperial College, Faculty of Natural Sciences. Centre for Environmental Policy, Master thesis.

Winkler, J., Altmann, M. (2012): Market Designs for a Completely Renewable Power Sector. Zeitschrift für Energiewirtschaft 77 (2), S. 77–92.

Winkler, J., Sensfuß, F., Keles, D., Renz, L., Fichtner, W. (2013): Perspektiven für die langfristige Entwicklung der Strommärkte und der Förderung Erneuerbarer Energien bei ambitionierten Ausbauzielen. Diskussionspapier: Perspektiven zur aktuellen

Kapazitätsmarktdiskussion in Deutschland. Karlsruhe: Fraunhofer Institut für System- und Innovationsforschung, Lehrstuhl für Energiewirtschaft, Karlsruher Institut für Technologie.

Zachmann, G. (2013): Electricity infrastructure: More border crossings or a borderless Europe? Brüssel: Bruegel. Bruegel Policy Contribution 13/05.

Ziehm, C., Wegener, H. (2013): Zur Zulässigkeit nationaler CO_2-Grenzwerte für dem Emissionshandel unterfallende neue Energieerzeugungsanlagen. Berlin: Deutsche Umwelthilfe. http://www.duh.de/uploads/media/Ziehm-Wegener_Zulässigkeit_nationaler_CO2-Grenzwerte_05-2013.pdf (05.09.2013).

Zittel, W., Zerhusen, J., Zerta, M., Arnold, N. (2013): Fossile und Nukleare Brennstoffe – die künftige Versorgungssituation. Neuss, Ottobrunn: Energy Watch Group, Ludwig Boelkow Stiftung, Reiner-Lemoine-Stiftung.

Chapter 6

acatech (Deutsche Akademie der Technikwissenschaften) (Hrsg.) (2012a): Anpassungsstrategien in der Klimapolitik. acatech Position. München, Berlin, Brüssel: acatech.

acatech (Hrsg.) (2012b): Die Energiewende finanzierbar gestalten. Effiziente Ordnungspolitik für das Energiesystem der Zukunft. acatech Position. München, Berlin, Brüssel: acatech.

Agora Energiewende (2013): Kostenoptimaler Ausbau der Erneuerbaren Energien in Deutschland. Ein Vergleich möglicher Strategien für den Ausbau von Wind- und Solarenergie in Deutschland bis 2033. Studie. Berlin: Agora Energiewende.

Altrock, M., Oschmann, V., Theobald, C. (Hrsg.) (2011): EEG. Erneuerbare Energien Gesetz. Kommentar. 3. Aufl. München: Beck.

Ancygier, A. (2013): Vom Primus zum Bremser. Die Entwicklung der deutschen Energiewende wird vom Ausland genau beobachtet. Nicht zuletzt auch von den polnischen Nachbarn. Neue Energie 23 (8), S. 36–38.

Asselt, H. van (2010): Emissions trading: the enthusiastic adoption of an “alien”. In: Jordan, A., Huitema, D., Asselt, H. van, Rayner, T., Berkhout, F. (Hrsg.): Climate Change Policy in the European Union. Confronting the Dilemmas of Mitigation and Adaptation? Cambridge: Cambridge University Press, S. 125–144.

Bäckstrand, K., Khan, J., Kronsell, A., Lövbrand, E. (Hrsg.) (2010): Environmental Politics and Deliberative Democracy: Examining the Promise of New Modes of Governance. Cheltenham: Edward Elgar.

Benz, A., Lütz, S., Schimank, U., Simonis, G. (2007): Einleitung. In: Benz, A., Lütz, S., Schimank, U., Simonis, G. (Hrsg.): Handbuch Governance. Theoretische Grundlagen und empirische Anwendungsfelder. Wiesbaden: VS Verlag für Sozialwissenschaften, S. 9–25.

Berkhout, F., Haug, C., Rayner, T., Asselt, H. van, Hildingsson, R., Huitema, D., Jordan, A., Monni, S., Johannes, S. (2010): How do climate policies work? Dilemmas in European climate governance. In: Hulme, M., Neufeldt, H. (Hrsg.): Making climate change work for us.

BürgerEnergie Berlin (2013): BürgerEnergie Berlin. Berlin: BürgerEnergie Berlin. http://www.buerger-energie-berlin.de/ (31.10.2013).

European perspectives on adaptation and mitigation strategies. Cambridge: Cambridge University Press, S. 137–164

BMU (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit) (2013): Märkte stärken, Versorgung sichern. Konzept für die Umsetzung einer Strategischen Reserve in Deutschland. Ergebnisbericht des Fachdialogs “Strategische Reserve”. Berlin: BMU.

Brunnengräber, A. (2013): Multi-Level Climate Governance: Strategic Selectivities in International Politics. In: Knieling, J., Leal Filho, W. (Hrsg.): Climate Change Governance. Berlin, Heidelberg: Springer, S. 67–83.

Brunnengräber, A., Walk, H. (Hrsg.) (2007): Multi-level governance. Klima-, Umwelt- und Sozialpolitik in einer interdependenten Welt. Baden-Baden: Nomos. Schriften zur Governance-Forschung 9.

Bruns, E., Futterlieb, M., Ohlhorst, D., Wenzel, B. (2012): Netze als Rückgrat der Energiewende. Hemmnisse für die Integration erneuerbarer Energien in Strom-, Gas- und Wärmenetze. Berlin: Universitätsverlag der TU Berlin. http://opus.kobv.de/tuberlin/volltexte/2012/3730/ (09.01.2012).

Busse, V., Hofmann, H. (2010): Bundeskanzleramt und Bundesregierung. Aufgaben, Organisation, Arbeitsweise. 5., neu bearb. und aktualisierte Aufl. Heidelberg, München, Landsberg, Frechen, Hamburg: Müller.

Calliess, C. (2008): Entflechtung im europäischen Energiebinnenmarkt: zur Vereinbarkeit der europäischen Pläne für ein Ownership Unbundling mit der Kompetenzordnung des EG-Vertrages, insbesondere Art. 295 EGV, und dem allgemeinen Gleichheitssatz. Stuttgart: Boorberg. Bochumer Beiträge zum Berg- und Energierecht 50.

Calliess, C., Dross, M. (2012): Neue Netze braucht das Land: Zur Neukonzeption von Energiewirtschaftsgesetz und Netzausbaubeschleunigungsgesetz (NABEG). JuristenZeitung 67 (20), S. 1001–1011.

Calliess, C., Hey, C. (2013): Multilevel Energy Policy in the EU: Paving the Way for Renewables? Journal for European Environmental and Planning Law 10 (2), S. 87–131.

Calliess, C., Hey, C. (2012): Erneuerbare Energien in der Europäischen Union und EEG: Eine Europäisierung von unten? In: Müller, T. (Hrsg.): 20 Jahre Recht der Erneuerbaren Energien. Baden-Baden: Nomos. Schriften zum Umweltenergierecht 10, S. 223–257.

Christensen, J. G. (2011): Regulierung im Interesse des Gemeinwohls. Eine kritische Bilanz. der moderne staat – dms 4 (1), S. 167–187.

Dagger, S. B. (2009): Energiepolitik und Lobbying. Die Novellierung des Erneuerbare-Energien-Gesetzes (EEG) 2009. Stuttgart: ibidem-Verlag.

dena (Deutsche Energie-Agentur) (2005): Energiewirtschaftliche Planung für die Netzintegration von Windenergie in Deutschland an Land und Offshore bis zum Jahr 2020. Konzept für eine stufenweise Entwicklung des Stromnetzes in Deutschland zur Anbindung und Integration von Windkraftanlagen Onshore und Offshore unter Berücksichtigung der Erzeugungs- und Kraftwerksentwicklungen sowie der erforderlichen Regelleistung. Endbericht. Köln: dena.

Deutscher Bundestag (2013): Stenografischer Bericht, 246. Sitzung. Berlin: Deutscher Bundestag. Plenarprotokoll 17/246.

Dosi, G., Nelson, R. R. (1994): An introduction to evolutionary theories in economics. Journal of Evolutionary Economics 4 (3), S. 153–172.

Duffield, J. S., Westphal, K. (2011): Germany and the EU Energy Policy: Conflicted Champion of Integration? In: Birchfield, V. L., Duffield, J. S. (Hrsg.): Toward a Common European Union Energy Policy. Problems, Progress, and Prospects. New York, NY: Palgrave Macmillan, S. 169–186.

Ecofys (2013): Impacts of restricted transmission grid expansion in a 2030 perspective in Germany. Final report. Berlin: Ecofys. POWDE1220.

EFI (Expertenkommission Forschung und Innovation) (2013): Gutachten zu Forschung, Innovation und technologischer Leistungsfähigkeit Deutschlands 2013. Berlin: EFI.

Enquete-Kommission Wachstum Wohlstand Lebensqualität (2013): Schlussbericht der Enquete-Kommission "Wachstum, Wohlstand, Lebensqualität – Wege zu nachhaltigem Wirtschaften und gesellschaftlichem Fortschritt in der Sozialen Marktwirtschaft. Berlin: Deutscher Bundestag. Bundestagsdrucksache 17/13300.

Ethikkommission Sichere Energieversorgung (2011): Deutschlands Energiewende – Ein Gemeinschaftswerk für die Zukunft. Ein Bericht im Auftrag der Bundeskanzlerin Dr. Angela Merkel. Berlin: Ethikkommission Sichere Energieversorgung.

Europäische Kommission (2013): Grünbuch. Ein Rahmen für die Klima- und Energiepolitik bis 2030. COM(2013) 169 final. Brüssel: Europäische Kommission.

Europäische Kommission (2011): Mitteilung der Kommission an das Europäische Parlament, den Rat, den Europäischen Wirtschafts- und Sozialausschuss und den Ausschuss der Regionen. Fahrplan für den Übergang zu einer wettbewerbsfähigen CO_2-armen Wirtschaft bis 2050. KOM(2011) 112 endg. Brüssel: Europäische Kommission.

Fischer, S., Geden, O. (2013): Strategiediskussion in der EU-Energie- und Klimapolitik. Neue Ziele für die Zeit nach 2020. Bonn: Friedrich-Ebert-Stiftung. Internationale Politikanalyse. http://library.fes.de/pdf-files/id/ipa/09599.pdf (11.02.2013).

GDV (Gesamtverband der Deutschen Versicherungswirtschaft) (2013): Positionspapier. Zur Verbesserung der Bedingungen für Investitionen in Infrastruktur und Erneuerbare Energien. Berlin: GDV. http://www.gdv.de/2012/04/verbesserung-der-bedingungen-fur-investitionen-in-erneuerbare-energien-und-infrastruktur/positionspapier/ (17.07.2013).

Groß, T. (2011): Klimaschutzgesetze im europäischen Vergleich. Zeitschrift für Umweltrecht 22 (4), S. 171–177.

Hey, C. (2012): Energiewendeaußenpolitik – ein Leitbegriff einer europäisch gedachten Energiewende. Impulsreferat zum Trialog Energiewende. Vortrag, Trialog Energiewende, 03.09.2012, Berlin.

Hirschl, B. (2008): Erneuerbare Energien-Politik. Eine Multi-Level Policy-Analyse mit Fokus auf den deutschen Strommarkt. Wiesbaden: VS Verlag für Sozialwissenschaften.

Hirschl, B., Salecki, S., Böther, T., Heinbach, K. (2011): Wertschöpfungseffekte durch Erneuerbare Energien in Baden-Württemberg. Endbericht. Berlin: Institut für ökologische Wirtschaftsforschung.

Holzinger, K., Knill, C., Arts, B. (Hrsg.) (2008): Environmental Policy Convergence in Europe. The Impact of International Institutions and Trade. Cambridge: Cambridge University Press.

Jacob, K., Feindt, P. H., Busch, P.-O., Biermann, F. (2007): Einleitung: Politik und Umwelt – Modernisierung politischer Systeme und Herausforderung an die Politikwissenschaft. In:

Jacob, K., Biermann, F., Busch, P.-O., Feindt, P. H. (Hrsg.): Politik und Umwelt. Wiesbaden: VS Verlag für Sozialwissenschaften. Politische Vierteljahresschrift, Sonderheft 39, S. 11–37.

Jacobs, D. (2012): Renewable Energy Policy Convergence in the EU. The Evolution of Feed-in Tariffs in Germany, Spain and France. Farnham, Burlington, Vt.: Ashgate.

Jacobs, D., Mez, L. (2012): Zur internationalen Vorbildfunktion von StrEG und EEG. In: Müller, T. (Hrsg.): 20 Jahre Recht der Erneuerbaren Energien. Baden-Baden: Nomos. Schriften zum Umweltenergierecht 10, S. 258–271.

Jacobsson, S., Bergek, A. (2004): Transforming the energy sector: the evolution of technological systems in renewable energy technology. Industrial and Corporate Change 13 (5), S. 815–849.

Jänicke, M. (2012): Dynamic governance of clean-energy markets: how technical innovation could accelerate climate policies. Journal of Cleaner Production 22 (1), S. 50–59.

Jordan, A., Huitema, D., Rayner, T., Asselt, H. van (2010): Governing the European Union: An introduction. In: Jordan, A., Huitema, D., Asselt, H. van, Rayner, T., Berkhout, F. (Hrsg.): Climate Change Policy in the European Union. Confronting the Dilemmas of Mitigation and Adaptation? Cambridge: Cambridge University Press, S. 29–51.

Kaiser, R. (2013): Auf dem Weg zu einem Energiewende-Ministerium. Zeitschrift für neues Energieerecht 17 (2), S. 107–113.

Kemfert, C. (2010): Energie, Klimaschutz und nachhaltige Mobilität – Warum Deutschland ein Energieministerium braucht. Vierteljahrshefte zur Wirtschaftsforschung 79 (1), S. 141–155.

Könnölä, T., Carrillo-Hermosilla, J., Loikkanen, T., Have, R. van der (2009): Governance of Energy System Transition – Analytical Framework and Empirical Cases in Europe and Beyond. GoReNEST Project, Task 3. Espoo: VTT Technical Research Centre of Finland. VTT Working Papers 134.

Kooiman, J., Jentoft, S. (2009): Meta-Governance: values, norms and principles, and the making of hard choices. Public Administration 87 (4), S. 818–836.

Lafferty, W. M., Meadowcroft, J. (Hrsg.) (1996): Democracy and the Environment: Problems and Prospects. Cheltenham: Edward Elgar.

Lockwood, M. (2013): Governance, Innovation and the Transition to a Sustainable Energy System: Perspectives from Economic Theory. Exeter: University of Exeter, iGov. EPG Working Paper 1305.

Löschel, A., Erdmann, G., Staiß, F., Ziesing, H.-J. (2012): Stellungnahme zum ersten Monitoring-Bericht der Bundesregierung für das Berichtsjahr 2011 der Expertenkommission zum Monitoring-Prozess “Energie der Zukunft”. Berlin, Mannheim, Stuttgart: Expertenkommission zum Monitoring-Prozess “Energie der Zukunft”.

Luhmann, H.-J. (2013): Das Verfahren der Öffentlichkeitsbeteiligung in der Stromnetz-Ausbauplanung – eine erste Bewertung. Energiewirtschaftliche Tagesfragen 63 (4), S. 32–36.

Luhmann, H.-J. (2012): Vom Ende her gesehen: Der Wettbewerb der Erneuerbaren untereinander nach dem Ausstieg aus Kernkraft und fossilen Energien Energiewirtschaftliche Tagesfragen 62 (12), S. 31–32.

Majone, G. (1997): The Agency Model: The Growth of Regulation and Regulatory Institutions in the European Union. EIPASCOPE 1997 (3), S. 1–6.

Matthes, F. C., Barth, R., Acker, H. (2010): Eckpunkte für ein Klimaschutzgesetz für Deutschland. Berlin, Darmstadt, Freiburg: Öko-Institut.

Matthes, F. C., Schlemmermeier, B., Diermann, C., Hermann, H., Hammerstein, C. von (2012): Fokussierte Kapazitätsmärkte. Ein neues Marktdesign für den Übergang zu einem neuen Energiesystem. Berlin: Öko-Institut, LBD-Beratungsgesellschaft, Raue LLP.

Mayntz, R. (2005): Governance Theory als fortentwickelte Steuerungstheorie? In: Schuppert, G. F. (Hrsg.): Governance-Forschung. Vergewisserung über Stand und Entwicklungslinien. Baden-Baden: Nomos. Schriften zur Governance-Forschung 1, S. 11–20.

Midttun, A. (2012): The greening of European electricity industry: A battle of modernities. Energy Policy 48, S. 22–35.

Müller, E. (1999): Zum Verhältnis von nachhaltiger Entwicklung und Organisationsstrukturen. In: Weiland, U. (Hrsg.): Perspektiven der Raum- und Umweltplanung. Festschrift für Karl-Hermann Hübler. Berlin: Verlag für Wissenschaft und Forschung, S. 159–173.

Müller, E. (1995): Innenwelt der Umweltpolitik. Sozial-liberale Umweltpolitik – (Ohn)macht durch Organisation? 2. Aufl. Opladen: Westdeutscher Verlag.

Nanz, P., Fritsche, M. (2012): Handbuch Bürgerbeteiligung. Verfahren und Akteure, Chancen und Grenzen. Bonn: Bundeszentrale für politische Bildung. Schriftenreihe 1200.

Nicolosi, M. (2012): Notwendigkeit von Kapazitätsmechanismen. Endbericht. Berlin: Ecofys.

Nilsson, M. (2011): EU Renewable Electricity Policy: Mixed Emotions toward Harmonization. In: Birchfield, V. L., Duffield, J. S. (Hrsg.): Toward a Common European Union Energy Policy. Problems, Progress, and Prospects. New York, NY: Palgrave Macmillan, S. 113–130.

Notenboom, J., Boot, P., Koelemeijer, R., Ros, J. (2012): Climate and Energy Roadmaps towards 2050 in north-western Europe. A concise overview of long-term climate and energy policies in Belgium, Denmark, France, Germany, the Netherlands and the United Kingdom. The Hague: PBL Netherlands Environmental Assessment Agency.

Ohlhorst, D., Tews, K. (2013): Deutschland als Laboratorium: Das Experiment Energiewende. In: Varwick, J. (Hrsg.): Energiewende. Schwalbach/Ts.: Wochenschau-Verl. . Politische Bildung 46,2, S. 26–45.

Ostrom, E. (2011): Was mehr wird wenn wir teilen. Vom gesellschaftlichen Wert der Gemeingüter. München: oekom.

Ostrom, E. (2005): Understanding institutional diversity. Princeton, NJ: Princeton University Press.

Plattform Erneuerbare Energien (2012): Bericht der AG 3 Interaktion an den Steuerungskreis der Plattform Erneuerbare Energien, die Bundeskanzlerin und die Ministerpräsidenteninnen und Ministerpräsidenten der Länder vom 15.10.2012. Berlin: Plattform Erneuerbare Energien.
http://www.bmu.de/fileadmin/Daten_BMU/Bilder_Unterseiten/Themen/Klima_Energie/Energiewende/bericht_plattform_ee_bf.pdf (16.05.2013).

Prittwitz, V. von (2012): Bound Governance (Verfahren). Berlin: Otto-Suhr-Institut für Politikwissenschaft der Freien Universität. http://www.volkervonprittwitz.de/bound_governance_031212.pdf (23.05.2013).

Prittwitz, V. von (1990): Das Katastrophenparadox. Elemente einer Theorie der Umweltpolitik. Opladen: Leske + Budrich.

Ragwitz, M., Held, A. (2012): Einspeiseregelungen als effizienter Weg zum Ausbau der Erneuerbaren Energien. In: Müller, T. (Hrsg.): 20 Jahre Recht der Erneuerbaren Energien. Baden-Baden: Nomos. Schriften zum Umweltenergierecht 10, S. 321–335.

Rave, T., Triebswetter, U., Wackerbauer, J. (2013): Koordination von Innovations-, Energie- und Umweltpolitik. München: Ifo Institut – Leibniz Institut für Wirtschaftsforschung. Studien zum deutschen Innovationssystem 10-2013.

Rest, J. (2011): Grüner Kapitalismus? Klimawandel, globale Staatenkonkurrenz und die Verhinderung der Energiewende. Wiesbaden: VS, Verlag für Sozialwissenschaften.

Rotmans, J., Loorbach, D. (2008): Transition Management: reflexive governance of societal complexity through searching, learning, and experimenting. In: Bergh, J. C. J. M. van den, Bruinsma, F. R. (Hrsg.): Managing the Transition to Renewable Energy. Theory and Practice from Local, Regional and Macro Perspectives. Cheltenham: Edward Elgar, S. 15–46.

RWE (2012): Akzeptanz für Großprojekte. Eine Standortbestimmung über Chancen und Grenzen der Bürgerbeteiligung in Deutschland. Essen: RWE.

Schambureck, D. W. K. (2010): Ressortstruktur und Ressortzuschnitt in der Bundesrepublik Deutschland insbesondere nach 1993. Bamberg, Universität Bamberg, Lehrstuhl für Verwaltungswissenschaft, Diplomarbeit

Scharpf, F. W. (1999): Governing in Europe. Effective and democratic? Oxford: Oxford University Press.

Scharpf, F. W., Reissert, B., Schnabel, F. (1976): Politikverflechtung. Bd. 1: Theorie und Empirie des kooperativen Föderalismus in der Bundesrepublik. Kronberg, Ts.: Scriptor-Verlag. Monographien Ergebnisse der Sozialwissenschaften 1.

Schreurs, M. A. (2008): From the Bottom Up: Local and Subnational Climate Change Politics. The Journal of Environment and Development 17 (4), S. 343–355.

Schuppert, G. F. (2010): Staat als Prozess. Frankfurt am Main, New York: Campus.

Sina, S., Meyer-Ohlendorf, N., Czarnecki, R. (2009): Ein Klimaschutzgesetz für Deutschland. Juristisches Kurzgutachten des Ecologic Instituts. Frankfurt am Main: WWF Deutschland.

Sørensen, E. (2006): Metagovernance : The Changing Role of Politicians in Processes of Democratic Governance. The American Review of Public Administration 36 (1), S. 98–114.

SRU (Sachverständigenrat für Umweltfragen) (2013): An Ambitious Triple Target for 2030. Comment to the Commission's Green Paper “A 2030 Framework for Climate and Energy Policies” (COM(2013) 169 final). Berlin: SRU. Comment on Environmental Policy 12.

SRU (2012): Umweltgutachten 2012. Verantwortung in einer begrenzten Welt. Berlin: Erich Schmidt.

SRU (2011): Wege zur 100 % erneuerbaren Stromversorgung. Sondergutachten. Berlin: Erich Schmidt.

Stigson, B., Babu, S. P., Bordewijk, J., Haavisto, P., Moosa, V., Morgan, J., Osborn, D., Yun, S.-J. (2013): Sustainability – Made in Germany. The Second Review by a Group of International Peers, commissioned by the German Federal Chancellery. Berlin: Rat für Nachhaltige Entwicklung. texte 44.

Stigson, B., Babu, S. P., Bordewijk, J., O'Donnell, P., Haavisto, P., Morgan, J., Osborn, D. (2009): "Sustainability Made in Germany". We know you can do it. Peer Review der deutschen Nachhaltigkeitspolitik. Berlin: Rat für Nachhaltige Entwicklung.

SVR (Sachverständigenrat zur Begutachtung der Gesamtwirtschaftlichen Entwicklung) (2012): Stabile Architektur für Europa – Handlungsbedarf im Inland. Jahresgutachten 2012/2013. Wiesbaden: SVR.

TNS Infratest (2013): Deutscher Energiekompass 2013. Eine Untersuchung von TNS Infratest im Auftrag des If.E zur Energiewende. München, Hannover: TNS Infratest, Innovationsforum Energiewende. http://www.innovationsforum-energiewende.de/wp-content/uploads/2013/08/130904_Abschlussbericht_DEK20131.pdf (10.09.2013).

WBGU (Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen) (2011): Welt im Wandel. Gesellschaftsvertrag für eine Große Transformation. Hauptgutachten. Berlin: WBGU.

Wunderlich, C. (2012): Akzeptanz und Bürgerbeteiligung für Erneuerbare Energien. Erkenntnisse aus Akzeptanz und Partizipationsforschung. Berlin: Agentur für Erneuerbare Energien. Renews Spezial 60.

Zelli, F., Asselt, H. van (2013): Introduction. The Institutional Fragmentation of Global Environmental Governance: Causes, Consequences, and Response. Global Environmental Politics 13 (3), S. 1–13.

Zürn, M., Faude, B. (2013): Commentary: On Fragmentation, Differentiation, and Coordination. Global Environmental Politics 13 (3), S. 119–130.

Ministry of the Environment, Nature Conservation and Nuclear Safety

Charter Establishing an Advisory Council on the Environment at the Ministry of the Environment, Nature Conservation and Nuclear Safety

1 March 2005

Article 1

The Advisory Council on the Environment has been established to periodically assess the environmental situation and environmental conditions in the Federal Republic of Germany and to facilitate opinion formation in all government ministries, departments and offices that have jurisdiction over the environment, and in the general public.

Article 2

(1) The Advisory Council on the Environment shall comprise seven members who have special scientific knowledge and experience with respect to environmental protection.

(2) The members of the Advisory Council on the Environment shall not be members of the government, a legislative body of the government or the civil service of the Federal Government, state governments or of any another public entity, universities and scientific institutes excepted. Further, they shall not represent any trade association, or employers' or employees' association, nor shall they be in the permanent employ of or party to any non-gratuitous contract or agreement with any such association, nor shall they have done so in the 12 months prior to their appointment to the Advisory Council on the Environment.

Article 3

The task with which the Advisory Council on the Environment is charged shall be to describe the current environmental situation and environmental trends, and to point out environmentally related problems and suggest possible ways and means of preventing or correcting them.

Article 4

The Advisory Council on the Environment is charged exclusively with the mission stated in this charter and may determine its activities independently.

Article 5

The Advisory Council on the Environment shall provide the federal ministries whose area of competence is involved, or their representatives, the opportunity to comment on important issues that emerge as a result of the Council's performing its task, and to do so before the Council publishes it reports on these issues.

Article 6

The Advisory Council on the Environment may arrange hearings for federal offices and *Länder* offices concerning particular issues, as well as invite the opinions of non-governmentally affiliated experts, particularly those who represent business and environmental associations.

Article 7

(1) The Advisory Council on the Environment shall draw up a report every four years, to be submitted to the Federal Government in May. The report is to be published by the Council.

(2) The Advisory Council on the Environment may make additional reports or statements on particular issues. The Federal Ministry of the Environment, Nature Conservation and Nuclear Safety may commission the Council to make further reports and statements. The Council is to submit the reports and statements mentioned in clauses (1) and (2) of this article to the Federal Ministry of the Environment, Nature Conservation and Nuclear Safety.

Article 8

(1) Upon approval by the Federal Cabinet, the members of the Advisory Council on the Environment shall be appointed by the Federal Ministry of the Environment, Nature Conservation and Nuclear Safety for the period of four years. Equal participation of women and men shall be aimed for as provided for in the law governing appointments to federal bodies (the *Bundesgremienbesetzungsgesetz*). Reappointment shall be possible.

(2) The members of the Council may give written notice to resign from the Council to the Federal Ministry of the Environment, Nature Conservation and Nuclear Safety at any time.

(3) Should a member of the Council resign before serving the full four-year period, a new member shall be appointed for the remaining period. Reappointment shall be possible.

Article 9

(1) The Advisory Council on the Environment shall elect, by secret ballot, a chairperson who shall serve for a period of four years. Re-election shall be possible.

(2) The Advisory Council on the Environment shall set its own agenda, which shall be subject to approval by the Federal Minister of the Environment, Nature Conservation and Nuclear Safety.

(3) Should a minority of the members of the Council be of a different opinion from the majority of the members when preparing a report, they are to be given an opportunity to express this opinion in the report.

Article 10

The Advisory Council on the Environment shall be provided with a secretariat to assist it in the performance of its work.

Article 11

The members of the Advisory Council on the Environment and its secretariat are sworn to secrecy as concerns the Council's advisory activities and any advisory documents that it classifies as confidential, and as concerns any information given to the Council that is classified as confidential.

Article 12

(1) The members of the Advisory Council on the Environment are to be paid a lump-sum compensation and to be reimbursed for their travel expenses. The amount of compensation and reimbursement shall be determined by the Federal Ministry of the Environment, Nature Conservation and Nuclear Safety, with the consent of the Federal Ministry of the Interior and the Federal Minister of Finances.

(2) The financial funding for the Advisory Council on the Environment shall be provided by the Federal Government.

Article 13

To accommodate the new date of submission to the Federal Government under Article 7 (1), the Federal Ministry of the Environment, Nature Conservation and Nuclear Safety may extend the appointments of the Council members in office when this Charter enters into force to 30 June 2008 without requiring the approval of the Federal Cabinet.

Article 14

The Charter Establishing an Advisory Council on the Environment at the Federal Ministry of the Environment, Nature Conservation and Nuclear Safety (GMBl. 1990, no. 32, p. 831), issued on 10 August 1990, is superseded by this charter.

Berlin, 1 March 2005

The Federal Minister of the Environment, Nature Conservation and Nuclear Safety

Jürgen Trittin

Publications

Environmental Reports, Special Reports, Research Materials and Statements

The Council's environmental reports and special reports published **from 2007** onwards are available both from book shops and directly from the publisher: Erich-Schmidt-Verlag GmbH und Co., Genthiner Str. 30 G, 10785 Berlin, Germany.

They are also available online at http://www.esv.info/neuerscheinungen.html.

Environmental reports and special reports published **between 2004 and 2006** are available from book shops or from the publisher: Nomos-Verlagsgesellschaft Baden-Baden; Postfach 10 03 10, 76484 Baden-Baden, Germany or www.nomos.de.

Bundestagsdrucksachen are available from: Bundesanzeiger Verlagsgesellschaft mbH, Postfach 100534, 50445 Köln, Germany or www.bundesanzeiger.de

Most publications issued since 1998 are available as PDF files and can be downloaded from the SRU website (www.umweltrat.de).

SRU (2008): **Environmental Protection in the Shadow of Climate Change.** Environmental Report. Berlin: SRU.

SRU (2011): **Pathways Towards a 100 % Renewable Electricity System.** Special Report. Berlin: SRU.

SRU (2012): **Responsibility in a Finite World.** Environmental Report. Berlin: SRU.

SRU (2013): **Fracking for Shale Gas Production**. Statement No. 18. Berlin: SRU.

SRU (2013): **An Ambitious Triple Target for 2030. Comment to the Commission's Green Paper "A 2030 Framework for Climate and Energy Policies".** Comment on Environmental Policy No. 12. Berlin: SRU.

Members

Prof. Dr. Martin Faulstich
(Chair)
Professor of Environmental and Energy Technologies
at Clausthal University of Technology,
Director of CUTEC Institute of Environmental Technology

Prof. Dr. Karin Holm-Müller
(Deputy Chair)
Professor of Ressource and Environmental Economics
at the Faculty of Agriculture
at Rheinische Friedrich-Wilhelms-Universität Bonn

Prof. Dr. Harald Bradke
Head of the Competence Center Energy Technology
and Energy Systems at the Fraunhofer Institute for Systems
and Innovation Research ISI in Karlsruhe

Prof. Dr. Christian Calliess
Professor of Public Law, Environmental Law and
European Law
Department of Law, Freie Universität Berlin

Prof. Dr. Heidi Foth
Professor of Environmental Toxicology and
Director of the Institute for Environmental Toxicology
at the Martin Luther University in Halle-Wittenberg

Prof. Dr. Manfred Niekisch
Professor for International Nature Conservation
at Goethe University of Frankfurt and
Director of Frankfurt Zoo

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

German Advisory Council on the Environment

Secretariat
Luisenstraße 46
10117 Berlin

Phone: +49 30 263696-0
E-Mail: info@umweltrat.de
Internet: www.umweltrat.de