Emissions Trading and Innovation in the German Electricity Industry

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Executive Summary

One major objective of the introduction of emissions trading in the European Union was to promote innovation towards mitigating climate change. Focusing on the German electricity industry, the extent to which this objective has been achieved up to now and how the design of the trading scheme could be improved towards achieving the intended objective shall be analyzed in this thesis.

These questions are tackled in the thesis from a theoretical and an empirical perspective. The theoretical analysis was largely based on neoclassical environmental economics by using an algebraic model which allowed for comparison of the relevant companies' profits under various configurations of the analyzed design options. The empirical analysis was grounded on two surveys of the electricity industry – one before the start of emissions trading, the other after two and a half years of experience – which enabled identification of the concrete changes in the companies' perceptions and attitudes towards innovation due to the introduction of emissions trading.

The analysis reveals some indications that the instrument has basically functioned as originally intended although it has certainly not yet developed its full potential in terms of promoting innovation towards a more climate friendly electricity system. From an environmental innovation perspective the following improvements are essential: 1) Closure provisions should be abolished as soon as possible because they basically extend the lifetime of old installations and thus rather delay innovation. 2) Fuel-specific allocation to new entrants should also be abandoned since it eliminates – at least partly – the incentives to shift investments towards technologies which use more carbon friendly fuels such as natural gas or biomass. 3) Introducing full auctioning for the electricity industry would remedy both of the above-mentioned weaknesses and at the same time eliminate the windfall profit generated by free allocation of allowances. 4) Innovation incentives could also be enhanced by improving the investment stability. For this purpose several commitment periods should be agreed in advance so that investors always have a clear perspective of at least 15 to 20 years.

The draft directive for the review of the EU ETS presented by the Commission in January 2008 has already taken on board some of these suggestions, most notably the transition from free allocation to auctioning, which should be the rule for the entire electricity industry from 2013 onwards. It can be expected that the innovation incentives of the EU ETS will be boosted considerably after the Council of Ministers and the European Parliament agreed upon the amendment of the EU ETS Directive in December 2008.

JEL Classification: O31, O33, Q48, Q54, Q55, Q58, Y40

Key words: Climate policy, emissions trading, allocation, new entrants, closure rules, banking, electricity industry, innovation, technological change, Europe, Germany

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Glossary

°C	Degree Celsius
€	Euro
AAU	Assigned Amount Unit
AEEI	Autonomous energy efficiency improvement indicator
AEG	Allgemeine Elektriztäts-Gesellschaft (General Electric Company)
AGFW	AGFW - Der Energieeffizienzverband für Wärme, Kälte und KWK e. V. (Association of CHP operators)
BAT	Best Available Technology
BEW	Berliner Electrizitäts-Werke (Berlin Electricity Plants)
CAES	Compressed air energy storage
CCGT	Combined cycle gas turbine
CCS	Carbon capture and storage
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CHP	Combined heat and power
CITL	Community Transaction Log
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
DEHSt	Deutsche Emissionshandelsstelle (German Emissions Trading Authority)
e.g.	exempli gratia
EC	European Community
ECCP	European Climate Change Programme
EDF	Environmental Defense Fund
EEG	Erneuerbare Energien Gesetz (Renewable Energy Sources Act)
EPER	European Pollutant Emission Register
ERU	Emission Reduction Unit
etc.	et cetera
ETG	Emissions Trading Group
EU	European Union
EU ETS	European Union Emissions Trading Scheme
EU-25	European Union with 25 Member States, as of 1 May 2004
EUA	European Union Allowances
F-gases	Fluorinated gases
FOC	First order condition
g	gram

GDP	Gross domestic product
GHG	Greenhouse gas
GJ	Gigajoule
GW	Gigawatt
GWh	Gigawatt hour
h.p.	horsepower
Hz	Hertz
i.e.	it est
IETA	International Emissions Trading Association
IGCC	Integrated gasification combined cycle
JI	Joint Implementation
KfW	Kreditanstalt für Wiederaufbau
kW	Kilowatt
kWh	Kilowatt hour
KWKG	Kraft-Wärme-Kopplungsgesetz (Cogeneration or CHP law)
Mt	Megaton
MW	Megawatt
MWh	Megawatt hour
N_2O	Nitrous oxide
NAP	National Allocation Plan
NGOs	Non-governmental organization
NO_X	Nitrogen oxide
NRW	Northrine Westphalia
PC	Pulverized coal
PCF	Prototype Carbon Fund
POLES	Prospective Outlook on Long-term Energy Systems (World Energy Model)
R&D	Research & development
RECLAIM	Regional Clean Air Incentives Market
SO_2	Sulfur dioxide
SSW	Siemens-Schuckertwerke (Siemens Schuckert Plants)
StEW	Städtische Elektrizitäts-Werke (Municipal Electricity Plants)
t	Ton
TIPS	Transformation and Innovation in Power Systems
TWh	Terawatt hour
UK	United Kingdom
UNFCCC	United Nations Framework Convention on Climate Change
US	United States
V	Volt
VDEW	Verband der deutschen Elektrizitätswirtschaft (Association of the German Electricity Industry)
VGB	VGB PowerTech e.V. (Association of large power plant operators)
VOC	Volatile Organic Compound

1 Introduction

1.1 Motivation

Since the European Council of Environmental Ministers agreed in early December 2002 on a joint position concerning an emissions trading scheme within energy intensive industry, it was clear that the German electricity industry would be confronted with this new climate mitigation policy instrument. According to the title of a brochure which the European Commission published shortly before the start of the trading scheme in December 2004, one major aim of the European Union Emissions Trading Scheme (EU ETS) is to “promot[e] global innovation to combat climate change” (DG ENV 2004). And in fact, the pace of technological advance was described at a much earlier date as “the single most important criterion on which to judge environmental policies” (Kneese, Schultze 1975: 82).

Therefore, this thesis focuses on the design options of emissions trading which determine the innovation incentives of the EU ETS in the German electricity industry. The electricity industry is to be understood in this context as the core power supply industry, i.e. all utilities which provide electricity to private households or industrial customers including auto-producers of electricity. It does not include the electrical industry which provides equipment for power supply but is not, however, directly covered by the EU ETS. The core electricity industry alone accounts for more than one third of the German CO_2 emissions and this share is increasing – despite the declining absolute emissions of the sector. The objective of this thesis is to identify and assess the innovation incentives induced in the German electricity industry by different configurations of design options in order to provide scientific knowledge relevant to the further development of emissions trading schemes.

1.2 Background

Since the publication of the third report of the first Enquête Commission of the German Parliament “Preventive Measures to Protect the Earth's Atmosphere” (“Vorsorge zum Schutz der Erdatmosphäre”, (Deutscher Bundestag 1990) at the latest, the issue of climate change has been and is widely perceived – in Germany by all political parties and the population at large – as a global threat. It is also basically accepted that policies and measures have to be undertaken to avoid, or at least reduce, the consequences of climate change.

In 1990, the German government committed itself to reducing CO_2 emissions by 25% up to 2005 compared with the level of 1990.[1] Two years later, the first Earth Summit was held in Rio de Janeiro where the United Nations Framework Convention on Climate Change (UNFCCC) was agreed upon, which has been signed by 192 nations in

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[1] Decision of the German government as of 13 June 1990 (Müller 1996).

the meantime.[2] During the first Conference of the Parties (COP) to this Convention 1995 in Berlin, the commitment of the German government was reinforced.

Intensive international consultations thereafter led to the Kyoto Protocol, which was agreed upon at the third Conference of the Parties (COP 3) in Kyoto in 1997. In the Kyoto Protocol, 38 industrialized countries and countries with economies in transition (so-called *Annex I Parties*) committed themselves for the first time to binding targets to reduce or limit their emissions of a “basket” of six greenhouse gases. 181 nations have ratified the protocol.[3] It entered into force on 16 February 2005 – 90 days after at least 55 nations covering at least 55% of the CO_2 emissions in 1990 had ratified the protocol.

The Kyoto Protocol was not only epoch-making in terms of its legally binding targets but also in terms of the new instruments which were introduced internationally through this protocol. Several of the countries which were participating in Kyoto negotiations were only willing to agree to such a protocol if a certain degree of flexibility to fulfil the commitments was incorporated therein. For this reason, three so-called flexible mechanisms were developed:

- *Emissions Trading* enables Annex I Parties to sell units of their assigned amounts of greenhouse gas emissions if they do not require them to fulfil their target during the first commitment period (2008 - 2012). These units may be bought by Annex I Parties which cannot cope with their commitments.
- *Joint Implementation* (JI) allows Annex I Parties to finance and perform greenhouse gas mitigating projects in other Annex I Parties. Emission reduction units (ERUs) generated through these projects will be transferred to the accounts of the financing country and, thus, help to fulfil its commitment.
- The *Clean Development Mechanism* (CDM) was suggested by Brazil in order to enable the developing countries (non-Annex I Parties) to participate in global efforts to mitigate greenhouse gas emissions. The basic idea of this instrument is that Annex I Parties finance and carry out greenhouse gas mitigation projects in non-Annex I Parties and, thus, contribute to both the reduction of global greenhouse gas emissions and sustainable development in the developing countries. Annex I Parties which carry out such projects can use the certified emission reductions (CER) to comply with their commitments under the Kyoto Protocol.

Germany and the European Union ratified the Kyoto Protocol in April and June 2002 (2002/358/CE), just before the second Earth Summit in Johannesburg in the summer of 2002. All Member States of the European Union as well as the European Union itself, which is also a Party to the Protocol, have committed themselves to reducing greenhouse gas emissions during the first commitment period from 2008 to 2012 by 8% compared with 1990 levels.

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[2] http://unfccc.int/essential_background/convention/status_of_ratification/items/2631.php

[3] http://unfccc.int/kyoto_protocol/status_of_ratification/items/2613.php

Keeping in mind both the options and the necessity to deal with flexible instruments and in particular with emissions trading, Denmark and the United Kingdom decided to establish domestic emissions trading schemes long before the start of the first commitment period of the Kyoto Protocol. In early 2001, the Commission of the European Union was confronted with four important developments:

- Total greenhouse gas emissions were decreasing and were more or less in line with the linear target for 2000. However, CO_2 emissions had started to grow again and projections for several Member States and EU-wide projections indicated the possibility that the EU might miss its Kyoto target (-8 %) unless additional measures to reduce greenhouse gas emissions are implemented (COM(2001) 708 final; Gugele, Ritter 2001).
- Discussions on effective instruments to mitigate greenhouse gas emissions on an EU-wide level such as an energy or CO_2 tax were stalled for years due to unanimity requirements for decision making with respect to unified taxation in the EU. It was not likely that an agreement on an effective CO_2 or energy tax could be reached soon enough to cope with the Kyoto requirements.
- In 2001, President Bush declared that the United States of America, the greatest single emitter of greenhouse gases, will not ratify the Kyoto Protocol as it is “fatally flawed” (The White House 2001). The new US government of that time expected unacceptable financial burdens for their economy through the fulfilment of the Kyoto Protocol.
- Denmark and the United Kingdom had already begun implementing emissions trading schemes. Whereas the Danish scheme covered only electricity generation, the British scheme was more comprehensive as it included several sectors on a voluntary basis and enables greenhouse mitigation projects to be conducted in almost all parts of the economy and in other countries. Other countries were considering the implementation of domestic emissions trading schemes to cope with their targets.[4] Several domestic schemes would have made it even more difficult to set up a harmonised EU-wide emissions trading scheme in the future.

Considering these trends, the Commission started to develop a draft directive on emissions trading in early 2001 which was presented just before the seventh Conference of the Parties (COP7) in Marrakech in October 2001. The idea of the proposed directive was to overcome the obstacles mentioned above and react to the developments which are unfavourable for compliance with the Kyoto commitments. The implementation of this proposal was expected to be more likely because, in contrast to CO_2 or energy taxes, the decision on this directive did not require unanimity.

Moreover, it was believed that this initiative would avoid other Member States intensifying their plans to implement domestic trading schemes which would make the development of an EU-wide emissions trading scheme prior to the first commitment period of the Kyoto Protocol from 2008 to 2012 even more difficult. Last but not least, the pres-

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[4] For example, Austria (Kletzan et al. 2002) or the Netherlands (Kolk, Harmsen 2002).

entation of this proposal had to be interpreted as a sign for the United States government as it showed that the European Union felt committed to the Kyoto Protocol even if the US withdrew from this process. Progress in multilateral processes seemed to be possible even if the United States pursues unilateral strategies.

The proposed directive was criticized strongly, in particular by Germany because its business associations feared that the Emissions Trading Directive would put extra burdens on German companies covered by the proposed trading scheme. These companies proposed, instead, to stick to their voluntary agreements with the German government to reduce CO_2 emissions by 45 million tonnes until 2010 compared to emissions in 1998, which is equivalent to -27 % compared to 1990 levels. However, after more than a year of intensive discussions, the Council of Environmental Ministers agreed upon a joint position in early December 2002, thereby starting the legislative process which resulted in the adoption of the so-called Emissions Trading Directive (2003/87/EC) on 13 October 2003.

This decision established a common emissions trading scheme for energy-intensive industries in Europe. Nevertheless, the Member States had some design flexibility in transposing this directive into national law. This design flexibility leads directly to the centre of the problem that forms the subject of this thesis: different configurations of the individual design options of an emissions trading regime will create different incentives for individual actors affected by the scheme and, thus, influence decisions taken by them. As a consequence, different configurations will also create different incentives for innovations and technological change in the electricity sector. Some configurations may induce innovations which are more favourable for a sustainability orientated transformation of the electricity system than others. Some configurations of the design options may stimulate sustainable transformation but others might obstruct or at least hinder such transformation.

1.3 Hypothesis

The basic hypothesis of this thesis is that *different configurations of design options of an emissions trading scheme create different innovation incentives and, thus, influence the level and structure of innovation and technological change in the electricity industry.* Central design options that could initiate or delay innovation and technological change are:

- Rules on the method of allowance allocation: Whether allowances are auctioned to incumbent installations or allocated free of charge according to their historic emissions in a selected base year (grandfathering) might influence innovation incentives, although only indirectly. However, whether new installations have to buy allowances or receive them free of charge would create substantially different innovation incentives.
- Regulations on the validity of allowances in the case of plant closure: allowances obtained via free allocation might expire if the plant to which they are allocated is closed during the commitment period. Alternatively, they might also keep their value

for a certain time after plant closure, at least until the end of the commitment period. The latter option is often criticized as a “plant closure premium”. However, it gives notable incentives to companies to close down greenhouse gas intensive power plants and replace them with newer, less greenhouse gas intensive ones. The first option, in contrast, would give an incentive to extend the lifetime of such plants as they guarantee the provision with sufficient allowances in the case of freely allocated allowances.

- Regulations on the transferability of allowances between commitment periods (banking and borrowing): Certain innovations might be impeded if the transference of allowances from a current period to a subsequent period is not permitted. This might be the case if a company implements an innovative technology which reduces emissions to a larger extent than necessary to comply with the companies commitments. In this case, the company may be forced by a non-banking regulation to sell allowances instead of using them to comply with its future obligation. If in this situation the market price of allowances is expected to be low, this innovation might not be implemented or at least substantially delayed although it might be economically feasible in the long run.
- Last but not least, the incentives for innovation and technological change might depend on the quantitative targets of an emissions trading regime: stronger targets will induce higher prices for greenhouse gas allowances and, thus, possibly induce more innovations.[5]

The ultimate aim of this thesis is to identify those configurations of design options which most effectively stimulate innovations towards a more sustainable electricity system.

1.4 Approach

Different methodologies were applied to scrutinize the basic hypothesis. First of all, a comprehensive analysis is provided of the perception of the concept of innovation in the relevant literature in order to develop a clear definition of innovation in the context of this thesis (chapter 2). After a review of the most relevant aspects of economic innovation theory, specific focus is laid on innovation in the electricity industry and its particularities in comparison to innovation intensive sectors such as car manufacturing or the chemical industry. The aim is to identify indicators which enable the detection of innovation incentives in the further steps of the analysis.

Based on this concept of innovation, the analysis then concentrates on the core research questions of the thesis: Does emissions trading really promote innovation and which design options and configurations are the most relevant in terms of innovation in

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[5] The different categories described above (allocation, banking, targets, etc.) which determine innovation incentives are usually characterized as “design options” whereas the various alternatives within each design option (e.g. grandfathering, auctioning, benchmarking for allocation) are usually described as “configurations”.

the electricity industry? After a short description of the history of emissions trading in general and the emergence and basic framework of the EU ETS, the research question is first addressed from a theoretical perspective (chapter 3). The innovation incentives of several design options and their potential configurations are derived by means of an algebraic profit maximisation model which allows for identification of whether individual companies are encouraged to innovate by the respective configuration or not. Particular focus is placed on the impact of the overall cap, of several allocation configurations, of the global climate change framework and its time frame as well as banking issues.

Thereafter the core research questions are addressed from an empirical perspective. An important element of the research approach was a survey of the electricity industry (chapter 4). The main objective of this survey was to identify the innovation strategies which companies of the electricity industry developed in reaction to the introduction of the EU ETS. For this purpose the companies were interviewed twice: once directly before the start of the EU ETS in the autumn of 2004 and once in the summer of 2007 after first experiences with the new instrument had been gained. As is the case with panel analysis, the set of questions and covered companies were kept rather similar in order to enable the detection of changes in perceptions and attitudes towards innovation in a horizontal comparison. The surveys were focused on changes in the companies' innovation strategies in general, on institutional changes, changes in the operation of power plants, changes in their investment strategies and on the companies' preferences with regard to the various design options and their potential configurations.

Finally, the issue of whether emissions trading has really encouraged innovation towards a more sustainable electricity system in Germany to date is examined (chapter 5). This analysis was based on data available up to now, which could provide indications of the impact of the EU ETS on innovation. An overview of allowance allocation and the corresponding developments of the carbon market and an analysis of various indicators for short-term impacts on the operation of power plants are provided. With regard to investment decisions, the analysis is more difficult. After only three years of experience with emissions trading, investment decisions are still very much in flux and may change substantially once the final decision on the review of the EU ETS or on the post 2012 climate regime has been taken. Therefore, the analysis can only detect first indications of the impact of emissions trading on long-term investment decisions.

The thesis concludes with a summary of the main results and a discussion of the innovation incentives induced in the German electricity industry by emissions trading (chapter 6). The final chapter also includes additional key findings and some deliberations on further research.

2 Innovation – concept and perception

To evaluate the innovation incentives and the innovation effects of emissions trading it is important to have a clear definition of the term "innovation". Innovation is a complex issue and the term is used for many different purposes and under various circumstances. The aim of this chapter is to clarify the understanding of innovation referred to in this thesis.

The chapter starts with a literature review in which the most relevant branches of economic innovation theory are summarized (section 2.1) and a description of the broad innovation concept on the basis of which the further analysis is constructed (section 2.2). Since the electricity industry is a service sector, its innovation processes cannot be directly compared with innovation processes in innovation intensive sectors like car manufacturing or chemistry. The particularities, mainly the division of responsibility for the entire innovation process between the core electricity industry and the manufacturers of generation and transmission equipment and technology, are addressed in section 2.3 of this chapter. The chapter concludes with an outlook on the approaches which are used to analyze the electricity industry's innovation processes in the further sections of this thesis (section 2.4).

2.1 Innovation in economic theory

The foundations of an economic theory of technological change can be traced back to Schumpeter (1942; 1939) who viewed innovation as the hallmark of modern capitalism. The company and above all the "creative inventor" which develops inventions into marketable products, driven by the perspective that the new product or process enables it to realize temporary extra profits until they are eliminated upon the emergence of imitators, lie at the centre of Schumpeter's approach. He termed this continuous process "creative destruction" (Jaffe et al. 2001: 3).

Schumpeter differentiates three stages up to the market penetration of a new product or production procedure, which became the typical characteristics of the process of technological change (Jaffe et al. 2001: 4):

- The *invention* of a scientifically or technically new product or production procedure is located at the beginning of this process.
- Many inventions never reach the stage of *innovation* in which inventions are developed further to marketable products or production processes. In this respect, invention is a necessary, but by no means sufficient, condition for a complete innovation process. Hence, a company can also carry out innovations without having its own inventions by developing to market maturity familiar ideas that have not yet been marketed.
- In the *diffusion* stage an innovation is then gradually adapted by companies or consumers and is made available for use in various ways.

Building upon Schumpeter's concept, research approaches emerged in the 1940s and 1950s which surmised a positive relation between the market power of a company and its innovation activity (Mansfield 1968; Scherer 1965). It was conjectured that only large companies would be in a position to finance the high – and rising – costs of research and development (R&D). The reason given for this was, amongst others, that the research costs contain a large share of fixed costs which can most likely be absorbed by large companies since increasing returns to scale can be generated in certain areas within them (production, distribution, etc.). On this basis, the assumption was deduced that innovation activities increase disproportionately with company size and increasing company concentration. However, in empirical analyses, only a weak relation could be proven between company size and innovation indicators (e.g. expenditure on R&D per unit of sales) (Hillebrand et al. 2000: 71-72).

Schumpeter's linear model of innovation also leads to technology-push and supply-push concepts (Bush 1945). The idea of demand-pull, i.e. demand for new services as a stimulator of inventive activity, is directly opposed to this (Griliches 1957; Schmookler 1966).

In neoclassical theory, however, innovation as a cause of structural change and economic growth was still being treated as exogenous. The effects of technical progress on long-term economic growth are noted, but are rarely interpreted. Technical progress falls to a certain extent "like manna from heaven" (Freeman 1994: 463). Its causes and effects are not primarily analyzed further. The key question is under which conditions existing technical knowledge is used (Hillebrand et al. 2000: 69-70). Only upon the arrival of new growth theory (section 2.1.1) do approaches emerge with which an endogenous explanation of technological progress and innovation in neoclassical models is attempted.

2.1.1 Autonomous innovation versus induced technical progress

It was Solow (1957) who founded the neoclassical theory of technological progress and economic growth. Solow demonstrated that economic growth can only partly be explained by the increasing use of input factors (capital and labor). The remaining share of economic growth is due to an unexplained residuum. He termed this residuum "technological progress". His empirical analyses demonstrated that technological change (which had been treated as residual in production functions up to that time) was a more important driver of growth than increases in labor and capital productivity. Later on Stoneman (1987) showed that about 40% of the total increase in US national income is due to technological change.

However, technological progress and technological knowledge were still regarded as a public good which emerge externally to the economy. This notion allows for the usual assumptions of neoclassical theory (perfect competition, optimizing - and thus rational - behavior, efficient equilibriums) to be retained. In such a neoclassical world, all markets stand in equilibrium, i.e. they work efficiently. In this sense, regulation or policy is not able to exercise any positive influence on the economy, technological progress or the like in Solow's model. This viewpoint dominated economic theory up to the 1970s and beyond.

In the 1980s this viewpoint changed upon the emergence of new growth theory (Lucas 1988; Romer 1986; 1990; amongst others). Technological progress is explicitly regarded as economic (investment) activity in new growth theory, i.e. technological progress or innovations originate endogenously of the optimizing behavior of economic subjects. Technological knowledge or innovation is characterized as a non-competing public good, the use of which is not or is only partly excludable (e.g. by means of patents). New growth theory thus differs from the neoclassical equilibrium concept. For example, several endogenous growth models (e. g. Romer 1990) revealed that the market invests insufficiently in R&D. Under the assumption of perfect competition and optimizing (profit-maximizing, rational) economic subjects, policies supported by R&D can thus trigger off new optimizing behavior, leading to more investments in R&D and welfare increases as well (see also Spence 1984, amongst others).

Based on Hicks' (1932) considerations, Ahmad (1966), Kamien and Schwartz (1968) and Binswanger (1974) highlighted the endogenous character of technological change independently of the new growth theory (Jaffe et al. 2002) and further developed the induced innovation hypothesis which explicitly asserts the relation between regulation and technological progress: policy interventions which induce changes in relative factor prices might spur innovation directed to economizing the use of the factor which has become relatively expensive. Löschel (2001) differentiates three forms by means of which endogenous technological progress could be embedded in economic models:

(1) investments in R&D,

(2) spillover effects of R&D (positive technological externalities) and

(3) technological learning (learning by doing, learning by using, learning by learning).

In addition, the induced innovation approach contains elements of demand-pull and supply-push, i.e. innovations are requested by the market (demand) or are supported on the supply side (e.g. by relevant policy provisions such as subventions, technology standards, etc.).

The understanding of technological progress as endogenous can, in principle, strengthen the impact of policy instruments. This, however, raises the question of possible 'crowding out' effects (or opportunity costs): does the stimulation of innovations (through policy) in a particular area or technology (e.g. CO_2 abatement) lead to a reduction of innovations in other sectors? The question of net effects cannot be unambiguously clarified. In the context of climate protection, Goulder and Schneider (1999) arrive at a positive net effect whilst Nordhaus (2002) argues that the crowding out effect exceeds the benefit of the CO_2 abatements. In this context, Goulder und Schneider also particularly take into account positive spillover effects of investments in R&D (Griliches 1992; see also Jaffe 1998). The knowledge acquired or the innovation handled by a company also benefits other companies (intra-sectorally, inter-sectorally, regionally and globally). Usually there is talk of a negative spillover (or leakage) if a company relocates its production (as a result of policy interventions) from the domestic country to abroad in order to evade the increased costs. This effect likewise needs to be taken into consideration; in most cases, however, the positive effect is dominant in empirical analyses of induced innovation literature (Grubb, Koehler 2000).

From the above, a number of potential influences on the dynamics of innovation may be derived. A policy may induce innovation through the following mechanisms:

(1) substitution effects induced by changes in relative factor prices when, for example, policy makes energy comparatively more expensive, which is then substituted by comparatively cheaper ones (e.g. labor or material).

(2) direct policy induced technical progress, when innovation is induced by new basic political conditions (e.g. in the form of additional R&D in the area which has become comparatively more expensive or is more strictly regulated), and

(3) autonomous technical progress (i.e. the trend that exists independently of policy changes) (DeCanio et al. 2000).

With respect to empirical evidence and economic modeling of technological change, the induced innovation hypothesis represents a particular challenge. The endogenization of technical progress leads to non-linear models and thus to more difficult and more complex calculation algorithms, which can lead to several optima that are not clear-cut. For this reason many empiricists prefer exogenous representations of innovation or develop so-called hybrid approaches. Exogenous approaches also encompass – alongside constant representations of technological progress, e.g. in the form of a constant productivity growth of 2-3% per year (Azar, Dowlatabadi 1999), or a so-called autonomous energy efficiency improvement indicator (AEEI) in energy and climate protection (Manne, Richels 1992; Nordhaus 1994) – an assumption on new future technologies (backstop technologies) that will become competitive at a certain point in time and hence are available as a further option.

2.1.2 Market forms and innovation incentives

In parallel to the above mentioned research by Scherer (1965) and Mansfield (1968) on size and market power of companies and their innovation activities, Kantzenbach (1967) analyzed the relation between market forms and the innovation incentives which can be derived from them. Under the terms of his influential model for competition policy in Germany (Fees 1997: 451), a so-called "wide monopoly" is optimal in respect of the incentives for technical progress.

To this end, Kantzenbach considers the competition intensity of various market forms. He understands "competition intensity" as the speed with which innovation-related extra profits are competed away by market participants who are already active in the market or are new. The competition intensity is optimal at the point at which technical progress is maximized.

In the process, Kantzenbach differentiates between potential and actual competition intensity. The difference between the two can be found in assumptions on the cooperative behavior of companies: in the case of the concept of potential competition intensity, any sort of cooperative behavior is excluded whilst explicit or implicit cartel-like behavior is assumed in actual competition intensity.

To determine competition intensity, Kantzenbach observed the number of sellers and the degree of product heterogeneity. He assumes that competition intensity decreases when the number of sellers and the degree of heterogeneity increase: if there are only a few sellers operating in the market, and the product is also very homogenous (e.g. electricity), each seller has to intently observe the other competitors since even small improvements in the situation of a competitor can have radical effects on one's own company. However, if the number of sellers is very high, the doubling of the market share of a competitor who has a small market share only minimally affects one's own company. By the same token, the competition amongst manufacturers of non-homogenous products is lower. The competition intensity is thus low in both of the latter cases.

The potential competition intensity is at its highest in the case of a duopoly with homogenous products (homogenous duopoly). However, at the same time, the actual competition intensity is next to nothing since parallel behavior can arise in a duopoly even without explicit prior agreements. In the case of a high number of competitors and a high degree of product heterogeneity (heterogeneous polypoly), the actual competition intensity is commensurate with the potential competition intensity since cartel-like behavior does not occur. On this basis, Kantzenbach draws the conclusion that the competition intensity is greatest in a wide oligopoly with moderate product differentiation.

Kantzenbach explains the relation between competition intensity and technical progress using the notion of innovation propensity and innovation possibilities. The longer the realization of extra profits can be sustained by cost reductions and the greater the loss from dormant innovations, the greater is the propensity to innovate. The former is the case in a climate of low competition intensity; the latter is the case with relatively homogenous products. As a result, the innovation trend is, in turn, greatest in a wide oligopoly. The innovation possibilities are determined by the profits and the greatest profits are to be found in a heterogeneous duopoly. The innovation trend in a duopoly is too slight, though. Overall, Kantzenbach comes to the conclusion that a wide oligopoly with moderate product differentiation optimizes innovation activity.

With regard to competition policy, it was thus deduced that fusions or company cooperation are supported in a heterogeneous polypoly; further concentration is forestalled in a wide oligopoly; and deconcentration by means of competition surveillance is to be aimed at in a tight oligopoly.

Electricity is on the one hand an absolutely homogeneous product. Since dormant innovations would thus result in substantial losses, the propensity to innovate should be comparatively high in the electricity sector. On the other hand, the German electricity market is dominated by four large companies which account for more than 80 %. According to Kantzenbach's model, such a market form does not allow for the sustaining of extra profits due to innovations, which again limits the propensity to innovate. In summary, it can be assumed that the electricity market does not provide optimal incentives for innovation since it does not perfectly match the criteria of a wide oligopoly with moderate product differentiation.

This approach was above all criticized for ignoring static allocation efficiency in its fixation on technical progress (dynamic efficiency). Furthermore, the product life cycle also has to be taken into account since innovations are likely in the case of new products whilst static allocation efficiency gains importance in the case of mature products. It was also criticized that the term “wide oligopoly” is so diffuse that operationalization is difficult in spite of the restriction of using only a small number of indicators (number of market participants, degree of product heterogeneity) (Fees 1997: 457-458).

2.1.3 Evolutionary concepts of innovation

At the end of the 1970s, new approaches rose out of criticism of the innovation concepts of the neoclassicists that are based on equilibrium models. These new approaches link up to the Schumpeter tradition and assumed that markets are constantly in a state of disequilibrium and that equilibrium phases occur only transiently. Particularly Nelson and Winter (1982) should be mentioned in this context; they developed an evolutionary theory of technical change and attempted to explain the process of technical change using the evolutionary concepts of variation, selection and stabilization made popular by biology research.

Nelson and Winter refer to a basic uncertainty concerning decisions on innovation, especially in the nascent phase in which it is often not possible to anticipate what the uses of the innovations will be. It was criticized that the consideration of optimization underlying neoclassical approaches is not suitable as an action model for situations “in which the ramifications of decisions are fundamentally unpredictable, as is generally the case with regard to innovation-related decisions ... Neoclassical economics does not address spontaneous development of coordination in terms of a disequilibrium. In contrast, the evolutionary concept approaches this question through reference to behavioral mutations (i.e. deviating actions on the individual level) and behavior selection” (Erdmann 1993: 5-6). Based on this observation, Nelson and Winter (1982) come to the conclusion that factors such as expected sales and expected profit cannot have the central role that is ascribed to them in neoclassical innovation research. Instead, how technicians view the feasibility of an innovation or what they believe should be analyzed more closely is regarded as being of decisive importance to the development of innovations (Neveling et al. 2002: 13-14). Nelson and Winter (1982) characterized a situation in which the attention and orientation of innovation and development activity are pre-selected as “technical regimes”. Within such a regime technical progress is heavily characterized in advance by the assessments of developers regarding the potential, the limitations and the untapped possibilities in specific trends.

Following on from Darwin’s evolutionary model, Nelson and Winter developed a phase-based model of technical innovations. In the first phase – the variation phase – a number of technical variants are developed. In the second phase – the selection phase – the variants to be developed further are filtered out from the first phase, taking into consideration the demand structures on the market as well as the non-economic factors like politics and culture.

Against the background of the great uncertainties regarding the potential outcome of investments in Research and Development (R&D), the companies are not able to take optimal decisions about R&D investments. Nelson and Winter (1982) thus take on the concept of bounded rationality from Simon (1947). According to this concept, the search for an optimal decision often calls for such high costs to compile and evaluate the relevant information that the additional costs in comparison to a sub-optimal decision can no longer be covered by the additional revenue. Thus, individuals and companies often act not as optimizers, but rather as “satisfiers” (Jaffe et al. 2002: 45), i.e. they abort the search for an optimal decision when the degree of goal achievement has exceeded a certain threshold. In accordance with Nelson’s and Winter’s (1982) evolutionary model of technological progress, companies therefore use rules of thumb and routines in addressing the question as to how much they should invest in R&D and the way in which they should search for new technologies. The empirical prognoses of the model correspondingly depend on the concrete set-up of the rules of thumb which the companies actually use (Winter et al. 2000).

On the basis of these considerations, Porter and van der Linde (1995) developed the theory that new environmental regulations do not always lead to higher costs. If companies do not optimize their innovation strategies in any case, there is – at least theoretically – the possibility that they will re-assess their strategies on the basis of the new external restriction and in the process discover new production procedures which are ultimately more cost-effective and more profitable. They claim that environmental regulation can then basically engender a “win-win situation” in which the environmental burden decreases and at the same time the company profits rise. Above and beyond that, Porter and van der Linde (1995: 98) argue that regulation can prompt innovation offsets in a non-optimizing context. The net costs of compliance with environmental provisions would thus decrease and absolute competition advantages against companies in other states or countries with similar regulation can be achieved at the same time.

The empirical plausibility of this so-called Porter hypothesis is limited. Porter and van der Linde (1995) stress that only environmental regulation which is correctly set up can induce such innovation offsets. However, in order for environmental regulation to be able to develop substantial information effects, the government would have to have better information at its disposal than the companies. In addition, Jaffe et al. (2002: 46) point out that environmental regulation can, on the one hand, stimulate the innovation and diffusion of technologies, the process of which simplifies the fulfilment of requirements. On the other hand, however, the development and adaptation of new technologies also use real resources and induce substantial opportunity costs. They come to the conclusion that the plausibility of the win-win hypothesis corresponds to the case of a ‘glass being half full’: depending on the viewpoint, it is either regarded as half full or half empty.

2.2 A broad concept of innovation

The above sections provide a brief overview of the emergence and progress of innovation theory from its beginnings to the most recent developments. In the new growth theory, the focus is placed on the inclusion and endogenization of innovation in macroeconomic models. The market forms approach addresses the firms' incentives to innovate depending on the degree of market concentration and product characteristics. The evolutionary innovation concepts deal with the uncertainty of decisions on innovation and highlight that rules of thumb are quite relevant in such situations.

Particularly building on Schumpeter's staged concept of innovation and the evolutionary approaches, a common understanding of innovation was developed within the TIPS research team to addressing innovation processes in the electricity system:

> *Innovation is understood as an intentional, goal-oriented invention, development and implementation of a socio-technical novelty in the electricity sector that solves a problem or is perceived as an improvement towards a more sustainable electricity system by a social group or actor* (Voß et al. 2003: 6).

This comprehensive concept consists of several components which need to be described in more detail:

- *Intentional, goal-oriented:* To qualify as an innovation, a novelty must be promoted by intentional, goal-oriented human action. A discovery may be made by chance, but to count as an innovation, there must be conscious considerations in terms of how to develop and implement it. However, the qualification of innovative action as intentional and goal-oriented does not imply that the process and its final outcome are fully under control. On the contrary, innovation is a complex process full of unintended side effects that may turn in completely unexpected directions. New actors may join the process and give it a new twist, new properties of the innovation may be discovered, political or economic factors may change the course of the process, or interactions between all of these factors may take place. The actual innovation journey can therefore be understood as a "trans-intentional" result of goal oriented interaction.
- *Invention, development and implementation:* An innovation process has different phases. The innovation is not completed upon the invention (cognitive construction or discovery) of a novelty. The invention needs to be developed into a model or prototype which is adapted to the actual conditions of its practical realization. These conditions include availability and physical features of materials, requirements of the production process, organizational procedures, needs and routines of users, aesthetical predispositions, institutional framework conditions, etc. In order to actually contribute to the solution of a perceived problem, however, the innovation also has to be put into effect, i.e. implemented in real world contexts. This means that the model or prototype needs to become effective as part of the operational working of the electricity system. For a product innovation, this means market introduction and diffusion, for a policy innovation, it refers to the actual implementation and en-

forcement of measures, for a social innovation it means the diffusion and stabilization of social attitudes and norms of behavior among relevant parts of society.

In conceptualizing innovation as a series of phases heuristic of invention, development and implementation, some implications need to be clarified. First, it is important to realize that the heuristic distinction of phases is not always clear in empirical reality. Phases may be temporally or spatially detached: an invention may be made at a specific point of time in a certain country, and only be implemented much later or in a different country. Moreover, the phases may not appear in a linear order but include iterative cycles and feedback between the different phases. Such is the case when changing conditions of implementation require adaptations of a prototype or when development capacities (e.g. laboratory infrastructure or political alliances) guide increased efforts in search of new inventions.

Another problem is the determination of the point at which the diffusion of an innovation process is completed. Certainly, there is a point in time when a (former) novelty is so firmly established that effects from further diffusion or improved implementation are only marginal and should not count as part of the innovation process anymore. But where exactly is this point? A helpful guideline is to consider the point at which an innovation starts having effects relevant to the operation of the electricity system. Naturally, the definition of this point depends on the type of innovation. A new product may become effective when it has reached a certain market share, when its potential market is saturated, or when market penetration has reached its climax and starts to slow down. Behavioral change may be defined as effective when it is firmly established among a sufficient number of people to have an effect on markets, or on the environment. A policy becomes effective through guiding social interaction processes.

- *Social, technical and socio-technical:* Our concept of innovation comprises both social and technical novelties. Technical novelties may be new materials, product components, products or production processes. Social novelties comprise new lifestyles, habits, attitudes and values, social relationships, routines, organizational processes, institutions, political regulations, organizations and the like. In modern societies, many innovations are of a socio-technical nature, necessarily combining social and technical elements. On the one hand, to have an effect, technological developments depend on their social context (for example, appropriate legal frameworks or a reorganization of the work flow). On the other hand, they influence and re-shape the social world (for example, by generating new use patterns). In complex innovations like the World Wide Web or mobile phones, technological solutions interact and co-evolve with behavioral changes, new habits, reorganization of work processes, the development of adequate legal frameworks, operating arrangements and more.

  In practice, these different components make up a “seamless web” of innovations, but for analytical purposes, it is helpful to distinguish a cluster of core innovations from impacting innovations and induced innovation. The core innovation is a product, technology, institution or policy strategy. Impacting innovations are innovations that influence the core innovation's functioning or development process. Induced innovations are additional innovations that are influenced by the core innovation.

- *Novelty:* To qualify as a novelty, it is required that something is new to the context to which it is introduced. It need not be 'new to the world'. Since the conditions for adapted development and implementation differ, the process of innovation needs to be studied separately for diverse contexts.
- *Solving a problem:* Many theorists define innovation normatively. They claim that innovations lead to more effectiveness or efficiency, improve living conditions or make society more humane. In order to have a wider analytical focus, others refer to a "neutral" concept of innovation that covers every deliberately introduced novelty without referring to improvement. In the definition it was stresses that the expectation of improvement or problem solving is the core motivation for deliberately undertaking innovation activities. However, there is no such thing as "objective" improvement or problem solving. Improvement is always improvement for a certain actor; a problem is somebody's problem. One group's solution may be another's problem, one group's improvement another's impairment.

  Nevertheless, the reference against which such improvements are to be assessed is an environmentally friendly electricity system: any improvement which results in a less polluting electricity system is considered to be an innovation while improvements which simply increase the economic efficiency without contributing to a less polluting electricity system are not regarded as an innovation. Since climate change is nowadays one of the most challenging environmental threats (Deutscher Bundestag 1990; IPCC 2007b; Stern 2006), the analysis is focused on greenhouse gas emissions or more specifically on CO_2 emissions: any improvement which contributes in the short and/or long term to a reduction of greenhouse gas emissions shall be regarded as an innovation towards a more environmentally friendly electricity system.
- *In the electricity sector:* To identify an innovation, it is important to specify the system of reference which is supposed to be affected. Here the focus is placed on innovations that have an effect on the electricity sector at the sector level. Thus, certain "novelties" which may usually count as innovations are excluded. For example, the restructuring of the production process in an individual power plant is not considered further if it is not diffused and thereby has little or no effect on sector processes and structures.

2.3 Innovation in the electricity industry

The process of innovation is a complex process in all industries which usually involves several internal and external actors. Innovation in the electricity industry is, however, different to the processes in other innovation intensive industries such as the chemical industry or the automobile sector. The main difference derives from the fact that the latter industries belong to the manufacturing sector while the electricity industry is part of the services sector.

In the next section the differences between innovation processes in the electricity industry and other industrial sectors will be analyzed in more detail (section 2.3.1). These considerations will be followed by an exploration of influencing factors and the historical circumstances which led to this specific situation in the electricity industry (section 2.3.2). Further support for the specific innovation situation of the electricity industry can be derived from numeric indicators which describe both the differences to other industrial sectors and the dynamics of innovation in the electricity industry in the last 60 years (section 2.3.3). Finally, the particular strategies which can be differentiated to establish innovative technologies and processes in the electricity industry will be elaborated (section 2.3.4.).

2.3.1 Differences to the innovation processes of other industries

While the manufacturing industries are continuously challenged with product innovations which emerge from their own or their competitors' research and development efforts, the core service of the electricity industry has barely changed in the last 100 years or more. Even though the tariff structure and the marketing concepts have consistently changed, particularly since liberalization and the introduction of competition in the late 1990s, the quality of the core service remained unchanged: alternate current with 50 Hz at various voltage levels (230, 380, etc.).

Manufacturing industries are confronted with both product innovations and process innovations. Product innovations include all improvements of the product itself which is delivered to the customer whereas process innovations improve the production process (Hauschildt 2004: 11-12).

The main driver for product innovation is the expectation that the manufacturer's market share can be increased by means of the new or improved product, thereby enhancing the profitability of the company. Important framework conditions for this motivation are the preferences and the demand of the consumers. However, they are not given as such but can often be influenced by cleverly designed marketing campaigns.

The main driver for process innovations is the expectation to reduce production costs through a reduced use of production factors such as capital, labor or resources and to augment this way the company's profits (Reichwald, Piller 2006: 99). However, process innovations might also reduce the environmental impact of the production process or improve the labor conditions for the employees. The latter improvements are sometimes a synergetic result of the firms' striving for increasing efficiency and profits. This is for example the case if an innovation increases profits by reducing the consumption of primary energy so that the corresponding pollutant and greenhouse gas emissions are reduced as well. Nevertheless, often the different goals of process innovation are in conflict: a reduction of the environmental impact or an improvement of the labor conditions result in decreased profits.

For marketing reasons, firms might wish to develop an environmentally friendly and socially friendly reputation. Therefore, they have also intrinsic motives for reducing their impact on the environment and improving labor conditions within the company. However, the levels achieved by the intrinsic motivations of the companies are usually substantially lower than those aspired to by society or the government. Process innovation which reduce the environmental impact or augment the labor conditions are, therefore, often a result of governmental regulations which have to be regarded as a framework condition in the companies' innovation strategies.

From a firm's perspective, product and process innovation can usually be clearly distinguished. From a macroeconomic perspective the distinction might be more difficult: a product innovation of one company might become a central element of the process innovation of another company (Rosenberg 1982: 4). This is for example the case for virtually all products of companies belonging to the engineering and plant construction sector. Whether an innovation is to be categorized as a product or a process innovation depends on the position of the firm within the product or service cycle from cradle to grave.

The extent to which a company covers all three phases of Schumpeter's (1942; 1939) innovation process (section 2.1) varies substantially between sectors and even between firms within a sector. In the automobile or chemical industry all three phases of the innovation process are often covered by each of the larger firms. Those companies have larger R&D divisions which sometimes even include basic research (Freeman, Soete 1997: 106). Inventions which emerge from these efforts are patented by the companies if possible. Therefore, the number of granted patents is often considered an indicator of a firm's innovation activity or even of its innovativity. In the development departments of these companies, inventions are further developed towards marketable products or services. This often includes an extensive series of tests and experiments to safeguard the quality and the security of the product or service. Generally, the marketing division is ultimately responsible for the diffusion of the innovative product or service (Hauschildt 2004: 166-168). They develop suitable marketing campaigns which aim to increase constantly the market share of the new product or to generate needs and demand for products or services when a market does not yet exist. From an innovation perspective such firms can be considered "integrated innovators" since they cover all three phases of the innovation process. That does not mean that such integrated innovators do not also include ideas and inventions from other firms in all three phases. However, they are at least capable of maintaining the entire innovation process with internal know how and resources.

Companies which do not address the entire innovation cycle can be described as partial innovators. They only assume responsibility for individual phases of the innovation process or even for part of these phases. Evidently such partial innovators depend more on cooperation with other companies to complete an integrated innovation process.

Against this background, the companies of the electricity industry clearly have to be categorized as partial innovators which – due to their relatively homogeneous product of electricity which has a rather inelastic demand – have to focus mainly on process innovations. They have the key responsibility for the diffusion of the innovations of equipment manufacturers since they decide which technologies and innovations are apply in their power generation and distribution processes. However, they also depend on the equipment manufacturers since the can only apply technologies and innovations which are provided by the manufacturers. The manufacturers, in contrast, rely on the experiences gained by the electricity companies when they operate their power plants or transmission and distribution technology. Therefore, a mutual interdependency between the technology manufacturers and the electricity companies can be assumed which requires a close cooperation between firms of both sectors in the overall innovation process of the electricity system.

There was no always this division of responsibility in the innovation process in the electricity supply branch. In the early days of the German electricity system, the industry consisted of companies which were much more vertically integrated and supplied not only the service electricity but also all of the required equipment, as will be shown in the next section. Since the industry structure was different in those days, the innovation processes in the electricity sector tended to resemble today's innovation processes in the automobile or chemical industry.

2.3.2 From integrated innovation to divided responsibility

The early years of the German electricity industry can be traced back to the period 1880 to 1890 (Zängl 1989: 20) and were initiated by the International Electrical Exhibition 1881 in Paris. Among others, the exhibition was visited by Werner von Siemens and Emil Rathenau, both of whom became rather influential in terms of the German electricity industry.

Edison's displays in Paris motivated Rathenau to buy the patent rights for Germany. In 1883, one year after Edison had introduced the world's first electric lighting system at Pearl Street Station in New York, he convinced three German banking houses to finance the acquisition of the patents and to establish the Deutsche Edison Gesellschaft für angewandte Electricität (German Edison Company for Applied Electricity) to industrially exploit measurement, distribution, transmission and application of electricity for lighting (Hughes 1983: 67). The company was headed by Rathenau and has been known since 1887 as AEG (Allgemeine Elektrizitäts-Gesellschaft – General Electric Company).

Siemens was already known as an electrical inventor and a manufacturer of telegraphs. His company, Siemens & Halske, founded in 1947, was already moving into arc lighting and began manufacturing incandescent lamps under the license of Edison's competitor, the Swan Company. In 1883, Siemens & Halske agreed to manufacture incandescent lamps under Edison's license. As a result, both German Edison and Siemens & Halske had the right to manufacture incandescent lamps in Germany. However, they did not compete in lamp production but agreed that only German Edison would manufacture the incandescent lamps while Siemens & Halske would provide the necessary generators and other equipments (Matschoss et al. 1934: 10).

German Edison developed plans to build two central stations in Berlin to provide electricity for its incandescent lamps. However, prior to this they had to make an agreement with the city of Berlin on the use of publicly owned territory for establishing the necessary electricity network. Berlin already had its own gas utility and some argued that Berlin should own and operate the electric utility as well. Others highlighted the risk that an electric utility might diminish the proceeds of the profitable gas works, since the main purpose of electricity at that time – as for gas – was lighting. Moreover, the majority of Berlin's municipal councils were convinced that private enterprises should shoulder the risk of innovation while the profits should be shared with the municipal government (Hughes 1983: 72).

The municipal authorities were skeptical about the new technology and were – due to a lack of economic experience with electricity – only willing to license electrical facilities and were not prepared to order electrical systems. Since a demand for electricity had not yet emerged at that time, a market for it had to be created. Apart from providing the supply of innovative goods and products, the electric industry also had to raise awareness of the latent demand for those products. If the electric industry intended to overcome the general skepticism in order to increase production and sales, it had to develop new business concepts which included the operation of electrical utilities. Feldenkirchen (1995: 36-37) terms the approach whereby the electric industry acted simultaneously as manufacturer of electrical equipment, operator of electrical utilities and finance company the "entrepreneur business" (Unternehmergeschäft). It was first introduced by AEG but later copied by other companies. Siemens & Halske started to establish its own electric utilities from 1888 onwards (Zängl 1989: 21).

In February 1884, German Edison was granted the concession to use streets in a specified area of Berlin for its electricity distribution system (Bohn, Marschall 1992: 46). Only a few months later in May, German Edison founded the Berlin utility called Städtische Elektrizitäts-Werke (StEW). In 1887, the name was changed to Berliner Electrizitäts-Werke (BEW) and AEG took over the management of BEW. A fast growing electricity demand motivated the expansion of the supply system beyond the actual demand since BEW's directors were convinced that new capacities would not remain idle for long. By 1895 BEW operated four central stations and was by far the largest utility in Germany.

"When founded in 1887, AEG was primarily a financier and operator of electrical utilities and a maker of incandescent lamps. In contrast, Siemens was a manufacturer of equipment. Within a decade, however, AEG had expanded its manufacturing to include power equipment and had introduced a line of polyphase machinery. … In cooperation with banks in Berlin and elsewhere, it also financed and constructed power plants for electric supply utilities and industrial facilities that used heavy-power equipment. … By 1900 AEG had established 248 power plants with a total capacity of 210,000 h.p." (Hughes 1983: 178)

AEG was active in several business areas: it sold generation technology and other heavy machinery as well as shares of utilities which it had received in compensation for their equipment supply and made profits from operating some of the utilities. In 1911, AEG held stakes in 114 public power plants in Germany. Siemens-Schuckertwerke (SSW), a merger of Siemens & Halske's business and the Schuckert-Werke in 1903, owned stakes in 80 power plants. Both manufacturers held interests in 12 larger power plants with a capacity of more than 10 MW, which supplied more than a quarter of the load in the market segment (Nussbaum 1968: 3, 137-38). Due to the control which both technology suppliers exerted over their market, “the relationship resembled vertical integration” (Hughes 1983: 179).

From an innovation perspective, the structure of Germany’s early electricity industry resembled the innovation structure in the car or chemical industry: all three phases of Schumpeter’s (1942; 1939) innovation concept – invention, development of a product and diffusion to the market – could be discovered within one of the larger vertically integrated companies. AEG used its subsidiary BEW for site tests of their new technologies and applied advanced marketing strategies to promote the diffusion of their innovation. When BEW promoted the replacement of steam engines with electrical motors, AEG rented these motors at a reasonable cost with the option of returning or acquiring those motors after an extensive test and evaluation period. Such close cooperation between manufacturer and utility stimulated both the innovation process in the electricity industry and the diffusion of electrical motors throughout the economy. An example of the close cooperation between AEG as manufacturer and BEW as a “full-scale testing ground” (Hughes 1983: 195) is the early introduction of AEG’s first steam turbine at BEW’s power station in Berlin Moabit in 1902.

However, this close cooperation between manufacturer and utility, which resulted in an innovation structure comparable to today’s innovation structure in the car or chemical industry, did not last long. It came to an end when Berlin’s city council decided to exert its right of preemption for BEW in 1915. Those who favored the takeover argued that the high risks of the early years of the electricity industry are a thing of the past and that the utility should be owned and managed by the city government like the gas utility. They also intended to improve the consideration of social objectives, for example by adjusting rates for lower-income customers, and believed that the takeover could improve control over the city’s industrial development. Although the city derived large revenues from its concession contract with BEW, particularly the socialists argued that profits of private owners should come to the city. Reducing the influence of AEG was, therefore, a central point in the debate which led to Berlin’s takeover of BEW (Hughes 1983: 199).

The takeover of BEW can be seen as a turning point in the phase of vertical integration in the electricity sector. The technology was now established for more than 30 years and had diffused remarkably. Demand was already growing in a self sustained manner and the economic risks were – due to the experiences gained – more calculable than in the early years. The separation of the utility business from the electrical industry then resulted in a division of responsibilities within the innovation process. While the electrical industry continued their responsibility for the invention and the phase of product development, the utilities took over the responsibility for the diffusion of innovations.

There were miscellaneous reasons for the separation of both businesses. Some are related to the structure of the innovation process, others not. The reduced risk after 30 years of experience and the intention to take into account social criteria for determining the tariffs have already been mentioned. The use of electricity was increasingly considered a basic need with the result that it became a good of basic supply, the provision of which had to be guaranteed by public authorities. Only a public supply or a strong regulation would guarantee that electricity was not only provided in the dense and profitable areas of the cities but in rural areas as well.

Besides these more political reasons, the separation was supported by technological characteristics. A consolidation of the product electricity had already been achieved. While the first stations provided direct current at 110 V, BEW introduced polyphase equipment in its central station on Schiffbauerdamm in 1896 and shifted to 220 V in 1899 (Hughes 1983: 186, 193). The characteristics of electric utilities' products have basically not changed since the end of the 19th century. From an innovation perspective the vertical integration of technology manufacturers and utility operators was therefore less essential. The technology manufacturers continued to innovate their products, i.e. generation technology and equipment for the electricity system, while the electric utilities began to innovate their processes by applying innovative products of the technology manufacturers.

Compared to the equipment manufacturers, the efforts of electric utilities in terms of research and development had been much lower since the end of the phase of vertically integrated companies. Generally, the utilities were not directly involved in basic research or product development. Their specific task and responsibility in the overall innovation cycle was to select those technologies and approaches which seemed to be most promising to them. However, in order to decide thoroughly on technological alternatives, they had to develop their internal understanding of the available alternatives. Moreover, some kind of cooperation between electric utilities and technology manufactures was still needed to integrate the experiences gained from operating new technologies into further development and improvement of those technologies. Despite several fundamental changes in the regulation of the electricity sector and the political system, this division of responsibilities in the innovation cycle between equipment manufacturers and electric utilities prevails until today: the manufacturers put all their effort into product development and, if necessary, into basic research while the utilities assume the responsibility for completing an innovation cycle by deciding on the penetration into the market and the diffusion of a new technology.

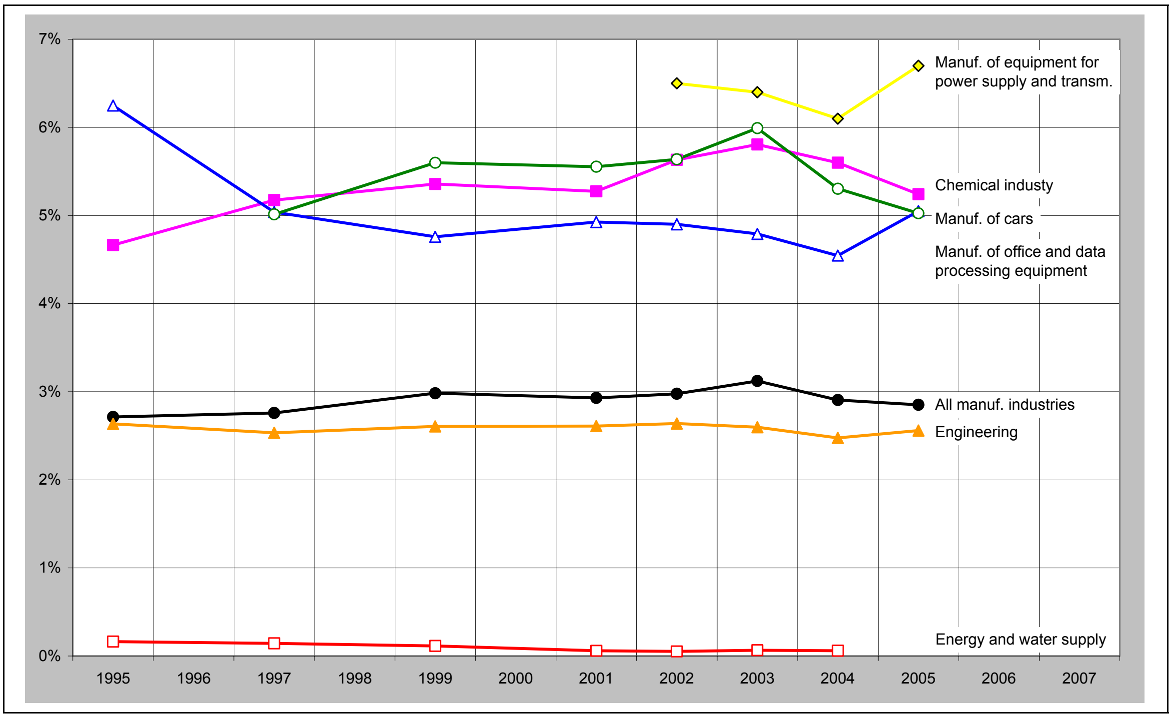
2.3.3 Indicators of innovation

Since innovation itself is a rather complex issue, measuring innovation is basically faced with several difficulties. In general, innovation indicators can be differentiated into indicators which address the input to or the output of the innovation process (OECD, Eurostat 1996: 26-28).

2.3.3.1.1 Input indicators

Typical indicators which describe the inputs to the innovation process are expenditure on R&D, the number of employees or the number of patents. They are applied for international comparison of innovation policies, for comparison on a sector level within a country or even for comparison of firms within individual sectors.[6] To facilitate comparison they are often expressed in relative terms. Depending on the coverage, the denominator might be the GDP, the aggregated sectoral turnover, the gross production volume or the companies' turnover. Input indicators often face the problem that firms are reluctant to provide the necessary information since it is considered confidential (OECD, Eurostat 1996: 82).

Figure 1 Development of the expenditure on R&D relative to the turnover in selected sectors in Germany



Sources: Destatis (2007a; 2007c); Stifterverband (2007)

Independently of the above mentioned problems, both input indicators are not very suited to measuring innovation in the electricity industry. Figure 1 and Figure 2 illustrate clearly that the electricity industry is not as innovation intensive as the manufacturing of cars, manufacturing of office and data processing equipment or the chemical industry. Both its R&D expenditure and its share of R&D employees are well below the averages of the manufacturing industry as a whole and are barely measurable. Nevertheless, the figures show as well that the manufacturing of equipment for power supply and transmission is one of the sectors with the highest innovation input in Germany. This again supports the hypothesis that the division of responsibilities for the innovation process between the electricity industry and the manufacturers of equipment for power supply and transmissions still prevails today and is unlikely to end in the near future.

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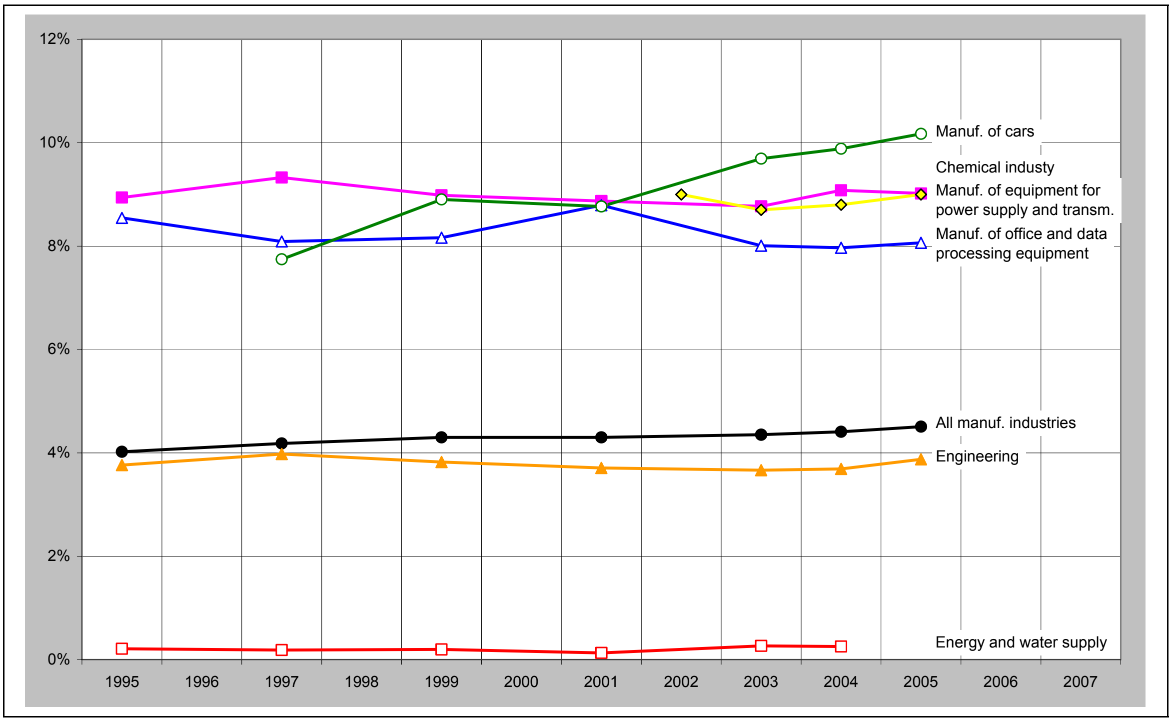
[6] See, for example, Rosenberg (1982: 274) and Freeman, Soete (1997: 112-121).

Figure 2 Development of the number of R&D employees as a share of the total number of employees in selected sectors in Germany

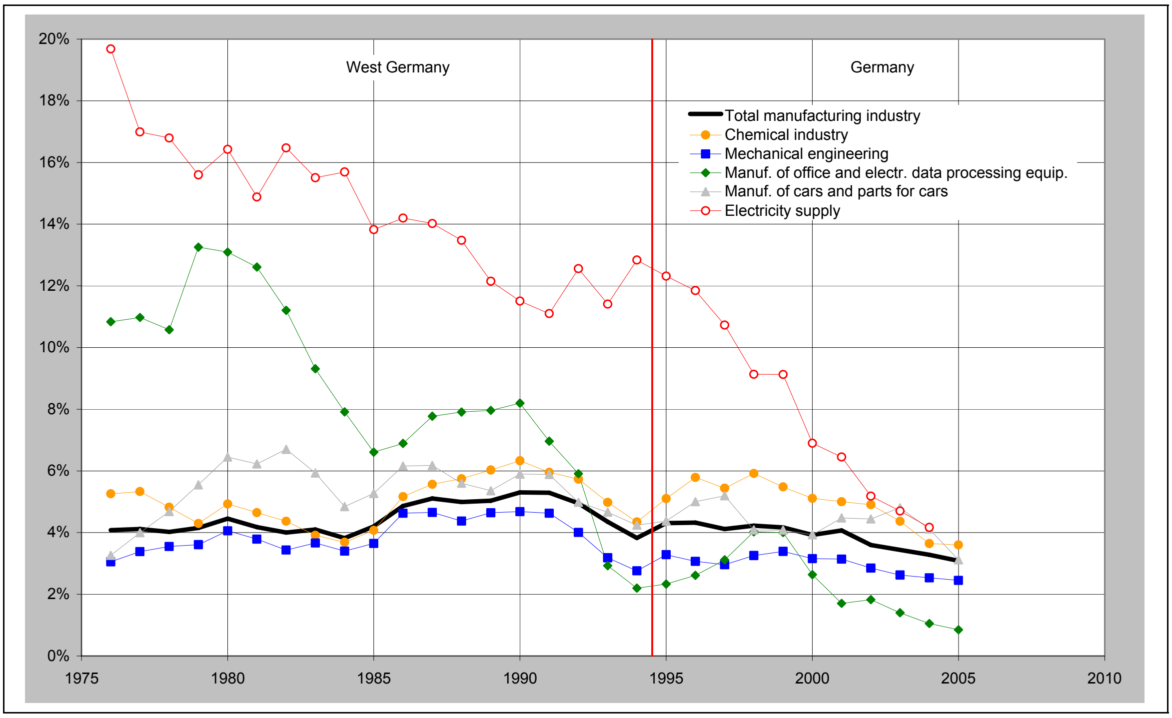


Sources: Destatis (2007a; 2007c); Stifterverband (2007)

According to the broad concept of innovation presented in section 2.2, innovation includes changes which require investment in technical infrastructure as well as changes without investment in hardware. The latter category includes, for example, options like switching to coal with lower carbon content, to biomass or waste within the same plant, reducing maintenance cycles to maintain the efficiency level, to shift generation from lignite or coal plants to natural gas plants or to shift generation from lignite plants to hard coal plants. However, the potentials of improving the aggregated efficiency or the aggregated emission factor of fossil power plants without investment are rather limited: the differences in the carbon content of fuels are small and are already covered in the price of coal, the potential to use biomass or waste are limited due to technological features of the plants and the availability of these resources, shortening of maintenance cycles has to be traded off with reduced availability of the plant and the potential to switch from lignite to hard coal or from lignite and hard coal to gas depends on the availability of free capacity in replacing plants. Major improvements of the aggregated plant efficiency or the aggregated emission factor therefore require investments in new plants or rehabilitation of existing plants. Also, new plants can be assumed to represent the current state of the art of technology investment, and thus represent innovative technologies.

The development of investment in the electricity industry can thus be considered an innovation input indicator for this sector. Higher investment in one year would indicate increased innovation activities compared to years with less investment.

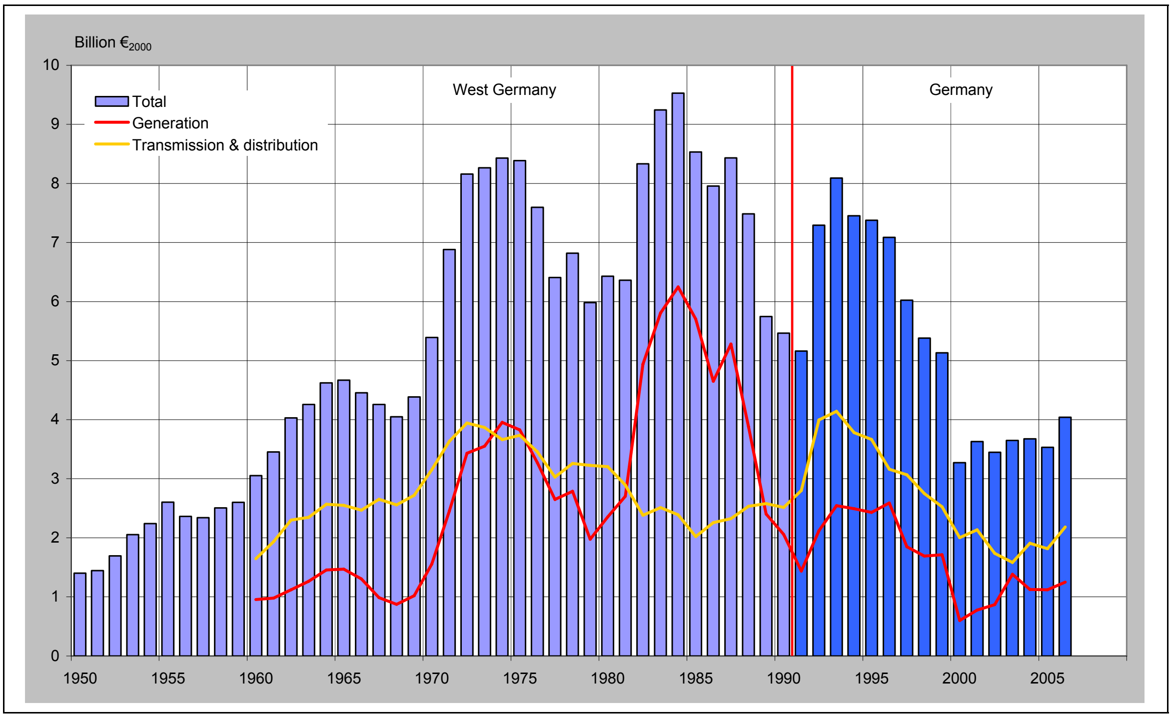
Figure 3 *Development of expenditures on investment as a share of the turnover by selected sectors*



Source: *Destatis (2005; 2007a; 2007c)*

A comparison of the investment quota of selected sectors in Germany reveals again that the electricity industry is different to other sectors (Figure 3). The investment quota, measured as the expenditure on investment as a share of the sector's turn over, was significantly higher in the electricity industry in the past than in other sectors. And although it converged towards the investment quotas of other sectors, particularly since 1994, it is still higher than average. One major reason for this convergence can be identified in Figure 4: expenditure on investment has considerably declined since 1993 and is currently by and large at the same level in real terms as in the early 1960s despite reunification and considerably increased electricity consumption. The investment per MWh consumed in Germany has decreased from more than 30 €/MWh in the mid-1970s to about 10 €/MWh in 2006.

Figure 4 Development of expenditure on investment in the German electricity industry



Sources: Destatis (2007b); VDEW (1993; 2007)

Figure 4 also reveals that investment in the electricity industry is cyclical: investment always peaked in the middle of each decade except of the first decade in the 21st century where such a peak cannot be clearly identified. The peaks were mainly determined by investment in power generation while investments in transmission and distribution were less cyclical.

The development of the investment quota (Figure 3) again supports the hypothesis that the responsibility for innovation in the electricity system is divided between the electricity industry and the technology manufacturers: while the latter have a R&D quota below the average, the first have an investment quota above the average of the total manufacturing industry. The electricity industry invests in those innovative technologies which the equipment manufacturers have developed with their comparatively high R&D and innovation efforts.

2.3.3.1.2 Output indicators

Innovation output indicators are not confronted by the reluctance of the companies to submit relevant information since they record the number of new innovative products or services. Usually, the firms have an incentive to publish and disseminate the introduction of a new product or service. Therefore, such information is often sent to trade or technical journals. Innovation output can thus be measured by counting all new products or services mentioned in the edited parts of a set of trade journals (OECD, Eurostat 1996: 83). However, the product, or rather the service of the electricity industry has actually not changed since the end of the 19th century so that innovation output also seems to be an inadequate indicator to grasp the innovation process in the electricity industry.

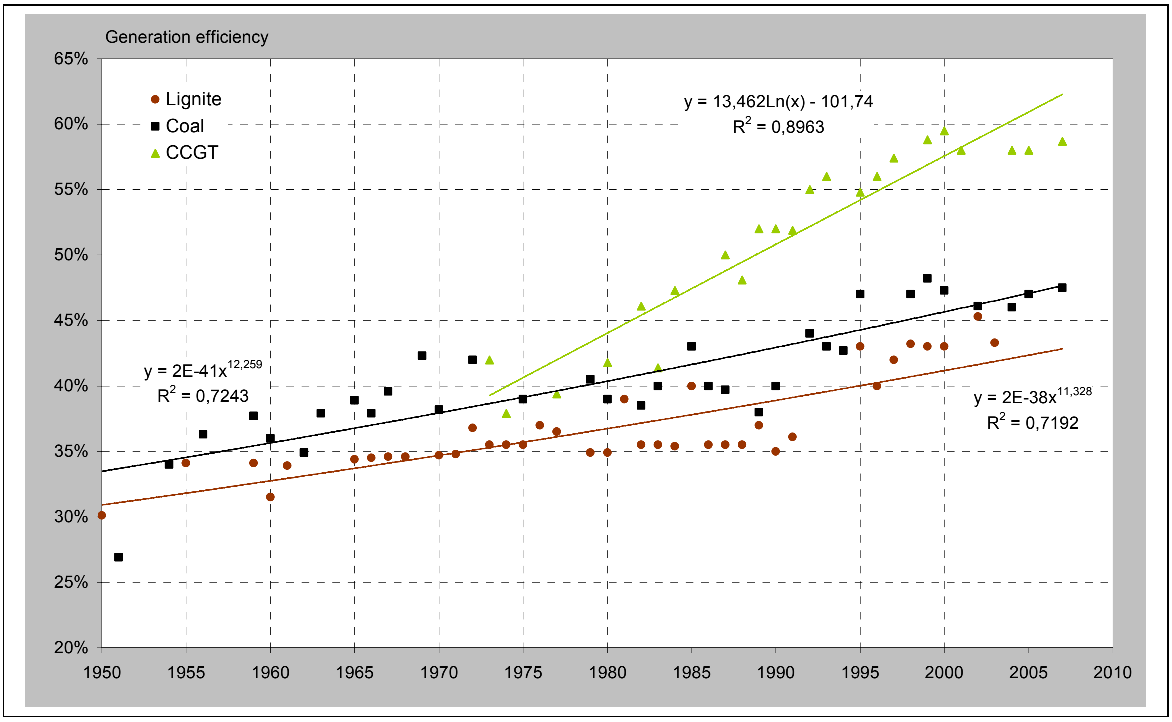
Since innovation output is barely suited to, and innovation input only partly suited to, an analysis of innovation in the electricity industry, a third kind of indicator is required which is more closely focused on the success or the outcome of the innovation process. Since innovation either results in improved products or enhanced services or in reduced prices for the product or service, the price might be a potential innovation outcome indicator.

2.3.3.1.3 Outcome indicators

Prices for consumer electronics or computers have compared to the enhanced convenience and computing power considerably declined in the last twenty years due to intensive and effective innovation processes in these industries. The same applies to telecommunication services. Thus, the product price might be considered an indicator of innovation outcome.

For the electricity industry the product price might be an even better indicator of innovation because the product itself has not changed so that changes might be directly attributed to innovation. Anyhow, the electricity price is too influenced by other factors, such as the development of fuel prices or fees and taxes, which interfere with the detection of the effects of innovation.

Figure 5 Development of the generation efficiencies of a new plant by fuel



Source: Author's own overview based on different sources in the corresponding literature

Against this background, more suitable innovation outcome indicators are the development of the generation efficiency or the development of the greenhouse gas emission rates or emission factors respectively. While the first indicator focuses more on the intrinsic motivation of companies, the latter indicator is more suited to addressing innovation effects due to governmental regulation towards a sustainable electricity system. Both indicators can be basically applied on aggregated or disaggregate levels. A faster increase of the average efficiency of all fossil power plants in Germany would indicate that innovation efforts were more successful in those years.

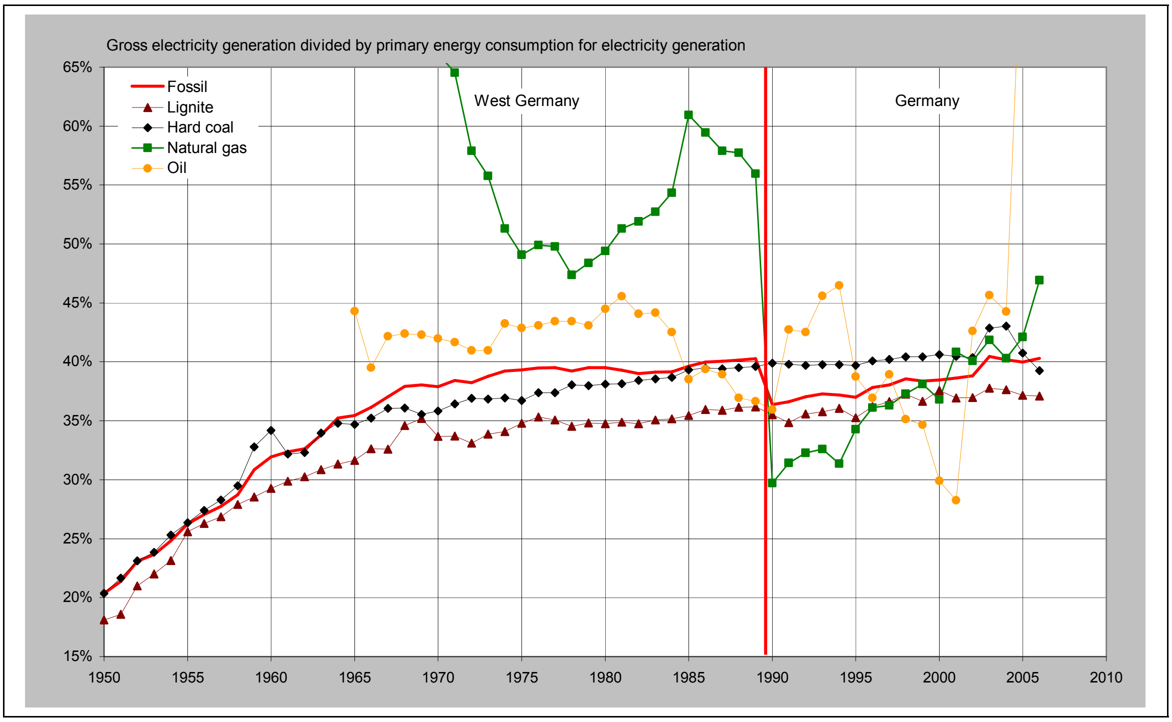
The data can either be obtained with a bottom up approach by gathering data of individual plants or with a top down approach. Figure 5 illustrates the first approach. It shows the development of generation efficiency of new power plants from 1950 to today. The rising slope of the linear trends illustrate that innovation occurred continuously during this period. The generation efficiencies of new coal and lignite power plants have basically developed at the same pace. Yet, the efficiencies of lignite power plants are some 3 to 5 percentage points lower on average than those of coal-fired power plants. Combined cycle gas turbines (CCGT) were only introduced in the mid-1970s. Their efficiency increased at a much faster pace and reached efficiencies of almost 60 % at the end of the 20th century but has not increased substantially since then.

The development of a new plant's efficiencies does not always translate into a similar development of the average generation efficiency of the entire electricity system. If the overall generation capacity is growing, the increase of the average generation efficiency is slowed down because older, less efficient plants continue generation and are not replaced by new plants. Moreover, the development of the average generation efficiency might be sluggish if investments in new plants are relatively decreasing as was the case in the second half of the 1980s or since the mid-1990s (Figure 4). The effects of these dynamics can be illustrated by the top down approach.

In the case of the top down approach fuel consumption or CO_2 emissions are to be divided by the electricity output. If more detailed data is available, such analysis can be carried out for individual fuels, technologies or even individual companies. Some of the data is basically publicly available, for example the CO_2 emissions of individual power plants in the European greenhouse gas emission register under the EU ETS Directive (EU COM 2007c). Yet the corresponding fuel input and electricity output is usually not available in the same detail. Moreover, it is often difficult to identify the correct ownership of a plant, for example in the case of joint ownership, or to determine the generation technology applied. In addition, not all companies are prepared to disclose this data since it is often regarded as confidential. The top down approach is not faced with these problems since it does not rely on individual company data.

Figure 6 shows the development of the average generation efficiency of fossil power plants in West Germany between 1950 and 1989 and in Germany as a whole from 1990 to 2006. On average, the generation efficiency increased continuously between 1950 and the mid-1970s. Since then the average generation efficiency remained more or less constant until 1989. In 1990 it dropped slightly because several very inefficient plants in East Germany have been included since then. However, the average generation efficiency started to increase again, mainly due to the rehabilitation or replacement of those inefficient power plants in the East. The generation efficiency of coal-fired power plants increased strongly between 1950 and 1965 and much more slowly between 1966 and 1985. Since then it remained more or less on the level achieved in 1985, mainly due to the fact that only a few new coal-fired power plants have been commissioned since 1985. For lignite the picture is slightly different: the generation efficiency increased strongly between 1950 and 1970 but remained on that level until 1991. Since 1992, it has started to increase again due to the rehabilitation or replacement of old lignite power plants in East Germany.

Figure 6 Development of the average generation efficiency by fuel



Sources: AGEB (2007a; 2007b); VIK (1991: 120-123); author's own calculations

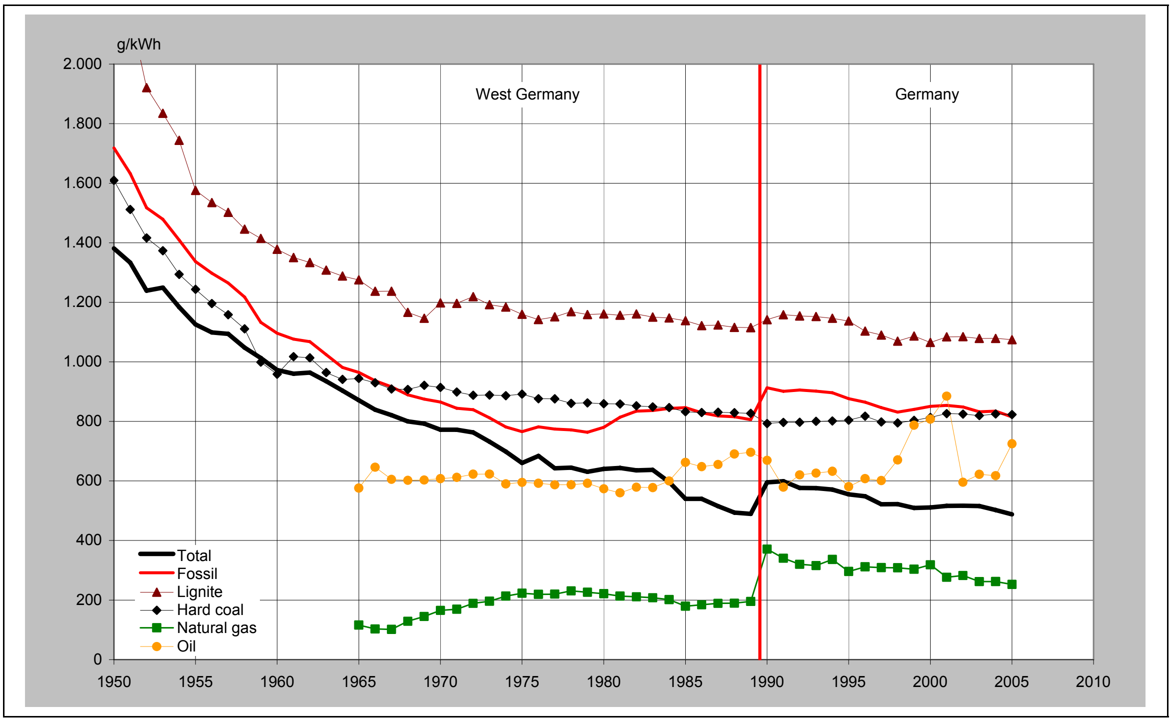
The development of gas and oil fired power plants was rather erratic. This is mainly because most of these plants usually supply peak load so that their average generation efficiency depends strongly on the duration of every single operation. If, for example, a gas power plant is operated in one year for fewer but longer periods or for longer periods closer to its optimal load, the effective efficiency in that year would be much higher than in another year in which the plant is operated only for minutes as well as being beyond its optimal capacity. After 1990, combined cycle gas power plants became competitive in the medium load band, which meant that the average generation efficiency underwent a less erratic and continuously increasing development: from 1990 to 2006, the average generation efficiency of gas power plants rose by some 15 percentage points.

Between 1950 and 1965 the average fossil generation efficiency is determined by coal-fired power plants. Electricity generation from natural gas started only in 1960 but has quickly increased since then. Between 1975 and 1980 some 25% of total fossil electricity generation was generated from gas. Due to the higher efficiencies of the new gas power plants the average fossil generation efficiency has risen more quickly since 1965 than the generation efficiency of coal and lignite plants. However, after 1980 gas prices increased considerably with the result that the share of fossil electricity from gas power plants declined to some 15% during the 1980s and that the average fossil generation approached again the efficiency of coal-fired power plants. After unification, the average fossil generation efficiency was usually below the efficiency of hard coal-fired power plants but increased continuously (+17%), mainly due to the increasing efficiency of lignite (+4.5%) and gas power plants (+58%) and due to the electricity generation from gas power plants rising again (+97%).

The development of the average CO_2 emission factor basically shows a similar development although one in the opposite direction because an increased efficiency results in lower CO_2 emissions (Figure 7). Apart from the average emission factors for lignite, hard coal, gas and all fossil power plants, the figure also includes the development of the average emission factor of the German electricity system as a whole (total). Since this line also includes electricity generation by non CO_2 emitting technologies such as nuclear, hydro and other renewables, the values of this line are naturally below the average fossil emission factor. Between 1950 and the mid-1970s the values of both lines have converged, mainly because the share of electricity generated from fossil resources has been increasing. But while the aggregate fossil emissions factor did not continue to decline from the mid-1970s onwards, the total emissions factor continued to decline, mostly due to the fact that the share of electricity generated by nuclear plants constantly increased in that period.

Between 1990 and 2006 the average emission rate of the German electricity system declined by 18% despite a declining share of generation from nuclear sources (-5%) and virtually no improvements in the emission rate of coal-fired power plants (+4%). The improvements can be attributed to the declining emission rate of lignite (-6%) and gas plants (-32%) and an increased share of electricity generation from renewable sources (+110%) and from gas (+97%).

Figure 7 Development of the average CO_2 emission factor by fuel



Sources: AGEB (2007a; 2007b); UBA (2007); VIK (1991: 120-123); author's own calculations

The developments depicted in Figure 6 and Figure 7 are the result – or rather the outcome – of several innovations processes:

- Old lignite power plants in the former East Germany were closed and replaced by new innovative designs with higher efficiencies and lower emission rates.
- The efficiency of innovative gas power plants was substantially increased with the result that their emission rate is now below half of a hard coal plant's emissions rate.
- The availability of electricity generation from renewable sources such as wind or biomass was improved by many innovations in the design of these technologies.

However, these innovations would not be reflected in the development of the average CO_2 emission rate of Germany's electricity system if those technologies had not diffused into the market: the market share of carbon free (renewables) or less carbon intensive technologies (gas) was considerably increased while the share of the fuel with the highest emissions rate (lignite) was slightly decreased by 15%.

These considerations show that the developments of the generation efficiency and the aggregated emission rate are indeed suitable indicators for the outcome of innovation processes in the electricity industry. They enable identification of whether innovation processes were successful or not and – if sufficiently differentiated – to determine the extent to which particular technologies contributed to these developments.

2.3.4 Strategies to establish innovations

In the previous sections, it was shown that the innovation process in the electricity system is carried out jointly by the equipment manufacturers and the electricity industry. The responsibility for the individual phases of the innovation process is divided between different players: while the equipment manufacturers assume responsibility for inventions and the development of marketable technologies, the electricity industry's responsibility is focused on the diffusion phase of the innovation process.

To understand and categorize statements made by the interviewees in the empirical analysis of the innovation process, it is essential to distinguish various strategies as to how innovations are established in the electricity industry. The categories elaborated in this section will be picked up in chapter 4 and make up the basis for the evaluation of statements on changes in the innovation process due to the introduction of emissions trading.

The division of responsibilities for the innovation process in the entire electricity sector clearly requires a close cooperation between the players involved. According to Hauschildt (2004: 241) such innovation cooperation can in general be characterized by several attributes:

- The partners have a joint aim which they would not be able to achieve to such an economically efficient extent or as quickly if they pursued it alone;
- The cooperation may include two or more partners;
- The players intentionally invest their own resources in the cooperation;
- Due to the division of responsibility the contributions to the overall innovation process of both partners are different; however, each of the contributions is necessary for the success of the entire process;
- Cooperation requires coordination which will be managed by means of contracts and agreed procedures; both will be controlled and adapted through the exchange of information;
- The partners agree upon an allocation of the expected proceeds depending on their individual utility function;
- The cooperation often results in a barter of services which are intentionally not evaluated in financial terms; nevertheless, such efforts are still considered an investment towards the aim of the cooperation;
- The cooperation is temporally limited and often depending on certain projects; after this period the cooperation can be basically revoked or renewed; in the case of repeated cooperation the organizational structures might be stabilized in the form of networks, alliances, joint ventures or even mergers.

In the electricity industry in particular, three specific forms of innovation cooperation with other companies can be distinguished:

1. **Joint research projects**: This kind of cooperation usually includes more than two partners, both on part of the manufacturers and on the part of the electricity industry. Often such large research projects are – at least partly – funded by the government and also include also universities or independent research institutes. In Germany, typical topics for such projects are advanced coal technologies[7], carbon capture and storage (CCS)[8], fuel cells (BMWA 2005: 32-37) or virtual power plants (BMWi 2007a). Apart from theoretical studies such research projects often comprise demonstration projects for gaining practical experiences with the innovative technology.

   While participation in such research projects is very common for larger electricity companies in Germany, smaller and medium sized companies often do not possess the financial resources to participate in these projects. The latter therefore often focus on participation in technological working groups of the respective industry associations (for example VGB, VDEW, AGFW, etc.) in which standards or framework conditions for innovation processes are developed.

2. **Onsite development**: This kind of innovation cooperation includes just two core partners in most cases, one from the equipment manufacturers and one from the electricity industry. However, both partners may carry out similar cooperation projects with other partners in parallel. While research projects are to be located at the earlier stages of an innovation process, onsite development is clearly to be located at a later stage of the process. It may refer to new investments or to installations that already exist.

   In the first case an equipment manufacturer might wish to implement an advanced version of an existing technology to gain experience with the specific features of the new design. The electricity company, however, might be reluctant to invest in this untested design since it fears interruptions in generation due to more failures and thus limited availability of the new design. To overcome this reluctance the equipment manufacturer might offer joint operation of the new installations in the first two or three years and coverage of the financial risks emerging from reduced availability. Participation in operation will provide the manufacturer with valuable experiences which are important to further develop the new design while the electricity company will be compensated for the reduced reliability until it is increased to an acceptable level.

   In the case of existing installations, onsite development refers to repeated improvements of these installations. This might include the complete retrofit of an

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[7] In the research project *Referenzkraftwerk Nordrhein-Westfalen* the design of an advance coal-fired power plant with an operating temperature of 700 °C and an efficiency of 50 % was developed (VGB 2004). This design is currently being implemented and will be tested in the *Component Test Facility* (COMTES700, VGB 2007). In both projects all major German electricity suppliers, several of the power plant manufacturers and various research institutes and universities were or are still involved.

[8] Options and strategies to sequester CO_2 from power plants are assessed in the COORETEC projects (BMWA 2003).

installation or just the replacement of certain components to improve the efficiency of a plant. Electricity companies therefore usually maintain a close cooperation with equipment providers to guarantee that they are also provided with the improvements and innovations resulting from onsite development in other installations. In practice this often results in regular visits of representatives of the equipment manufacturers to the sites of their clients, for example once every three months.

3. **Venture Capital**: This strategy is the farthest reaching of the inter-firm cooperation strategies because the cooperation is not usually limited to certain projects and because the firms become economically interrelated. Electricity companies acquire shares of new startup firms to get access to their innovative technologies and to their know how or patents (Dushnitsky, Lenox 2005; Engel, Keilbach 2002). Often electricity companies have established specific funds which are dedicated to manage these investments. The accepted risks thresholds are higher than for the usual risk strategy of the company so that some “burning of money” is allowed. However, since the fund is limited, the risks for the entire company remain calculable. Basically such acquisitions are not limited to certain technologies but include all business activities of the electricity companies, whether they are those in the field of generation, transmission or distribution. Sometimes venture capital investments are also considered a strategy to develop new business fields or markets which are not yet served by the company.

Apart from this inter-firm cooperation, innovation is also established through internal **search policies** for innovative products, services or products and improvements in general. Such internal search strategies include inter alia options such as employee suggestion schemes for improvements, regular meetings or seminars of all employees which are involved in innovation related decisions, systematic screening of journals and other media for potential innovations, benchmarking and inter-company comparison for identifying innovation deficits which should be eliminated and – last but not least – internal tenders to identify the most efficient and viable options towards a given aim.

2.4 Outlook – approaches and understanding

The innovation effects of emissions trading in the German electricity industry will be analyzed in this thesis on the basis of two different approaches. The first approach is based on neoclassical environmental economic theory and mainly addresses the different innovation incentives of the individual configuration of the EU ETS design options (chapter 3). This analysis is supported by an empirical analysis of the effects of emissions trading on the development of certain indicators of the German electricity system (chapter 5). While in the first approach the research question is analyzed from a top down perspective, it is addressed from a bottom up perspective in the second approach (chapter 4). In the bottom up approach, innovation incentives in the electricity industry are identified from the horizontal comparison of survey results which have been conducted before (2004) and after (2007) the introduction of emissions trading.

Both approaches address different aspects of the innovation process and require, therefore, different concepts and understandings of innovation. The top down approach is based on a rather narrow understanding of innovation whereas the bottom-up approach is based on a broader concept of innovation (section 2.2). Any change within a company which is triggered by the introduction of emissions trading is considered a potential innovation. Such changes may include organizational measures within the company (establishing new departments or routines, etc.), changes in the operation of existing generation and transmission technologies (utilization of a power plant, fuel shift, etc.) or changes in the investment and innovation strategy and their implementation. However, these changes should contribute in some way to the reduction of greenhouse gas or CO_2 emissions or at least be considered a necessary condition for reducing those emissions in the long run to qualify as an innovation.

The innovation concept applied in the top down approach refers above all to the third phase of Schumpeter's (1942; 1939) three phases of the innovation process. It was elaborated in the previous sections that the responsibility for the innovation process in the electricity sector is divided between the electricity industry as such and the manufacturers of generation and transmission technologies. While the latter assume responsibility for the second phase (development of marketable products or services) and sometimes also include parts of the first phase (basic research and inventions), the electricity industry is mainly responsible for the diffusion of innovation (third phase) by selecting those innovative products or services which suit most to their production process. Due to the focus on the core electricity industry in this thesis, the diffusion phase of the innovation process is of special interest in the top-down approach: innovation usually means diffusion of innovative technologies, products, services or processes to the market even if that is not explicitly mentioned.

Since investment decisions involve the selection of products or services, investment decisions are a precondition of technology diffusion and innovation and thus a potential indicator for innovation incentives in the top down perspective. Apart from the development of expenditure on investment in absolute and relative terms (investment quota), the observed or projected development of the available generation capacity and changes in the structure of the generation capacity are also important innovation indicators. Configurations which result in incentives to invest in new capacity may be considered innovation friendly even if they are qualified as economically less efficient.

However, it is often not sufficient to distinguish whether a configuration is innovation friendly or not. It is also necessary to determine which of several alterative options induces the most incentives towards a more environmental friendly electricity system. Despite the “degree of innovativeness”, the options may also differ in their contribution to emission reduction over a long-term perspective: one option may result in innovations which substantially contribute to the reduction of greenhouse gas emissions in the short-term but will not contribute to further emission reductions in the future. Other options may, in contrast, allow for a continuous reduction of greenhouse gas emissions even over a long-term perspective.

Another issue which needs to be addressed in the evaluation of alternative configurations of design options is the question of whether a fuel shift towards less carbon intensive fuels, mainly from lignite or coal to gas or renewables, should be considered an innovation or not. One could argue that improvements of the efficiency and the emission factor for each of the fuels are to be regarded as technological innovations while fuel shifting is a different measure which should not qualify as an innovation. However, in terms of an environmentally friendly electricity system any option which contributes to a reduction of greenhouse gas emissions is to be considered an innovation. Configurations which result in a fuel shift towards les carbon intensive fuels should thus not be excluded from the analysis and are, in contrast, an important option for achieving the targets of greenhouse gas reduction.

The development of the fuel specific or general generation efficiency does therefore not cover all innovations which contribute to meeting the environmental target. Nevertheless, this aspect should not be ignored since it enables distinction of whether the contributions to greenhouse gas reductions stem predominantly from efficiency improvements or from fuel shifting. The main indicator on the basis of which any design option and configuration of emissions trading shall be evaluated in this context is thus the development of the overall emissions factor of the German electricity system (g CO_2e/kWh consumed).[9] However, it will not always be possible to operationalize this indicator for each of the design options because the effect on the emission factor cannot always be determined.

In summary: The innovation concept used in this thesis is a normative concept. Innovations are evaluated according to their contribution towards achieving a more environmental friendly electricity system. This holds for the bottom-up approach in which changes within the electricity companies due to the introduction of emissions trading are identified and as well for the top-down approach in which the contribution of alterative design options of the EU ETS to a reduction of the overall emissions factor of the German electricity system are evaluated. The bottom up approach is based on a broad concept of innovation which includes any changes within the company that are induced by the introduction of emissions trading and which are at least necessary conditions for a long-term reduction of the company's greenhouse gas emissions. In the top down approach, a narrower concept of innovation is used which focuses on the development of indicators such as expenditure on investment, development of the aggregated generation efficiency and development of the aggregated greenhouse gas emissions factor of the German electricity system. With respect to Schumpeter's phases of the innova-

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[9] It might be argued that the development of greenhouse gas emissions from the German electricity system could be an even better and simpler indicator. However, the total greenhouse gas emissions depend not only on the improvement in efficiency and the fuel structure of the electricity system but also on the development of consumption. In the case of this indicator, the core innovation effects are disturbed by changes in preferences and electricity consumption patterns. Unless such changes are not considered innovations – which is possible in theory but is not put into practice in this thesis – the development of the emission factor should, therefore, be preferred to the development of total greenhouse gas emissions from the electricity system.

tion process, the concept focuses predominantly on the diffusion phase rather than on the first two phases.

3 Emissions trading – design options and innovation incentives

Since the early pilot projects in the late 1970s, emissions trading has developed into an important instrument of today's environmental policy. Major stages in this development were the US Clean Air Act of 1990, which established emissions trading for the first time on a national level, and the Kyoto Protocol in 1997, which embodied the new instrument on an international level (Hansjürgens 2005: 5-6). As a consequence, a global market for greenhouse gas allowances and carbon credits has emerged since then, particularly after the start of the EU ETS for energy intensive industries in January 2005.

According to the title of a brochure which the European Commission published shortly before the start of the trading scheme in December 2004, one major aim of the EU ETS is to "promot[e] global innovation to combat climate change" (DG ENV 2004). Climate friendly innovation is clearly a core issue of the EU ETS. However, does emissions trading really promote innovation towards a climate friendly and more sustainable electricity system? And, which of the design options are particularly relevant to the overall innovation incentives of the trading scheme and how should they be configured to provide strong incentives to innovate?

This chapter tackles these questions and elaborates on the concept, the economics and the design setting of the EU ETS. The chapter begins with an introduction of the core concept of emissions trading (3.1) including its history and development, its specific economic differences and advantages in comparison to command and control policies and considerations on the political acceptance and consequences for the implementation of the new policy instrument. The second section (3.2) focuses more specifically on the emergence of the EU ETS and additionally tackles the basic framework of the scheme, projected economic impacts of the EU ETS and issues related to the adoption and further development of the scheme. The specific innovation incentives of individual design options and their alternative configurations are discussed in the third section (3.3). This discussion is focused on those design options which were considered most important in terms of innovation in the electricity industry (see section 4.3.5). It encompasses a detailed analysis of the innovation incentives of the overall cap, of several allocation provisions and of issues related to the climate policy framework and to time plan aspects of the EU Emissions Trading Scheme. The chapter will close with some concluding considerations in section 3.4.

3.1 Concept of emissions trading

Emissions trading is a comparatively new instrument of market based environmental policy. It is based on the concept that property rights are assigned to emissions and the availability of these emissions rights or allowances is limited to an environmentally acceptable level. Potential emitters have to surrender allowances for each ton of emissions. Since the allowances are freely tradable, those emitters with lower marginal abatement cost reduce relatively more emissions and sell excess allowances while emitters with higher marginal abatement costs predominantly buy allowances instead of reducing emissions. As a result the marginal abatement costs of sellers increase whereas those of buyers decline. In a competitive market, allowance trading continues until a market equilibrium is achieved, which is the case once the marginal abatement costs of all market participants are equivalent to the market price of allowances (Weimann 1991: 158-159). In this way, emissions trading guarantees that the aspired emission reduction is achieved at minimal cost. The fundamental elements of any emissions trading scheme include:

- defining property rights to emit a substance which is harmful to the environment and assigning allowances to individual actors,
- limiting the number of allowances according to the desired cap or target path,
- creating demand for allowances by obliging specific actors to surrender emission rights at defined points in time,
- establishing a rigorous monitoring and reporting scheme for the addressed emissions; and last but not least
- enacting a strong compliance system which guarantees the enforcement of the whole scheme.

All these elements together generate a market with demand and supply for emissions, a public good in origin. The price of this good is determined by the scarcity of the allowances and the specific design of each of those elements.

3.1.1 History and genesis

Basically, the concept of emissions trading stem from the ideas of Pigou, Coase and Dales (Rudolph 2005: 24-27): in 1920, Arthur Cecil Pigou (1932) developed the concept that all costs of economic activities should be covered by prices including those costs which where borne by third parties (external costs). He suggested internalising these effects by taxing those activities which cause external costs (Pigou tax). However, due to high informational requirements, the implementation of such a Pigou tax is virtually impossible (Endres 2007: 98). Ronald Coase (1960) challenged this polluter pays principle and showed that assigning property rights to public goods would result in an efficient allocation of resources in the case of external effects (efficiency thesis), irrespective of whether the property rights are assigned to one or the other of the involved parties (invariant thesis). Based on these two concepts John H. Dales elaborated the concept of transferable property rights for public goods in 1968: “Once the property right is separated from the person, it becomes transferable, and transfers of assets (rights) then take place at explicit prices. Transferable property rights stand in a one-to-one relationship to prices; everything that is owned is priced, and everything that is priced is owned” (Dales 1968: 796).

Compared to command and control policy, which was the preferred approach to environmental policy until the mid-1970s, emissions trading seemed to be a promising instrument because it enables a reduction of the costs of implementing environmental policy through enhanced flexibility. The concept was first applied in the second half of 1970s when it was intended that traditional environmental policy under the US Clean Air Act would prevent the establishment of new plants and hence restrain economic growth in certain areas (Rudolph 2005: 77f). Under the new approach, companies were allowed to offset higher emissions through emission reduction credits from plants which did not exceed their thresholds. Tietenberg (1984: 303f; 1985: 38-59) estimates that the flexible approach reduced implementation costs by up to 90 % compared to traditional command and control policies. Moreover, the new approach also increased the incentives for innovation since companies could – compared to traditional environmental standards – gain more from replacing old polluting technologies by less polluting ones (Fritsch et al. 2003: 147; Weimann 1991: 168-170).

The new policy instrument spread widely in the USA throughout the 1990s. Several schemes were set up on a regional level and the concept of emissions trading gained dominance in the policy discourse. A prominent example is the Regional Clean Air Incentives Market (RECLAIM) for the regulation of NO_X and SO_2 in the Los Angeles area from 1994 (Harrison 1999). Other examples which gained some international visibility are the NO_X Budget program, which was set up in 1999 and comprises nine states in the Northeast of the United States (US EPA 2007), and the Illinois Volatile Organic Compound (VOC) trading scheme, established in 1999 for the Chicago area (IEPA 2007).

The transfer of the new policy instrument to Europe, however, still met with resistance. While the new instrument induced some exploratory activity in Europe,[10] the dominant regulatory culture provided a less favorable selection environment for a market based policy instrument. Command and control based regimes of environmental regulation were stronger in many European countries than in the USA where incumbent interests and institutional inertia make radical innovation more difficult (Cass 2005; Woerdman 2002).

Six years after its start, the US Acid Rain Program was deemed a success. While commentators emphasized that “(t)he explanation must lie in departures from the textbook world of perfect rationality, perfect competition, and perfect certainty, in which the system always follows the long-run equilibrium path – that is, in mistakes, market imperfections, and forecasting errors” (Ellerman et al. 2000: 299), the new instrument was recommended for large scale application: “We believe that our analysis of the U.S. Acid Rain Program supports a number of general lessons… The experience … clearly establishes that large-scale tradable permits programs can work more or less as textbooks describe…” (Ellerman et al. 2000: 315). With the US Acid Rain Program as a working exemplar in place, “the concept of harnessing market forces to protect the environment has gone from being politically anathema to politically correct.“ (Stavins 2002: 1).

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[10] For instance, a proposal for SO_2 emission regulation in the United Kingdom (Sorrell 1999) and a proposal by the business community in Norway (Hoibye 1999).

With the emergence of emissions trading – or more general tradable property rights for public goods – the “environmental toolbox” was enhanced by a fundamentally different and new instrument. While the traditional environmental policy perspective was limited to the link between pollution and polluter, the new instrument broke with this link and increased the flexibility of environmental policy. From an ethical perspective, the polluter was responsible for avoiding or reducing the pollution in traditional environmental policy. Based on Coase’s consideration of the reciprocity of external effects, the perspective was widened. Together with Dale’s concept of tradable property rights it was possible to uncouple the link between a specific pollution and its actual polluter. Instead, attention was now focused on the overall level of pollution and the differences in cost incurred by individual polluters in reducing their emissions without abolishing the responsibility of the polluters entirely.

This new approach established not only a completely new philosophy of steering in environmental policy but also entirely new markets with novel additional institutions. Moreover, the new instrument required different know-how and expertise in the affected companies and environmental administration. As a consequence, the responsibility for environmental issues within the companies tended to shift from engineers to economists. In addition, new actors such as banks, brokers and traders became more interested in environmental problems and began to participate in this new market (Voß 2007: 337-338).

3.1.2 Innovation and advantages

Compared to traditional command and control, the new environmental policy tool has several advantages from an economic perspective. Endres (2007: 104-105) and Fritsch et al. (2003: 117-118) suggest assessing advantages and drawbacks of environmental policy instruments against three economic criteria:

- The aspect of *environmental accuracy* addresses the question of whether the politically determined environmental goal can effectively be achieved with an instrument.
- The criterion of *static efficiency* tackles the issue to what extent an instrument can yield a static optimum, i.e. to what extent a specific environmental goal can be attained at the lowest cost with given technology.
- The requirement of *dynamic efficiency* deals with the innovation incentives of an instrument: How far does an instrument stimulate the search for production processes which can reduce the environmental impact at lower cost than with the given technology? And how far does it encourage the application of such innovative technologies?

3.1.2.1 Environmental accuracy

Under emissions trading the regulator determines the absolute amount of allowances which shall be allocated to the companies covered by the scheme. The amount is usually the result of a political compromise which takes into account both the environmental requirements provided by scientific bodies such as the German Parliament’s

Enquête Commission (Deutscher Bundestag 2002) or the IPCC (2007c) and potential economic impacts illustrated by model simulation and scenario studies (see section 3.2.3). Provided that a stringent monitoring, reporting and compliance regime is in place, the emissions will not exceed the amount of allocated allowances. The environmental goal will thus be exactly achieved without further intervention by the regulator.

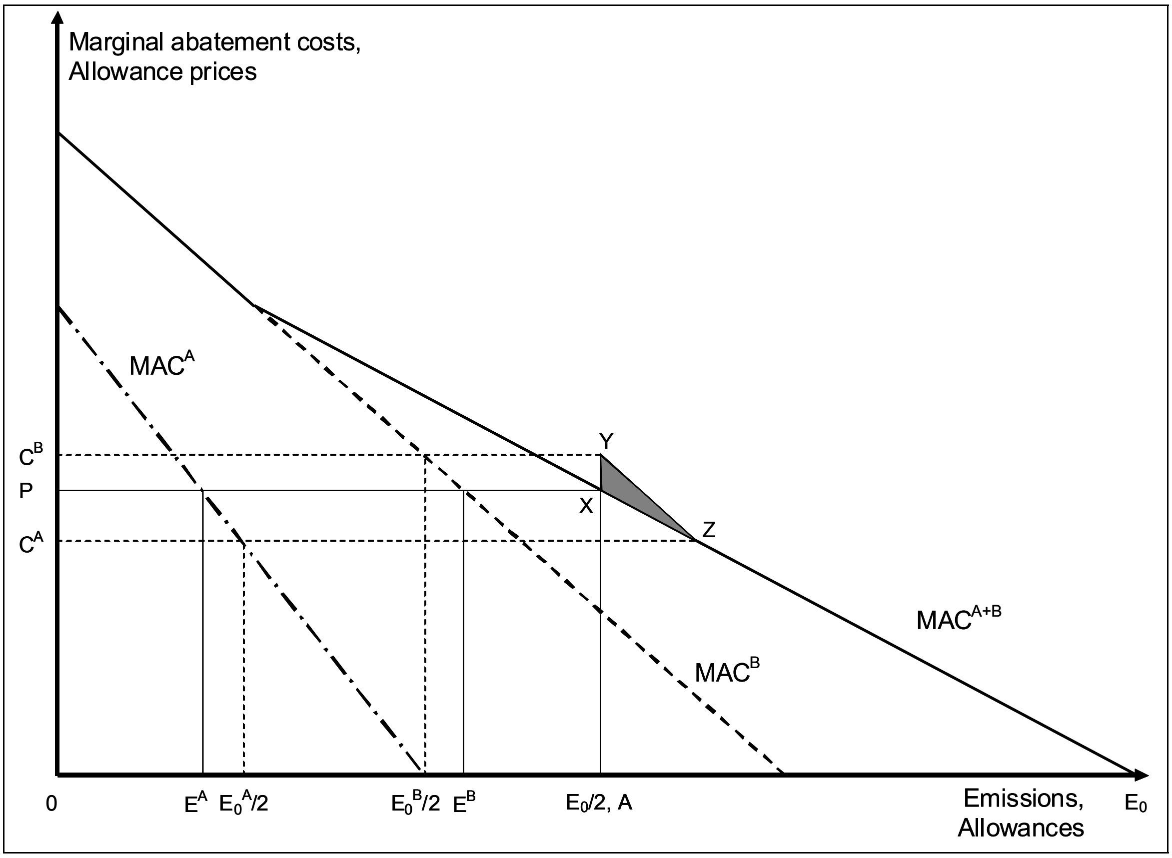
But what is the advantage of precisely achieving an environmental goal which itself is somewhat uncertain? The advantage is not to arrive exactly at the environmental goal but to achieve it without additional intervention by the regulator. This is neither the case with command and control policies nor with environmental taxation. If the economy's growth rate deviates substantially from the growth rate assumed for determining the emission standard or the tax rate, the actual emissions might considerably fall short of the goal or exceed it. A tax rate might be additionally disturbed if the actual inflation rate deviates from the projected inflation rate (Bader 2000: 52-53; Rudolph 2005: 43).

Emissions trading is, conversely, not affected by such interference; the environmental goal will always be achieved. In the case of command and control policies or taxes the regulator might have to adapt the standard or the tax rate to achieve the envisaged goal if the economy develops unexpectedly. Since government intervention is susceptible to lobbying and exertion of political influence, such repeated interventions might stimulate undesirable political uncertainty, which the companies find harder to deal with and hedge than ordinary market uncertainties. Emissions trading does not require such government intervention since it strengthens (weakens) the incentive to reduce emissions if the economy grows faster (slower) or if the inflation rate is higher (lower) than expected through increased (decreased) allowance prices.

3.1.2.2 Static efficiency

In contrast to command and control policies, market based instruments can achieve the environmental goal at cost. In Figure 8 the cost advantages of emissions trading over command and control policies are illustrated in the case of two companies A and B. Company B has higher marginal abatement costs than company A. The marginal abatement cost curve for society as a whole (MAC^{A+B}) can be determined by aggregating the marginal abatement cost curves of both companies. For this example it is assumed that emissions should be reduced by half through both policy instruments.

Figure 8 Efficiency of emissions trading compared to command and control



Sources: Pearce, Turner (1990: 110-112), Rudolph (2005: 35-37)

Under a command and control policy, company A has to reduce its emissions to $E_0^A/2$ at marginal abatement costs of C^A. Company B has to halve its emissions to $E_0^B/2$ but is confronted with higher marginal abatement costs of C^B. The total emissions are reduced to $E_0/2$. Under command and control both companies have different marginal abatement costs, which indicates that this situation is not efficient and could be improved (Weimann 1991: 18).

In the case of emissions trading emissions should also be reduced to $E_0/2$. Assuming that one allowance entitles the company to emit one unit of emission the regulator issues A = $E_0/2$ allowances. Company B with higher marginal abatement costs will reduce its emissions only to E_B at marginal abatement costs of P and will buy allowances for the remaining emissions ($0E^B$). Company A with lower marginal abatement costs will reduce its emissions more than is the case under the command and control policy to E_A but will also face marginal abatement costs of P. For the remaining emissions, company A will also buy allowances ($0E^A$). Companies with comparatively high marginal abatement costs evidently prefer buying allowances to abatement while companies with relatively low marginal abatement costs favor emission reduction instead of acquiring allowances. The flexibility provided by the option to trade allowance enables the companies to equalize their marginal abatement costs at P and results therefore in an efficient solution (Rudolph 2005: 36; Weimann 1991: 158).

The total abatement costs are represented by the areas below the MAC curves. To determine the social cost of abatement, the cost of companies A and B have to be aggregated. Under a command and control policy the total abatement costs are thus described by the area $E_0/2YZE_0$. In the case of emissions trading the aggregated abatement costs are represented by the area $AXZE_0$. The total costs of emission reduction seem to be lower under the emissions trading than under the command and control approach. The cost difference, described by the area XYZ, is the efficiency improvement which can be gained by applying emissions trading instead of command and control policies.

As a result it can be concluded that emissions trading provides – in contrast to command and control policies – an efficient solution to the goal of reducing emissions. As long as perfect competition on both product and factor markets and perfect information about the shape of the aggregated marginal avoidance cost curve can be assumed, this solution is basically identical with the solution provided by environmental taxes (Bader 2000: 45; Weimann 1991: 172). However, the aggregated avoidance costs are definitively unknown and thus uncertain and is should be scrutinized whether perfect competition can be assumed.

In the relevant literature, the issue of whether taxes or emissions trading would be the more suitable instrument to combat climate change is controversial. According to Weitzman (1974) both instruments provide the same solution only if the marginal abatement cost curve and the marginal damage curve have – in absolute terms - the same slope. If they have different slopes it may result in welfare losses. With respect to climate change it can be assumed that the marginal damage curve is rather flat while the marginal avoidance curve is relatively steep. This is because the concentration of greenhouse gases in the atmosphere is only marginally determined by current emissions whereas additional abatement efforts contribute only slowly to a decline of the atmospheric concentration. According to Weitzman (1974) this would call for a tax as the appropriate instrument to tackle the climate problem.

However, newer climatologic results provide evidence that the marginal damages might increase disproportionately steep if certain atmospheric concentrations will be exceeded. Moreover, both the marginal damages and the marginal costs are rather uncertain. Stavins (1996) shows that Weitzman’s results will be reverted in cases of simultaneous uncertainty and a correlation of the uncertainties of marginal damages and costs. In the case of a negative correlation, a tax should be preferred while emissions trading is more appropriate if uncertainties of marginal damages and costs are positively correlated.

With regard to the competitive issues it is of particular interest whether the allowances market shows a particular sensitivity for strategic behavior or not. Individual companies with some degree of market power might intend to withhold allowances in order to discourage the market entry of new competitors. However, it is rather inefficient to crowd out competitors on heterogeneous product markets by developing market power on factor markets since such an action would also affect other industries with which they are not in competition. The efforts to achieve market power would thus be partly diluted and would only affect real competitors to a certain extent. Instead, it would be more efficient to use these efforts to directly gain market power on the respective product markets (Rudolph 2005: 41).

With respect to efficiency, emissions trading has clear advantages over command and control policies. Whether emissions trading or taxes are more appropriate to dealing with the problem of climate change is not immediately clear. However, since this question is not in the focus of this study but particularly design issues of emissions trading, this debate will not be addressed in greater detail.

3.1.2.3 Dynamic efficiency

In the above analysis of the static efficiency, the issue of whether an instrument fosters the efficient use of resources with a given technology was scrutinized. In the long run, though, it is also, or even more, important whether and to what extent an instrument encourages companies to search for more efficient technologies and processes and to what extent it promotes application of these new technologies and processes. In addition to the static efficiency, the dynamic efficiency is therefore of important relevance. An instrument is considered to be dynamically more efficient than another instrument if it induces stronger incentives for innovation. An environmental innovation is achieved if the same level of emission reduction is realized at lower costs or if a higher level of emission reduction is attained at the same costs (Endres 2007: 133).

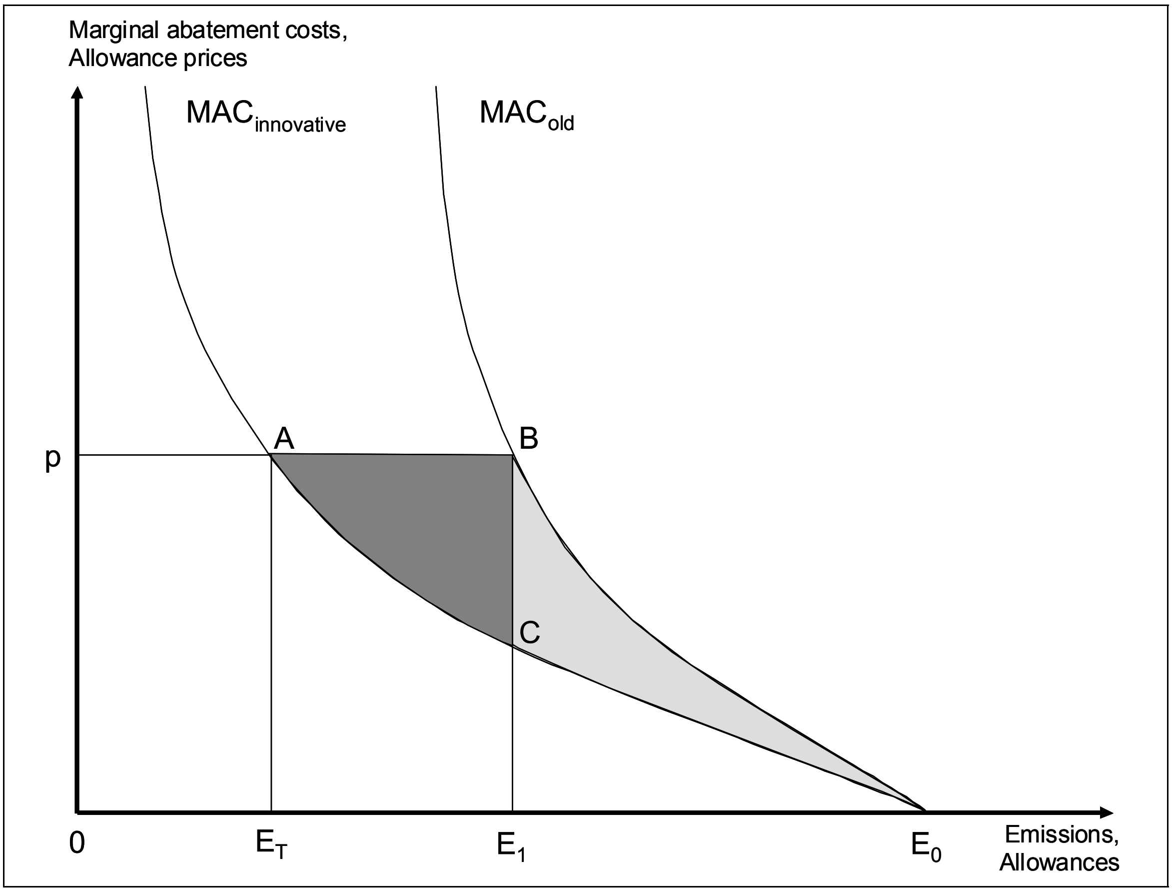
Under command and control policies, companies have an incentive to search for innovative technologies which allow them to comply with the given emissions standard at lower costs. However, there is no incentive to reduce emissions beyond this standard because the additional efforts would not be rewarded. Emission reductions beyond the standard might only occur as a by-product of improvements in the regular production process.

In the case of emissions trading, the companies have initially the same incentive to introduce new processes which reduce the costs of emission reduction. However, this incentive is not limited to the compliance with a specific standard. On the contrary, any unit of emission which can be additionally reduced through the implementation of innovative technologies reduces the demand of companies for allowances. Companies can thus improve their profits by applying such innovative technologies until the marginal abatement costs of those technologies are equivalent to the market price of allowances. With respect to the dynamic efficiency, emissions trading is thus clearly more advantageous than command and control policies.

The stronger innovation incentives of emissions trading compared to command and control policies can also be illustrated graphically (Figure 9). In this example, it was assumed that companies emit E_0 emissions before implementation of a climate policy.

In the case of the command and control policy, the regulator establishes a standard which requires the company to reduce emissions to E_1. With the old technology, the company faces marginal abatement costs of p and total abatement costs equivalent to the area E_0E_1B. An innovative abatement technology is characterized by lower marginal abatement costs, i.e. a shift of the MAC curve to the left. If the company applies the innovative technology, total abatement costs are reduced to the area E_0E_1C. The saved abatement costs are equivalent to the area E_0CB. They can be regarded as a measurement of the incentive to apply new technologies. The stronger the incentives, the greater are the costs to be saved through the new technology.

Figure 9 Innovation incentives of emissions trading compared to command and control policies



Sources: Endres (2007: 140), Rudolph (2005: 48)

Under emissions trading, the regulator issues E_1 allowances resulting in an allowance price of p. With the exiting technology the company faces total abatement costs equivalent to the area E_00pB.[11] By switching to the innovative abatement technology, the

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[11] This holds independently of whether the allowances are auctioned or allocated free of charge. In the first case, the company is confronted with real costs equivalent to the area E_00pB. In the latter case, the real avoidance costs are much smaller. If, for example, E_1 allowances are allocated free of charge, the real cost correspond to the area E_0E_1B. However, instead of using the allowances received free of charge, the company might also sell them. The opportunity cost of an allowance is thus equivalent to the market price. The opportunity costs of all allowances received free of charge are accordingly equal to the area E_10pB. The total costs, comprised of real and opportunity costs, are therefore identical with total costs in the case of auctioning.

company can reduce its abatement cost to the area $E_0$0pA. The savings due to applying the innovative technology are equivalent to the area E_0AB.

Under emissions trading, the saving of switching from the traditional to the innovative abatement technology is larger by the CAB area than under a command and control policy. Thus, the incentive to switch to the innovative abatement technology is correspondingly larger under emissions trading than in the case of the command and control policies.

Admittedly, this consideration omits that the shift to new technologies will reduce the company's demand for allowances to E_T. If this is a general trend in the covered industries, the price for allowances and, along with it, the incentive to innovate will gradually decline. However, this effect might be offset if the amount of available allowances is reduced at the pace of technological progress. Taking into account that global greenhouse gas emissions have to be halved by the middle of the century, it is however more likely that the reduction requirements will become more ambitious in the future so that the innovation incentive will tend to increase rather than decline.

As regards dynamic efficiency, emissions trading is clearly superior to a command and control approach (Endres 2007: 143) because the innovation incentive is not cut off as soon as the environmental standard is achieved. Emissions trading induces stronger innovation incentives than command and control policies. Since it can be assumed that the ambitious greenhouse gas reduction targets can only be achieved with continued technological innovation, emissions trading clearly seems to be a more suitable instrument for dealing with climate change than command and control policies.

3.1.3 Incidence and acceptance

From an economic perspective, emissions trading is in many aspects superior to command and control policies. From the company perspective, standards still have the advantage that they avoid financial transfers from business sectors to the state (Hahn, Stavins 1991). Economic based instrument reduce indeed the social costs of achieving a certain environmental target. However, in a trading scheme with auctioned allowances (or in a tax regime) the covered companies are confronted with substantially higher costs because in addition to the direct avoidance costs, which they have to bear under a command and control regime, they also have to bear the costs of allowances (or taxes) for the remaining emissions. Economic instruments might reduce the social cost of emission reductions but they do not on average reduce the private costs of the covered companies. The costs of allowances (or taxes) accrue every year and constitute a substantial transfer of purchasing power from the business sectors to the state (Bonus 1990). For these reasons, industry representatives were initially not in favor of economic instruments.

In contrast to carbon taxes, these financial transfers to the public sector could be avoided or reduced under an emissions trading scheme if free allocation of allowances takes place. The costs which were to be absorbed by the covered companies would on average be reduced to the direct avoidance costs. The transfer of purchasing power from the companies to the public budget for the remaining emissions would be smaller because the firms would receive free allocation.

However, even if they are allocated for free, such allowances are not worthless. On the contrary, the value of these allowances is mainly determined by the overall scarcity of allowances in the entire trading scheme and the availability of cost efficient mitigation options. In their cost calculations the companies thus include the value of the allowances as an additional production cost factor. This is because the companies have to take into account the opportunity to stop or reduce their production and to sell instead the “freed” allowances at their market price. Depending on the price elasticity of their product and their exposure to competition from outside of the EU ETS, the companies could pass through these opportunity costs to their clients. According to the extent to which the firms can pass through the opportunity costs of the allowances acquired via free allocation, the affected companies could gain windfall profits. Free allocation does not, therefore, avoid financial transfers between sectors at all but rather redirects these transfers: instead of transfers from the covered companies to the public sector, it results in transfers from the consumers of the relevant products to the covered companies.

Not surprisingly, such an allocation approach received more support from the affected business sectors. Up to now the majority of the trading schemes have been set up using free allocation of allowances (Mackenzie et al. 2007). This is because grandfathering was always a key element in gaining support from industry for emissions trading (Sterner, Hammar 2005: 31).

3.2 EU Emissions Trading Scheme

3.2.1 Emergence and motives

In 1997, emissions trading became a core element of the international climate policy governing framework. With the support of the international business community US diplomats negotiated the integration of international emissions trading into the Kyoto Protocol – against resistance from the European Union which feared that reduction commitments could be watered down by importing excess emissions rights (“hot air”) from former socialist countries (Damro, Luaces Méndez 2003: 76; Oberthür, Ott 1999: 188-190).

However, the development of a working rule system for international emissions trading under the Kyoto Protocol soon became stranded when differences emerged between the EU and the USA (Cass 2005; Woerdman 2002: 350-384). In an attempt to overcome this deadlock, the Environmental Defense Fund (EDF) encouraged business corporations to move ahead with company internal trading schemes as a means of demonstrating their support for the instrument. In 1999, the oil companies BP and Shell established greenhouse gas emissions trading schemes of transnational scope (Zapfel, Vainio 2002: 8). These schemes also attracted particular attention as the first applications of emissions trading to greenhouse gases.

In the context of these ongoing developments on a supra- and sub-national level, policy initiatives started to take shape, also on a national level in Europe. In 1999, Denmark introduced the first emissions trading scheme in Europe. While this case gained little attention – as CO_2 trading was restricted to eight utilities – (Pedersen 2000: 3-5), a parallel initiative stirred up debate in policy cycles around Europe. In the UK, business actors set up the Emissions Trading Group (ETG) to develop a voluntary scheme as an alternative to tax proposals. The ETG comprised multinational companies which had experience in emissions trading in the USA. Central actors from the US emissions trading innovation network participated regularly in working group sessions (Smith 2004: 83-84). With the ETG a European bridgehead of the emissions trading innovation network became established. In 2002 the UK government endorsed and financially supported a pilot scheme developed by the ETG because it was thought "to enable business to gain practical experience of emissions trading ahead of a European and international system, and to help the City of London establish itself as a global centre for emissions trading" (DEFRA 2003).

The European Union and its Member States still rejected emissions trading under the Kyoto Protocol, but within European policy networks emissions trading was enrolling an ever larger constituency. It was increasingly believed that emissions trading would come anyway and that the only sensible thing to do was to get involved. The more stakeholders believed in it, the more likely it was that it would happen. This made it difficult to be against emissions trading. Around 2000, a reversal happened in Europe. Actors who were critical of emissions trading turned into supporters; the debate shifted from the question of "if" to "how" (Zapfel, Vainio 2002: 9-10).

The European Commission became a hub of informal consultations and exploration of emissions trading as a policy instrument for domestic climate policy. Already in May 1999, the EU Commission presented the Communication "Preparing for Implementation of the Kyoto Protocol" to the Council and Parliament saying that this "means to bring our own house in order and involves taking the necessary action for enabling the full application of the Kyoto provisions" (COM(1999) 230: 1).

In March 2000, the Commission tabled a Green Paper which contained a proposal for a European Emissions Trading Scheme (EU ETS). This proposal assumed that "emissions trading will be an integral and major part of the Community's implementation strategy [of the Kyoto Protocol]" (COM(2000) 87: 4). The Green Paper was linked to a broad stakeholder process. A central platform for stakeholder consultations was Working Group 1 on "flexible mechanisms" under the European Climate Change Programme (ECCP) set up in June 2000. Comprising experts from various Directorates of the European Commission, from national governments, industry and environmental NGOs this group took on an entrepreneurial role for emissions trading within Europe. US experts were regularly invited for consultation. "Astonishingly, the group – bringing together diverse interests with about 30 representatives from some Member States, industry, and environmental pressure groups – achieved a high degree of consensus and failed only to adopt a consensual recommendation in very few issues" (Zapfel, Vainio 2002: 11). The group recommended "that emissions trading start as soon as practicable. Implementation of emissions trading within the EC should not wait for progress made in defining the Kyoto mechanisms, and should be developed in the context of, and with a view to influencing the design of, an international scheme from 2008. A pre-Kyoto EC system should be viewed as a "learning-by-doing" process" (DG ENV 2001: 4).

When the USA withdrew from the Kyoto Protocol in 2001, the next critical juncture arose. The EU was urged to take over the lead in climate policy and demonstrate concrete success in order to keep the international process alive (Wettestad 2005: 16). Another important factor made a particularly good fit of emissions trading with the domain of European climate policy at that time: while the Commission had worked towards an unanimity vote of the Council on a proposal for a European energy tax for years without success, emissions trading (as a non-fiscal measure) was allowed to move ahead on the basis of a majority vote only. Moreover, the Commission, supported by an increasing number of European business actors, had an interest in avoiding uncoordinated development of national emissions trading systems which would prove incompatible with each other and impinge on the project of creating an internal market (Christiansen, Wettestad 2003: 6-7; COM(2000) 87).

In October 2001, the Commission tabled a draft directive to establish the EU ETS. The proposal contained a mandatory emissions trading scheme for all Member States covering CO_2 from all energy intensive sectors except the chemical industry. Allowances were to be allocated free of charge on the basis of historical emissions (grandfathering).[12] The proposal acknowledged the Member States' diversity in economic and technological circumstances by providing an overriding common framework which, however, enabled subsidiarity in several design elements. This framework was to be embodied by National Allocation Plans (NAPs) in which the Member States specified their overall cap, the methods of allocation to individual installations and other design elements. Since the national caps are the most crucial and hence politically most embattled element in terms of effectiveness, it was essential to gain support for the adoption of the directive that was to be defined at Member State level (Zapfel 2007).

The final directive was adopted after an "ultra-quick process" (Wettestad 2005) in October 2003. It included the core elements of the Commission's proposal and minor amendments by the European Parliament and the Council: optional auctioning of up to 10 % of the allowances, an opt-out provision for individual installations in the first period and an opt-in of additional gases were added. The use of project based flexible Kyoto mechanisms should be enabled through a separate Directive at a later stage.

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[12] Apart from political pressure by particularly the power industry there was uncertainty about classifying the auctioning of allowances as a fiscal measure, which would have required unanimity in the European Council. This might have put the adoption of the Directive at risk and was therefore ruled out by the European Commission (Zapfel 2007).

3.2.2 Framework and structure

This EU Emissions Trading Scheme (EU ETS) was established by the European Directive 2003/87/EC. The scheme is organized in trading periods. The first two trading periods extend from 2005 to 2007 and from 2008 to 2012 respectively. The scheme is designed to continue after 2012 although the Directive only directly refers to these two periods. However, in Article 11 (2) it is mentioned that each subsequent period will last five years.

The first period was considered a preliminary phase intended to gain experience in greenhouse gas trading before international emissions trading under the United Nations Framework Convention on Climate Change (UNFCCC) would start in 2008 (COM(2001) 581: 3). Accordingly, Article 30 provides for a review of the Emissions Trading Directive. This review should take into account experiences with the application of the Directive and development under the UNFCCC. Depending on the progress made on monitoring of greenhouse gas emissions, the review should also address the inclusion of additional greenhouse gases and further activities.

The scheme is set up as a cap and trade scheme. The overall amount of emissions for each period is fixed in advance and certified as emissions rights. These emission rights are freely tradable between the participants. Earlier trading schemes in the USA were often setup as baseline and credit schemes without a cap on aggregate emissions (Burtraw et al. 2006: 199). Instead, a baseline for each of the covered installation was defined. This baseline was usually derived from historical emissions or a performance standard. Reductions against this baseline were converted into reduction credits which were – after administrative approval – eligible for sale (Gagelmann, Frondel 2005). Baseline and credit schemes emerged from early efforts to make command and control policies more flexible by allowing offsets between individual installations. Most of these schemes were voluntary and had limited success because participants had few incentives to supply reduction credits on the market but preferred to bank them for later use (Burtraw et al. 2006: 199-200). Later, trading schemes were predominantly established as cap and trade schemes. The Kyoto Protocol combines elements of both approaches: countries mentioned in Annex B of the protocol have committed to an absolute target or cap respectively. However, they may comply with their commitments by purchasing reduction credits from the project based flexible Kyoto mechanisms CDM and JI which are instruments of the baseline and credit approach. Since most EU Member States are included in Annex B of the Kyoto Protocol it became clear that the EU ETS should be set up as a cap and trade scheme in order to guarantee compatibility between both schemes.

Emissions might be either registered at the point where the respective source material or fuel is extracted or imported into the area of the trading scheme (upstream) or at the point of emission, i.e. at the individual installation which releases the greenhouse gas into the atmosphere (downstream). Under the upstream approach extractors or importers of source material and fossil fuels would be obliged to surrender allowances while under the downstream approach this obligation would fall on the various installations which directly emit greenhouse gases. Basically, the upstream approach covers emissions in all sectors whereas the coverage might be restricted to certain sectors under the downstream approach. Extractors and importers of source material and fossil fuels would pass through the additional cost to their consumers and thus create an incentive for companies and private households to reduce their consumption and hence emissions. From the consumer's perspective, an upstream trading scheme would hence resemble an environmental tax. Since initiatives to establish a CO_2 and/or energy tax in the EU were – due to the required unanimity (see section 3.2.4 for more details) – already deadlocked for several years, the Commission suggested already in its green paper to follow the downstream approach (COM(2000) 87: 13). An additional advantage of this approach is that it is easier to extend the scheme to other, not fuel related greenhouse gases such as N_2O or F-gases at a later stage.

The EU ETS covers the greenhouse gas emissions of about 10,800 installations (EU COM 2007c) in the EU Member States.[13] Apart from installations in the energy intensive sectors of energy supply, steel, cement, glass, pulp & paper and ceramics all combustion installations with a rated thermal input above 20 MW are included (2003/87/EC, Annex I). In the preliminary phase the scheme covers only the CO_2 emissions of the covered installations. However, Article 24 provides for unilateral inclusion of other greenhouse gases and activities by Member States. In this regard the Commission has brought forward a proposal to include international aviation within the EU from 2011 and additionally flights from and to the EU from 2012 onwards under the EU ETS (COM(2006) 818). In the ongoing review process the Commission has also suggested the inclusion of certain activities of the chemical industry and installations for carbon capture, transportation and storage as well as perfluorocarbons and nitrous oxide emissions of certain activities from 2013 into the EU ETS (COM(2008) 16 provisional: 34-36).

The tradable emissions rights are called European Union Allowances (EUA), each one of which enables the holder to emit one ton of greenhouse gas equivalents during the specified period. From 2008 onwards, each EUA is mirrored by an Assigned Amount Unit (AAU) under the Kyoto Protocol. Transfer of EUAs between Member States will thus involve corresponding adjustments of AAUs (2003/87/EC, Recitals (10)). By distinguishing EUAs from AAUs it is guaranteed that AAUs from international emissions trading under the Kyoto Protocol cannot be directly used for compliance with the EU ETS. In this way, it should be prevented that potentially rather cheap surplus AAUs of countries in transition, so-called “hot air”, flood the EU ETS and eliminate the incentive to reduce emissions domestically. Allowances that have not been used during the specified period will be cancelled and replaced by an EUA for the next period (2003/87/EC, Article 13). Therefore, allowances can be saved for the next period

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[13] The trading scheme started in 2005 with the then 25 Member States. In 2007, it was expanded to include the new Member States of Bulgaria and Romania. In October 2007, the Commission announced that the trading schemes of Norway, Iceland and Liechtenstein will be linked to the EU ETS. The newly linked systems will cover 30 countries across the European continent (EU COM 2007d).

(banking).[14] EUAs will be issued until the end of February each year while allowances should be surrendered by the end of April. At the time of surrendering, operators have the allowances issued in the previous year and those of the current year available so that “borrowing” within a trading period is possible. However, borrowing of allowances between periods is not allowed.

In the first two periods allowances are generally to be allocated free of charge (2003/87/EC, Article 10), except for a small share of 5 % in the first and 10 % in the second period, which may be auctioned or sold. Since the definition of the national cap and the methods of allocation to individual installations are economically rather sensitive issues, it was essential for the acceptance of the directive by the Member States that they were conceded subsidiarity in both issues. Hence, the individual Member States are responsible for determining the national cap and the methods of allowance allocation to the operators of the covered installations in their country. For this purpose each Member State had to submit a NAP eighteen months before the start of each trading period, in which reasons for the definition of the overall cap were substantiated and the methods of allocation to the installations were explained in detail. To guarantee a minimum level of homogeneity, the Member States have to take into account the criteria of the Directive’s Annex III while developing their NAPs. The European Commission reviewed each NAP and may reject it if it is not congruent with the European Union’s agreement on burden sharing in greenhouse gas mitigation (2002/358/CE) or if it violates the rules of fair competition.

The operators of the covered installations are required to monitor their emissions in accordance with the monitoring and reporting guidelines (2004/156/EC). By the end of March of each year they have to report their emissions of the previous year to the competent authority. These reports have to be verified by an independent verifier. Operators who do not comply with these requirements are suspended from trading until they have submitted a satisfactory report. Compliance with the trading scheme is guaranteed by penalties which apply if an operator does not surrender sufficient allowances. In the first period the excess emission penalty is € 40 and in the second trading period € 100 per ton in addition to the allowance which still has to be surrendered afterwards.

The use of credits from the project based Kyoto mechanism CDM and JI is only marginally mentioned in the Directive itself (2003/87/EC, Article 23 (3)) but is in more detail regulated in the so-called Linking Directive (2004/101/EC). Since 2005 and 2008 respectively CER and ERU can be basically exchanged for an EUA so that they can be used for compliance under the EU ETS. However, since these credits should be supplemental to domestic action, the use of these credits is restricted to a certain share of allocated allowances which has to be specified in the NAPs.

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[14] Since EUAs of the first period were not yet mirrored by AAUs, the Member States were not required to but might have enabled banking between these periods. Only two Member States (France and Poland) made use of this provision but limited the amounts of bankable allowances to strict criteria.

3.2.3 Effects and impacts

The economic impacts of achieving the EU's Kyoto or burden sharing targets respectively with the help of the EU ETS have been analyzed in a number of studies.[15] The simulation by Capros and Mantzos (2000) resulted in 24 % reduced losses of GDP in 2010 (average of the period 2008-2012) due to the introduction of emissions trading within the EU-15 Member States compared to the case with only domestic policies. Compliance costs or CO_2 prices respectively, were estimated at € 33/t CO_2e. Using the POLES model model, ITPS (2000) arrive at comparable results regarding the reduced GDP loss. However, the compliance costs are at € 50/t CO_2e and thus substantially higher. Böhringer et al. (2004) estimate a gain in GDP of 36 % at compliance costs of € 10/t CO_2e. The analysis of Klepper and Peterson (2004) includes all 25 EU Member States as of May 2005. Depending on the assumptions regarding the allocation methods applied within the EU ETS, the welfare gains of EU-wide emissions trading vary between -0.1 % and +0.7 % at compliance costs from € 7 to € 11/t CO_2e. Reilly and Paltsev (2005) do not state the impacts on GDP or welfare. However, they estimate compliance costs of less then € 1/t CO_2e. In several sensitivity analyses they examine the impacts of oil and gas prices that are up to 50 times higher and a 20 % reduced electricity supply from nuclear and hydro power plants due to extended droughts in summer. Even under these extreme assumptions, the compliance costs might only rise to € 19/t CO_2e in the first period. For the second period they assume changes in the design and sectoral coverage of the EU ETS. Under some of these assumptions compliance costs might rise to € 32/t CO_2e. More recently, Kemfert et al. (2006) scrutinize the impacts of EU-wide emissions trading in comparison to only domestic or no emissions trading. Their simulations result in compliance costs of € 1.50/t CO_2e in the EU-wide trading case. In the cases of only domestic trading or no trading at all, compliance costs vary between the Member States and between sectors respectively. However, in all cases they are higher than in the trading case and in some sectors up to 80 times so.

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[15] A comprehensive overview is provided by Oberndorfer et al. (2006).

Table 1 *Overview of simulation results regarding the economic impacts of the EU ETS*

Reference	Coverage	Model	Year	Change in GDP or welfare compared to no trading case	Compliance cost [€/t CO_2e]
Capros and Manzos 2000	EU-15	PRIMES	2010	24%	33
IPTS 2000	EU-15	POLES	2010	25%	49
Böhringer et al. 2004	EU-15	SIMAC	2006	36%	10
Klepper and Peterson 2004	EU-25	DART	2010	-0,1%[a] to +0,7%	7 to 11
Reilly and Paltserv 2005	EU-25	EPPA	2006		1 to 19 [b]
Reilly and Paltserv 2005	EU-25	EPPA	2010		1 to 32 [c]
Kemfert et al. 2006	EU-16	GTAP-E	2006		1,50

[a] Change in welfare compared to no trading case; [b] Depending on assumptions for oil and gas prices and availability of hydro and nuclear power plants; [c] Depending on assumptions regarding the design and coverage of the EU ETS.

Table 1 provides an overview of the main economic impacts of emissions trading. Due to varying assumptions and different models being applied, the results of the studies differ substantially. However, all studies result in a gain in GDP or welfare and reduced compliance costs in comparison to the no trading or the business as usual case. Potential losses in GDP are not a result of the EU ETS but of emission restrictions applied by the Kyoto target. “The ETS is indeed lowering the negative effects of reaching this target compared with pure unilateral action” (Klepper, Peterson 2004: 12)

3.2.4 Adoption and advancement

In the draft directive, the Commission defined emissions trading as an “environmental measure”. As an environmental measure it could be adopted on the basis of Article 175 (1) of the EU Treaty, i. e. by a qualified majority in the Council of Ministers with co-decision of the European Parliament (Wettestad 2005: 4). In this way, it should be avoided that the emissions trading initiative experienced the same destiny as the proposals on a carbon or energy tax which were already presented in the early 1990s but not yet adopted when the draft Emissions Trading Directive was presented. Decisions on fiscal measures, conversely, are based on Article 175 (2) of the EU Treaty and require unanimity in the Council. These tax proposals got stuck in the Council because several Member States brought forward various sorts of objections to the proposals, often fuelled by intense industrial lobbying (Wettestad 2005: 4, 8). Auctioning of allowances would have put the draft Emissions Trading Directive at risk of being classified as fiscal measure due to the considerable revenues of such an approach (Zapfel 2007).[16] Free allocation was, therefore, a key element in the Commission's strategy to avoid the same deadlock with emissions trading as experienced with the tax proposals although economic analyses had suggested that auctioning of allowances would be more efficient (see for example Burtraw et al. 2002: 18; Jaffe et al. 2001: 56-65). Moreover, free allocation could substantially contribute in gaining support of the covered industries for emissions trading (see section 3.1.3).

Buchner et al. (2006: 19) provide another argument which justifies free allocation to some extent, at least at the start of a trading scheme. With reference to the prior rights norm, they highlight that the right to emit, now limited under the EU Emissions Trading Scheme, was previously freely exercised. In contrast to command and control policies where no charge is applied to the use of these rights as long as the installations is deemed in compliance, under an emissions trading scheme a charge is applied to the continued use of these rights despite the fact that the use is to a certain aggregate extent allowed. Establishing the carbon constraint would thus induce a substantial redistribution of these rights which would not occur under a command and control approach. Burtraw et al. (2002) analyze the effect on asset values of different allocation options. With an electricity market model they simulate the changes in asset values due to a 6% reduction of greenhouse gas emissions between 2004 and 2012 against the business as usual baseline. They find that allocation free share would offset losses induced to incumbent installations by the trading scheme. However, only 7.5% of the allowances would be needed to offset the aggregate losses. Although the numerical results cannot be directly transferred to the EU ETS due to its more ambitious targets, they still illustrate that continued free allocation in general runs the risk of overcompensating potential losses of incumbents. Nevertheless, some share of allowances allocated for free at the start of an emissions trading scheme can be justified as a compensation for the losses which arise from sunk costs due to the introduction of emissions trading.

Free allocation enables firms to offset potential losses with additional windfall profits. Yet, the conditions for generating such extra profits are not identical in all covered sectors. Particularly the electricity industry has favorable conditions for passing through opportunity costs to their customers: competition from outside of the EU is virtually not existent due to, on the one hand, limited electricity transmissions capacities or high costs of extending these capacities respectively and, on the other hand, a rather inelastic electricity demand – at least in the short and medium term (Ellerman 2006: 13; Lijesen 2007). Sijm et al. (2006: 57-58) estimated that the German electricity industry passed through between 60 and 100% of their opportunity costs in 2005. Matthes and Neuhoff (2006: 20-21) reckon that windfall profits of Europe's electricity industry could have amounted to almost € 30 billion in 2005. VIK (2005) assumed that the utilities' windfall profits could add up to € 5 billion alone in Germany.

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[16] In order to not resemble an environmental tax, the EU ETS was also designed as a downstream scheme from the start (see section 3.2.2).

These tremendous amounts attracted the attention of industry, consumers and political parties and caused intensive debates about options for limiting windfall profits. One of the discussed solutions was to exploit the option provided in the EU ETS Directive to auction up to 10 % of the allowances in the second trading period. However, the government's first draft of the second NAP submitted to the European Commission did not include any auctioning. The debates culminated in a parliamentary initiative to amend the government's draft which finally got adopted (Stratmann 2007). In the final NAP for Germany, the compliance factor for the electricity industry was hence considerably toughened in order to obtain a budget of 40 million EUA per year or 8.8 % of the overall cap which should be auctioned.

The debate on windfall profits and auctioning as a means of limiting these profits was also intensively discussed in the review process according to Article 30 of the EU ETS Directive. A number of Member States argued in favor of auctioning, some of them advocating full auctioning from 2013 onwards (DG ENV 2007: 19). Based on this debate the Commission concluded that there was a lot support for auctioning due to its merits with regard to transparency, delivering a clear price signal and avoiding windfall profits (DG ENV 2007: 21). The first draft of amendment to the EU ETS Directive reflects these conclusions. According to this draft, free allocation should be drastically reduced in 2013 and then gradually phased out: free allocation to the industrial sectors should be reduced to 80 % of the average in the period 2008-2012 and then decrease by equal amounts each year, culminating in zero free allocation by 2020. For the electricity industry full auctioning should be the rule from 2013 onwards. Only heat delivered by the power sector to district heating or industrial installations would be eligible for free allocation (COM(2008) 16 provisional: 7-8).

It seems that the Commission's strategy yields that which was intended: before the start of the trading scheme it was less important to develop a – from an economic perspective – optimal design but to get the scheme up and running. Once the scheme was in place, it would be easier to gradually amend the scheme towards the design many economists had favored beforehand. However, this preferred design might not have received enough political support to establish the EU ETS at all.

The Commission's strategy was supported by the specific institutional dynamic which was triggered in the course of preparations for and start of the trading scheme. Increasingly, actors beyond established environmental policy networks were also becoming involved. "(…) market intermediaries and other potential service providers (auditing companies, consultants, lawyers, academics, commercial conference organisers) saw a potential market arising and were more than willing to invest some resources under the header of business development." (Zapfel, Vainio 2002: 7). Their "helper's interest" (Prittwitz 1990: 116-121) brought forward exploratory studies and research and development activities in Europe which were justified by the need to be prepared for upcoming policy debates. In the years prior to the introduction of the EU ETS, part of the dynamics was the emergence of what is now called the "carbon industry" – an increasingly organized sector of specialized businesses that provide services for the development and maintenance of emissions markets. The International Emissions Trading Association (IETA) was set up in 1999 to promote the worldwide development of emissions markets. Its members are specialized consultancies, banks, brokers, exchanges, risk managers, project developers, journals, conference organizers, news services, etc. Emissions trading gained additional momentum – not only as an environmental policy instrument, but also as a thriving service economy which started to actively advertize its products and lobby for the expansion of its market (Voß 2007: 337-338). By involving additional actors which increasingly developed intrinsic economic interests in the trading scheme, the EU ETS developed a self-reinforcing dynamic which would have not occurred under a tax or a command and control regime.

With emissions trading, new perspectives have been introduced in environmental policy. By defining tradable property rights it was possible to address problems related to the commons by privatizing public goods. The new concept enabled the responsibility for environmental pollution and mitigation activities to be decoupled, thereby substantially increasing the flexibility of affected companies. With this approach, environmental goals can be precisely and economically efficiently achieved. Moreover, with its focus on profit maximization this new approach fosters technological innovation to a greater extent than traditional command and control policies.

3.3 Innovation incentives

The basic concept of emissions trading seems to be clear and rather simple at first glance. However, the devil is in the details. The innovation incentives of the trading scheme depend on the specific configurations of the various design options. Particularly the amount of the total cap and the specific design of various allocation provisions as well as time-related issues within the trading scheme and the overarching climate policy framework are crucial to the innovation incentives of an emissions trading scheme.

In the following subsections the incentives to innovate electricity generation induced by the individual design options and their potential configurations will therefore be analyzed in detail. For this analysis, it should be recalled (from chapter 2) that the usual innovation indicators are largely unsuitable for the electricity industry, not least of all because the responsibilities for the different phases of the innovation processes are differentiated in the electricity sector (section 2.3.1): the electricity industry is particularly responsible for the diffusion of innovative technologies which are invented by universities or research institutes and developed to marketable products by transmission and generation technology manufacturers. The electricity industry's investments in generation technologies are always an opportunity to establish innovative technologies. Incentives for investments in generation technology are hence an adequate proxy indicator for the degree of innovation induced by emissions trading (section 2.3.3.1.1). However, although new generation capacities are as a rule substantially more efficient than old installations, not every investment in generation technology should be considered an innovation. In addition to the investment incentives induced by the individual design options and their potential configurations, it has also to be scrutinized whether the new capacities actually contribute to a long-term reduction of greenhouse gas emissions from electricity generation or not (section 2.3.3.1.3).

3.3.1 Cap

The overall cap determines how many allowances are available and thus how environmentally effective a trading scheme is. Emissions will be the more reduced, the more stringent the cap is. However, due to increasing marginal abatement costs a more stringent cap will also result in higher absolute avoidance costs of the entire scheme. Due to this trade-off, policy makers have to balance the cap between the environmental requirements and the economic impacts (Fischer 2005: 46).

The stringency of a target not only determines the environmental effectiveness but also the degree of innovation incentives created by a scheme. Basically, a more stringent cap will induce more technological innovations than a weaker cap because a more stringent cap will result in a greater scarcity of allowances and hence higher allowance prices. Higher allowance prices, in turn, spur innovation since they allow more innovative mitigation options to enter the market than is the case under a weaker cap (Schleich, Betz 2005: 1496). Innovative options which are not yet economically feasible under a weaker cap will become competitive under a more stringent cap with higher allowance prices.

Figure 10 Innovation incentives of the cap

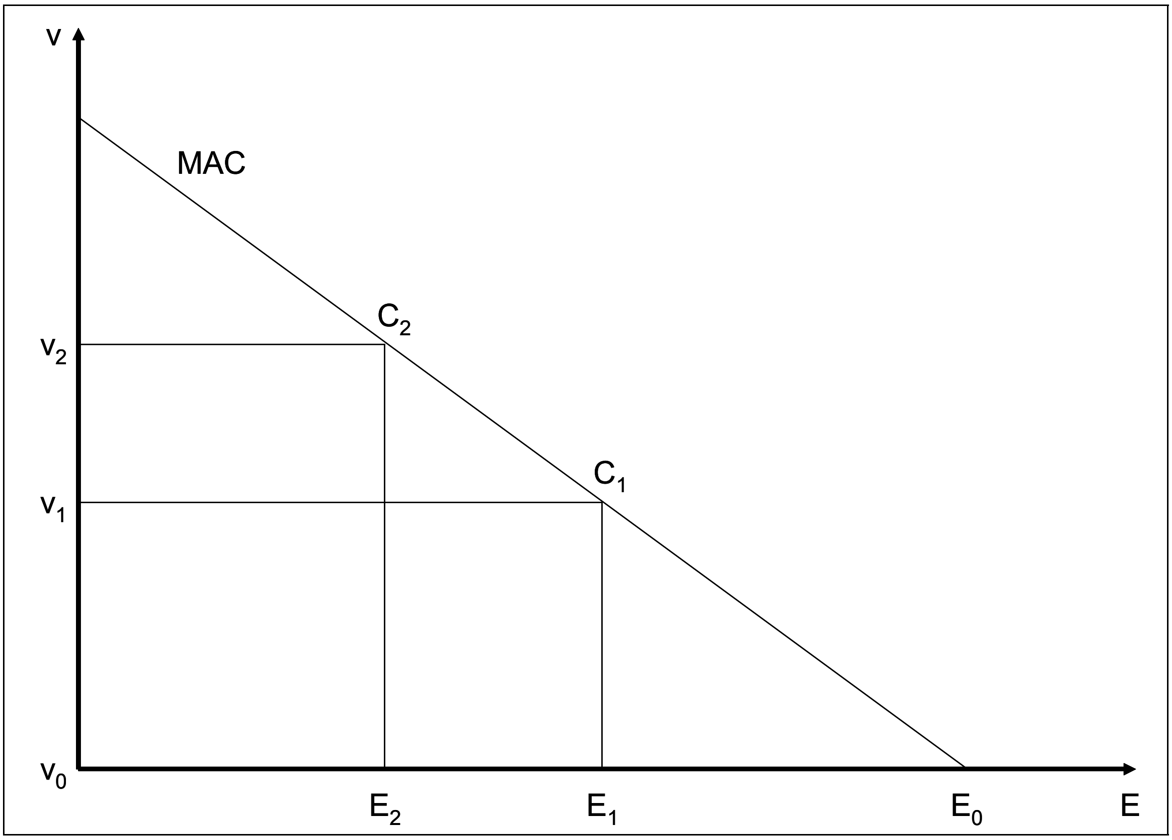

Figure 10 illustrates the impact of a more stringent cap. The horizontal axis shows the level of emissions while on the vertical axis the respective allowance price is indicated. The marginal abatement cost curve (MAC) is given for an entire economy, e.g. the EU or Germany. Before the start of the EU ETS no abatement technologies will be applied (E_0, v_0). If a carbon constraint is introduced, operators will first all apply abatement options which have the lowest marginal costs. If the cap is introduced at C_1, emissions will decline to E_1 and the resulting allowance price will be v_1. The investment in abatement is represented by the area C_1, E_0, E_1. If the carbon constraint is strengthened to C_2, emissions will be reduced to E_2 and the allowance price will rise to v_2. The additional investment in abatement is represented by the area C_2, C_1, E_1, E_2. All the abatement options between E2 and E1 would not be applied under cap 1 since their marginal abatement costs are higher than the allowance price. Clearly the reduced cap enables more abatement options to enter the market, thereby stimulating innovation.

The stringency of a cap and the allowance price are therefore good indicators of the degree of innovation incentives created by an emissions trading system. It is basically the case that the more stringent an allowance scheme is, the more incentives for innovation will emerge from the scheme.

3.3.2 Allocation

All issues related to the right of disposal over allowances are key design elements of emissions trading: How many allowances will be available for the different categories of participating entities? Under which conditions can allowances be transferred or are to be returned to the competent authority? The specific configuration of design options related to allocation, transfer and return of allowances may have a significant impact on incentives to innovate.

In the subsections below it will be analyzed which innovation incentives arise from those design options and their potential configurations. Since innovation itself cannot be directly measured, incentives for investments in new generation technology are considered an indicator for innovation. This follows considerations already discussed in more detail in chapter 2, particularly in section 2.4.

In the short-term emissions trading will induce substantial changes in the management of electric utilities and in the operation of their installations such as shifting generation from installations with higher emission rates to installations with lower ones or substituting fossil fuels by biomass. Such rather operational changes are without doubt an important part of the innovations induced by emissions trading. However, it is clear that such operational innovations would not be sufficient for achieving a more environmentally sustainable electricity system. In the long run the contribution of emissions trading to achieving a more environmentally sustainable electricity system will depend on its ability to direct investment towards generation technologies which emit substantially less or no greenhouse gas emissions. In this sense, investment can be regarded as a precondition and thus also as a potential indicator of innovation. Or in other words, allocation provisions which do not foster investment in new generation technology or even provide incentives to extend the lifetime of existing installations are usually not innovation friendly. The question of whether the individual allocation provisions potentially induce incentives to innovate can hence be analyzed by scrutinizing the investment incentives of those provisions.

Against this background, however, investment is a necessary but usually insufficient condition for innovation in power supply. If firms invest in traditional technology, it can scarcely be termed an innovation. Nevertheless, for two reasons it is assumed that investment in the electricity industry is strongly correlated to innovation and hence an important indicator for innovation:

1) Efficiencies of power plants have continuously increased in the past (Figure 6, p 35) and will continue to increase in the future due to perpetual innovation in generation technologies. Taking into account the long lifetimes of generation technologies of 20-40 years or more and that utilities usually invest in state of the art or even more advanced technologies, it can be assumed that new plants are substantially more efficient than those plants which are decommissioned instead. Investment in generation technology is thus virtually always an innovation because it usually improves the average emission rate of the electricity supply system.

2) The responsibilities for the different phases of the innovation process in the electricity sector are shared: the generation technology manufacturers and research institutes or universities are responsible for the invention and the very innovation phase in which inventions are developed to marketable products while the electricity industry is particularly responsible for the diffusion of innovative technologies (see section 2.3.2). Assuming again that the utilities predominantly invest in state of the art or even more advanced technologies, an increased level of investment would result in faster diffusion of innovative technologies to the market and hence a higher degree of innovation.

Within each of the various generation technologies or fuels respectively investment is a strong indicator for innovation: A new lignite plant, for example, will be substantially more efficient than an old lignite plant and a new gas plant will be significantly more efficient than an old one. Even so, a specific configuration might foster the diffusion of one of these innovative technologies more strongly than the other. Due to the considerably different CO_2 emission factors of fossil fuels, individual allocation provision might thus induce a stronger or weaker decline of the electricity system's emission rate or, under unfavorable conditions, even an increase of the emission rate.

Therefore, in a first step the possible impacts of the allocation provisions on generation capacities will be analyzed, along with the question of whether some provisions foster investment in individual generation technologies differently. However, the impact on the electricity system's overall emission rate depends on the output and operation of available power plants which again depend on the specific market conditions, particularly on the competition from outside of the EU ETS and on the demand price elasticity of electricity. In a second step, accordingly, the impact of the changes in generation capacities on output, emissions and emission rates will be scrutinized (section 3.3.2.6).

Both steps of the analysis take up and extend the considerations of Ellerman (2006). Investment decisions primarily depend on the expected profitability of an investment option. An investment is economically attractive if the expected costs are lower than the expected revenues. In addition to the variable generation costs (fuel, labor, maintenance, etc.) and the costs for capital recovery (interest service and redemption), investors also have to take into account the costs of allowances under emissions trading. The investment incentives are therefore derived analytically be comparing the covered companies' profit maximization equations before the start of the EU ETS with those equations applied under the EU ETS. The analysis begins with a comparison of the short-term profit maximization although short-term profits do not take into account capital recovery and are thus not directly relevant for investment decisions. However, starting with analysis of the short-term profits allows for the analysis to be gradually expanded and made more transparent.

For these analyses, fully competitive markets are assumed so that the agents are price takers on all markets. As usual, it is also assumed that agents maximize the profits resulting from their revenues minus various cost elements. In the short run capital stock is considered fixed. Correspondingly, cost elements for capital recovery are considered profit maximization in the long run but not in the short run.

3.3.2.1 Allocation to incumbents

Basically, two options of allowance allocation to participants which are already operating in the market can be differentiated: free allocation on the one hand and selling or auctioning of allowances on the other hand. For the latter option, auctioning by a government agency or by a private entity on behalf of the state is usually preferred to sales at a pre-defined price because it provides more transparency to the market. However, selling allowances at a fixed price can also be considered as an option to “inject” the allowances into the market.[17] But if the fixed price is lower or higher than the equilibrium price, there will be either excess demand for, or excess supply of, allowances. In addition, two prices would exist in the same market for an absolutely homogeneous product, which is always an indicator of economic inefficiency. Auctioning of allowances is, therefore, not only a more transparent but also a more efficient option if allowances are not allocated for free.

Free allocation is – due to better political acceptance and for other reasons (see sections 3.1.3 and 3.2.4) – often the more likely option at the beginning of a trading scheme. Two basic approaches to free allocation can be distinguished: grandfathering and benchmarking. Under grandfathering allowances are allocated according to the historic emissions of the covered installations whereas under benchmarking allowances are allocated according to a product of the covered installations’ output data and a benchmark, i.e. a product or technology specific emissions rate.[18] The output data may, in general, also be historical data or data derived from projections. Yet, the latter option is less objective and more open to lobbying efforts. If the trading scheme aims at reducing emissions, installation specific emissions are usually multiplied by a compliance factor (< 1) which scales the reference emissions to the overall cap. In both approaches the companies receive a share of the allowances available for incumbents which is equivalent to their share of the calculated overall reference emissions which again are aggregated from historic data, emissions projections or a mixture of both.

Each of the approaches is confronted with certain difficulties which have to be considered in the concrete design. If just one single history year is selected as a reference, specific conditions of that year, such as weather, business cycle, plant failures, etc., might substantially influence the allocation to individual installations so that the allocation might not be considered fair by the covered entities. Therefore, usually a range of years is selected as a reference period (moving average) assuming that such year-specific conditions cancel out during a longer period. Sometimes operators are also allowed to eliminate the most unfavorable year from the selection.

Improvements in environmental performance which have been achieved before the start of the trading scheme (so-called “early action”) would be rewarded under the

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[17] The German federal government has commissioned the KfW bank group to sell allowances (40 million EUAs in 2008 and 2009 respectively) at market prices until the auctioning of allowances will start in 2010 at the latest (BMU 2007b).

[18] In the US literature, benchmarking is therefore often termed output- or performance-based allocation.

grandfathering approach if the reference period is sufficiently long ago. However, the data availability might not be adequate for this purpose. Since the allocation of allowances includes the distribution of real values, the requirements for the data quality are definitely very high. Therefore, reference periods usually only date back a few years. If necessary, early action can be rewarded through additional allocation rules.

Benchmarking would automatically reward early action since the same emission rate would apply to all operators. The operators whose current emission rate exceeds the benchmark would receive relatively fewer allowances – in terms of what they need – while those whose emissions rate is below the benchmark would receive relatively more allowances in terms of what they need. However, the difficulty with the benchmark approach is to identify and agree upon the relevant product category which can be used as the denominator of the benchmark. If the product groups covered by the scheme are too heterogeneous, the number of necessary benchmarks may be great. A large number of benchmarks could diminish incentives for shifting economic activity to less emission intensive production processes and increase the administrative burden.

3.3.2.1.1 Short-run optimization by firms

Grandfathering

Before the start of emissions trading, a company's short-term profit π is basically derived from revenues achieved minus costs. The revenues are achieved by selling a quantity (q) of their product at a price of p. The costs depend of the cost function C which in turn is depending on the quantity sold.

$$\pi = pq - C(q) \tag{1}$$

With:

π: short-term profit

p: product price

q: quantity produced

$C(...)$: short-run cost function

With the introduction of emissions trading, equation (1) has to be amended by several elements. Operators of covered installations have to surrender allowances for each unit of emission to the competent authority. The amount of allowances they have to surrender depends on the emission rate per unit of output (r) and the quantity produced.[19] Multiplying the amount of allowances which have to be surrendered by the allowance prices (v) results in the additional cost element which companies have to take into account for their short-term profit maximization. However, since grandfathering is as-

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[19] Building or liquidation of stocks is neglected so that the quantity produced equals the quantity sold.

sumed they receive a quantity of allowances which equals their emissions in the base period (a_B) times the compliance factor (f) free of charge. Multiplied by the price of allowances this allocation can be regarded as additional revenue. Finally, the cost function has to be adopted because costs now also depend on the emissions rate.[20]

$$\pi = pq - C(q,r) - vrq + va_B f \tag{2}$$

With:

r:	emission rate per unit of output
v:	price of allowances, $(v > 0)$
a_B:	number of allowances allocated
f	compliance factor, $(0 < f < 1)$

As usual it is assumed that costs increase with the quantity produced and decrease with the emissions rate, i.e. they increase with a decreasing emissions rate. Furthermore, economies of scale are assumed for the quantity, i.e. a concave shape of the cost function with regard to the quantity and a convex shaped cost function for the emissions rate:

$$\partial C / \partial q > 0, \quad \partial^2 C / \partial q^2 < 0, \quad \partial C / \partial r < 0, \quad \partial^2 C / \partial r^2 > 0 \tag{3}$$

Under the emissions trading regime, operators have to determine the quantity and the emissions rate which maximizes their profits. For simplicity reasons it is assumed that both decisions are independent, i.e. any level of emission rate can be achieved with any level of production. The first condition for a profit maximum is that the first derivatives to the independent variables of the profit maximization function become zero. The corresponding first order conditions (FOCs) are given in equations (4) and (5).

$$\partial \pi / \partial q = p - \partial C / \partial q - vr = 0, \quad p = \partial C / \partial q + vr \tag{4}$$

$$\partial \pi / \partial r = -\partial C / \partial r - vq = 0, \quad v = -\partial C / \partial r / q \tag{5}$$

Equations (4) and (5) are an equation system with two equations and two variables which is sufficiently determined so that it can be solved. Replacing v in equation (4) with the right term of equation (5) results in equation (6).

$$p = \partial C / \partial q - \partial C / \partial r \; r / q \tag{6}$$

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[20] The abatement decision refers to the emission rate rather than to emissions. Reducing the emission rate would usually induce higher short-term production costs and vice versa (input substitution).

Two conclusions can be drawn from equation (6):

- The right term does not contain a_B. Thus, the short-term profit maximization does not depend on the amount of allowances allocated to the company. The production and abatement decision of the company is hence independent of allowance allocation.
- Before the start of emissions trading, the profits were maximized if the cost of the last unit produced – the marginal costs – equaled the product price. After the start of emissions trading, this equation is amended by an additional term in equation (6). Since the marginal abatement costs are negative while the emission rate divided by the quantity is positive, the whole additional term is positive. Correspondingly, profit maximization will be achieved at a higher price than before the start of the EU ETS. Even though allowances have been allocated for free, operators have to pass through – at least a share of – their opportunity costs to maximize their profits.

Benchmarking and auctioning

Based on equation (2) the respective equations for profit maximization under the benchmarking and auctioning approach can be developed. Under the benchmarking approach the amount of allowances does not depend on the historic emissions in a base period but on the output of a base period (q_B) times a general emissions factor, for example the average emissions factor during the base period (e_{AV}) or the emission factor of the best available technology (e_{BAT}). Correspondingly, a_B in equation (2) has to be replaced by $e_{AV}q_B$. Under the auctioning approach no allowances are allocated for free, meaning that companies do not receive any additional revenue. Accordingly, the last term in equation (2) has to be deleted entirely.

Benchmarking: $$\pi = pq - C(q,r) - vrq + ve_{AV}q_B f \qquad (7)$$

Auctioning: $$\pi = pq - C(q,r) - vrq \qquad (8)$$

With:

e_{AV}: average emissions factor for comparable installations

q_B: quantity produced in the base year

The first FOCs for both approaches are identical with equations (4) and (5). Clearly the conditions for short-term profit maximization do not depend on the type of allowance allocation. Firms do not consider the number of allowances they have received and whether they received them free of charge or not. In the short term, they simply determine their production and greenhouse gas reduction strategy according to their marginal production and emission avoidance costs.

As a result of the considerations above, it can be concluded that short-term profit maximization neither depends on the type of allowance allocation nor on the amount of allowances allocated. Moreover, the introduction of emissions trading causes an increase of product prices since operators have to pass through – at least a part of – their real or opportunity costs to their clients to maximize their profits.

3.3.2.1.2 Long-run optimization by firms

For decision on long-term profit maximization two basic changes have to be introduced into equation (2). First, under a long-term perspective the capital stock cannot be considered fixed. Accordingly a term for the recovery of invested capital over the economic lifetime of the investment has to be integrated. Second, while prices in the short-run can be considered known and fix the same cannot be assumed for the long run. Prices for products or allowances may substantially change in the future. Operators therefore depend on their individual expectations of the development of those prices over time when they decide on the profitability of an investment. However, these price developments can be represented by average expected prices. To distinguish these long-term price and profit expectations from the short-term prices and profits they will be marked with a circumflex in the following.

Grandfathering

The additional costs which have to be taken into account under a long-term perspective are shown by the optimal capacity (K), which depends on the planned product quantity times the unit cost of capital investment; and (Z) which depends on the emission rate. However, these total investment costs have to be distributed over the expected economic lifetime of the investment by a capital recovery factor (δ) which also takes into account interest payments.

$$\hat{\Pi} = \hat{p}q - C(q,r) - \hat{v}rq + \hat{v}a_B f - \delta Z(r)K(q) \tag{9}$$

With:

$\hat{\Pi}$: expected long-term profit

$\hat{p}$: expected long-term product price

$\hat{v}$: expected long-term price of allowances

δ: capital recovery factor

$Z(r)$: per unit price of capital investment

$K(q)$: optimal capacity of investment

It is assumed that the optimal capacity increases with the planned product quantity and that the unit cost of investment increases with a decreasing emission rate so that the respective cost curves have the following shape:

$$\partial K/\partial q > 0, \quad \partial Z/\partial r < 0 \tag{10}$$

To receive the first order conditions, equation (9) is differentiated towards the independent variables q and r:

$$\hat{p} = \partial C/\partial q + \hat{v}\, r + \delta Z\, \partial K/\partial q \tag{11}$$

$$\hat{v} = -\left(\partial C/\partial r + \delta K\, \partial Z/\partial r\right)/q \tag{12}$$

Both equations (11) and (12) differ from the short-term equations (4) and (5) in the right hand term which represents an additional positive cost element for the recovery of the invested capital (Ellerman 2006: 7). Investment decisions in both production and mitigation capacity will only be taken under the carbon constraint if the expected product or allowance prices exceed these thresholds which are even higher than for the short-term production or abatement decisions.

As for the short-run perspective, the investment decisions do not depend on the amount of allowances allocated to the company because a_B is completely eliminated from the FOCs (Ellerman 2006: 7).

Benchmarking and auctioning

The equations for the long-term profit maximization under the benchmarking or the auctioning approach are adapted as per the short-term perspective:

Benchmarking: $$\hat{\Pi} = \hat{p}\, q - C(q,r) - \hat{v}\, rq + \hat{v}\, e_{AV} q_B f - \delta Z(r) K(q) \tag{13}$$

Auctioning: $$\hat{\Pi} = \hat{p}\, q - C(q,r) - \hat{v}\, rq - \delta Z(r) K(q) \tag{14}$$

However, since the adapted term contains neither q nor r (benchmarking) or was completely eliminated (auctioning), the FOCs are identical to FOC equations (11) and (12) under the grandfathering approach.

With regard to the discussion of the effects of different types of allocation it can therefore be concluded that:

- Emissions trading results in higher prices on the product market and will result in investment decisions for production or mitigation technology only if the long-term expectations of the product and the allowance prices exceed the respective short-term prices.
- Neither short- nor long-term decisions depend on the amount of allowances allocated to the company. The allowance allocation (a_B, $e_{AV} q_B$) does not appear in either of the FOCs. Initial allowance allocation does not interfere with the firms' profit

maximizing decisions. However, the provision appears in the profit equation and thus improves – c. p. – the firms' short and long run profits (Ahman et al. 2007; Ellerman 2006: 7).

- The type of allocation neither directly influences the firms' decisions on production or abatement nor their decisions on investment in production or mitigation technology.

Since the type of allocation or the individual amount allocated to a company does not influence the company's decisions on investment, it might be assumed that both also have no direct impact on innovation.[21]

However, Milliman and Prince (1989) and Jung et al. (1996) analyzed firm-level incentives for technology diffusion provided by different environmental policy instruments. They found that auctioned permits would provide the largest adoption incentive of any instrument, with emissions taxes and subsidies second, and freely allocated permits and direct controls last (Jaffe et al. 2001: 57-58). According to these studies auctioning induces stronger innovation incentives than free allocation (grandfathering or benchmarking). The main argument is that innovation reduces the cost of emission reduction and thus the price of allowances (Requate, Unold 2003: 134). The resulting depreciation of the value of freely allocated allowances reduces the innovation incentives under free allocation. Since this depreciation effect does not occur with auctioned allowances, innovation incentives of auctioned allowances are considered to be higher. Cramton and Kerr (2002) highlight that the innovation incentive does not depend on whether allowances are auctioned or allocated for free, but depend on who owns the allowances at the time of innovation and who is faced with the depreciations. If allowances are auctioned for a long time in advance, the incentives are identical under auctioning and free allocation.

However, these results are challenged by more recent analyses. Schwarze (2001) and Requate and Unold (2003) point out that under a competitive allowance market, in which an individual firm's decisions do not influence the allowance price, firms will not expect the allowance price to fall due to their innovation decisions. Yet, without the anticipated allowance price effect the difference between auctioning and free allocation disappears so that the incentive to adopt innovative technology is the same under auctioned and freely allocated allowances.

As a result it can be concluded that the initial allocation to incumbents seems to have no direct impacts on the innovation incentives of emissions trading. However, allocation to new entrants does have an effect on innovation as will be shown in the next section.

3.3.2.2 Allocation to new entrants

Another issue which especially needs to be addressed in the case of free allocation is the question of how to handle new installations which enter the market or capacity ex-

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[21] Further below (see sections 3.3.2.2.2 and 3.3.2.3) it will be shown that the type of initial allocation may have indirect effects on innovation.

tensions of existing installations, so-called new entrants. From an environmental economics perspective, such new entrants should not be allocated with allowances free of charge since they can – in contrast to incumbents – include the additional costs of allowances into their investment decisions (CCAP 1999: 8; Graichen, Requate 2003: 21-22). If new entrants have to purchase all necessary allowances on the market, they will only enter the market if their marginal abatement costs do not exceed the expected allowance price.

However, the Emissions Trading Directive (2003/87/EC) basically allows allocation free of charge to new entrants although only two references can be found to the term “new entrant” in the directive. In Article 3 (h) a new entrant is defined as any installation “which has obtained a greenhouse gas emissions permit or an update of its greenhouse gas emissions permit because of a change in the nature or functioning or an extension of the installation, subsequent to the notification to the Commission of the national allocation plan”. In Annex III (6) the Directive requires that each NAP shall contain information on how new entrants will be able to participate in the EU ETS.

In the NAP guidance document the European Commission elaborates in more detail how Member States may shape this design option: Member States may require operators of new or extended installations to buy all allowances on the market or to set aside a reserve of allowances from the overall budget which can be used to allocate new entrants free of charge (COM(2003) 830: 11-14). Moreover, the Commission highlights that the requiring of operators of new or extended installations to buy all allowances on the market is in line with the principle of equal treatment because new entrants can take into account the new conditions under the carbon constraint while incumbents have made their investment without having been able to take the cost of carbon into account.

Nevertheless, some Member States argued that operators with several incumbent installations can provide allowances for a new installation without purchasing allowances simply by closing some of their existing installations which operate at the margin. This was considered a way of gaining an advantage over very new operators which would have to purchase all of their allowances on the market. Free allocation to new entrants was therefore regarded as an option to encourage new operators to enter the market and to burst this way oligopolistic market structures (CCAP 1999: 8; Reinaud 2005: 74-76).

Although this consideration neglects the opportunity costs of those allowances transferred from closed to new installations, all Member States ultimately decided on the free allocation of allowances to new entrants[22] (DEHSt 2005; Schleich et al. 2007: 1476) – not at least because they were in a classical prisoners dilemma: each single Member State might have increased its attractiveness for new investments in comparison to other Member States if it would have allocated allowances free of charge to new entrants while all other Member States would have only guaranteed a free market ac-

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[22] Some Member States restricted access to allowances for new entrants only to specific categories of installations such as Combined Heat and Power (CHP) plants.

cess for new entrants (Blyth, Yang 2006: 46). To avoid individual Member States gaining such a competitive advantage, all Member States decided on the free allocation of allowances to new entrants. Since each Member State would have to accept disadvantages for investments in new installations if they diverge from the overall trend, a change within the EU towards not allocating new entrants can only be achieved in a harmonized approach by amending the Directive correspondingly.

In the following subsections the ways in which a new entrant provision affects investments in new capacities shall be analyzed.

3.3.2.2.1 With new entrant provision

Since historic emissions or the output of new installations are not known, the free allocation has to be based on projected emissions. Such emission projections are usually contingent on the capacity of the new installation and a standard emission factor or benchmark ($\tilde{e}$) for each category of new installations. Finally an installation specific load factor (l) has to be taken into account in the calculation of the projected emissions. The allocation term in the long run profit maximization equation changes accordingly:

$$\hat{\Pi} = \hat{p}\, q - C(q,r) - \hat{v}\, rq + \hat{v}\, \tilde{e}\, lK(q) - \delta Z(r)K(q) \tag{15}$$

With:

$\tilde{e}$: standard emission factor for new entrants (benchmark)

l: standard load factor for new entrants $(0 < l < 1)$

Differentiating equation (15) provides the FOCs for long-term profit maximization with new entrant provisions:

$$\partial\hat{\Pi}/\partial q = \hat{p} - \partial C/\partial q - \hat{v}\, r + \hat{v}\, \tilde{e}\, l\, \partial K/\partial q - \delta Z\, \partial K/\partial q = 0 \tag{16}$$

$$\hat{p} = \partial C/\partial q + \hat{v}\, r + \delta Z\, \partial K/\partial q - \hat{v}\, \tilde{e}\, l\, \partial K/\partial q \tag{17}$$

$$\partial\hat{\Pi}/\partial r = -\partial C/\partial r - \hat{v}\, q - \delta K\, \partial Z/\partial r = 0 \tag{18}$$

$$\hat{v} = -\left(\partial C/\partial r + \delta K\, \partial Z/\partial r\right)/q \tag{19}$$

Comparing equations (17) and (19) with the situation without new entrant provisions illustrated in equations (11) and (12) reveals three notable points:

- The FOCs may be considered thresholds for market entry. If the right term of an envisaged investment is lower than the expected market price for a product or allowances, investment in production capacity or mitigation technology is profitable. The new entrant provision reduces the threshold for market entry of new installations and thus results in increased production capacity compared to the situation without new entrant provision.
- The new entrant provision reduces the burden of capital recovery. Since it is granted if new generation capacity is commissioned it may be regarded as an investment subsidy.
- However, the new entrant provision does not change the threshold for investment in abatement technology since equations (19) and (12) are absolutely identical.

In summary: The new entrant provision does not change the incentives related to the environmental performance of a planned investment but raises the incentives for market entry, therefore resulting in increased production capacity. Since the new entrant provision is contingent on the investment in new capacity, it can be regarded as an investment subsidy which, however, is not a lump sum as usual but depends on the expected market price for allowances (Ellerman 2006: 9).

Since investment is a precondition for the diffusion of new and innovative technologies, a new entrant provision might improve innovation incentives in the electricity sector. However, whether increased investment in the electricity sector will really result in lower CO_2 emissions of the electricity sector will be discussed further below (section 3.3.2.6).

3.3.2.2.2 Fuel specific new entrant provision

In the previous section it was assumed that the projected emissions are calculated with a uniform emissions factor or benchmark for all installations of each product category. In Germany, the benchmark for electricity generation is differentiated according to the fuel used for generation. Power plants which use gas receive 365 allowances per GWh of projected electricity generation while plants which use hard coal or lignite receive with 750 EUA/GWh more than the double of gas powered plants (ZuG 2012: 1799).[23] Natural gas contains substantially less carbon than hard coal or lignite; taking into account the higher efficiency of gas fired power plants one can conclude that gas power plants roughly emit half as many CO_2 emissions as power plants running on hard coal. Clearly, the new entrant provision is contingent on the emissions rate in Germany. A higher emission rate results in a higher new entrant provision and vice versa. This changes the profit maximizing function for new investments in the German electricity industry:

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[23] The load factor applied for the calculation of the emission projection is also differentiated between fuels (ZuG 2012: 1800). However, since the quantitative difference is smaller and since the difference in the load factor can basically be transferred into differences of the emissions factor while the load factor remains uniform, this aspect will be neglected in the further analysis.

$$\hat{\Pi} = \hat{p}\, q - C(q,r) - \hat{v}\, r q + \hat{v}\, \tilde{e}(r) l K(q) - \delta Z(r) K(q) \tag{20}$$

$\tilde{e}$ is now not a parameter but a function of r. Basically it can be assumed that the emission factor is somehow proportionate to the emission rate of the technology. For simplicity reasons it is also assumed that the function is linear so that the derivatives have the following shape:

$$\partial \tilde{e} \big/ \partial r > 0, \quad \partial^2 \tilde{e} \big/ \partial r^2 = 0 \tag{21}$$

To receive the relevant FOCs under a fuel differentiated new entrant provision, equation (20) is differentiated toward q and r:

$$\partial \hat{\Pi} \big/ \partial q = \hat{p} - \partial C \big/ \partial q - \hat{v}\, r + \hat{v}\, \tilde{e}\, l\, \partial K \big/ \partial q - \delta Z\, \partial K \big/ \partial q = 0 \tag{22}$$

$$\hat{p} = \partial C \big/ \partial q + \hat{v}\, r + \delta Z\, \partial K \big/ \partial q - \hat{v}\, \tilde{e}\, l\, \partial K \big/ \partial q \tag{23}$$

$$\partial \hat{\Pi} \big/ \partial r = - \partial C \big/ \partial r - \hat{v}\, q + \hat{v}\, l K\, \partial \tilde{e} \big/ \partial r - \delta K\, \partial Z \big/ \partial r = 0 \tag{24}$$

$$\hat{v} = -\left(\partial C \big/ \partial r + \delta K\, \partial Z \big/ \partial r \right) \Big/ \left(q - l K\, \partial \tilde{e} \big/ \partial r \right) \tag{25}$$

Equation (23) is absolutely equivalent to equation (17) which indicates that the incentives for investments in new capacities are basically not different to the situation with a uniform new entrant provision.

However, the fuel differentiated new entrant provision changes the abatement decision. It increases the entry price for investment in abatement technology because it diminishes the denominator in equation (25) compared to equation (19). The increase of the entry price is the stronger, the steeper the slope of the relationship between r and $\tilde{e}$ is. Therefore, additional capacity will emit more emissions on average compared to the situation of a uniform benchmark. Since the supply of allowances is capped, the additional allowance demand results in higher allowance prices and hence higher compliance costs compared to the situation with a uniform benchmark. In addition, more (older) installations with higher emission rates will be crowded out.

Since a new entrant provision as such effectively functions as an investment subsidy, fuel specific new entrant provisions will subsidize technologies with higher emission rates even stronger than those with smaller specific emissions. In this way, fuel specific benchmarks eliminate – at least partly – the incentive to shift investments towards technologies which use fuels with a relatively smaller carbon content such as CCGTs (Cames, Weidlich 2006: 47-49).

From an environmental economics perspective fuel specific new entrant provisions do not make any sense because they create perverse incentives for technologies with comparatively higher emission rates. However, the advocates of this provision argue that emissions trading would otherwise give an advantage to natural gas over hard coal and lignite. As a consequence, the structure of the primary energy consumption for electricity generation would substantially shift from hard coal and lignite towards natural gas. This is seen as a risk for the security of supply because in the future natural gas will mainly be exported by countries which are considered to be politically less stable or even untrustworthy. In this sense a fuel specific new entrant provisions can be seen as a flanking measure which compensates for unintended side effects of emissions trading. However, fuel specific benchmarking does not come for free. Compared to grandfathering or undifferentiated benchmarking it results in higher emissions of the electricity sector and thus higher allowance prices and overall compliance costs (Matthes et al. 2006: 100).

Although a fuel specific benchmark compared to a uniform one does not influence the increase in total capacity, it changes the selection of technologies towards those technologies with higher emissions. The diffusion of technologies with lower emission rates (gas plants) is crowded out by technologies with higher emissions rates (coal plants). Taking into account that coal-fired power plants have substantially longer lifetimes than gas fired power plants (IEA 2007: 76), it can be conjectured that fuel specific benchmarks diminish the potential for further emission reductions in the future without "generating" larger amounts of sunk costs.

In addition to the direct effects of new entrant provisions, indirect incentives of the allocation rules for incumbents might influence investment decisions as well. This is particularly the case if new entrants are treated as incumbents after a specific period of time, for example from the start of the next or second next trading period (Gagelmann 2006: 13-16). Investors would anticipate the status change of their installations in their investment decisions. In general, the incentives to increase capacity would be greater, the more allowances can be expected from the allocation rule for incumbents. Although allocation rules for incumbent installations do not directly affect investment incentives (see section 3.3.2.1.2), they might influence these incentives indirectly. Provided that grandfathering or average benchmarking would result in higher allocations than Best Available Technology (BAT) benchmarking, it can be assumed that grandfathering would indirectly create stronger incentives for investments in new capacities than BAT benchmarking. Those indirect effects would be the more important, the earlier a new installation changes its status from new entrant to incumbent.

3.3.2.3 Treatment of closures

At the time when the EU ETS Directive was adopted, closure of installations was not considered as an issue that deserves specific attention. Closure is neither mentioned in the Directive (2003/87/EC) nor in the Commission's NAP guidance document for the first trading period (COM(2003) 830). However, during the allocation process for the first period it quickly became clear that this issue was rather contentious. Not surprisingly the NAP guidance document for the second trading period (COM(2005) 703) includes some considerations on closures in Annex 7 without suggesting a specific treatment by Member States.

Some Member States obliged operators of installations to return the remaining allowances they had received free of charge if the installations were closed because they were not needed anymore (DEHSt 2005; Schleich et al. 2007: 1477). Other Member States allowed operators to retain those allowances. However, as the EU ETS is organized in allocation periods, operators of closed installations can retain allowances only until the end of a trading period. In the subsequent period, closed installations will not receive allowances since allocation of allowances is contingent on the operation of an installation.

One difficulty with closures is the precise determination of when an installation was closed. To avoid returning allowances, operators might operate installations which are actually closed until the end of the period at 10 % capacity or less. Hence, some Member States regarded those installations which were operated below a certain threshold of its capacity (e.g. 60 %) as closed. Moreover, the obligation to return allowances – as will be shown analytically below – creates incentives to extend the operational period of existing installations (Cames, Stronzik 2002: 9-10; Ellerman 2006: 10-11).

The profit maximization equation for closure is a mixture of the short and long run equations. Since the investment decision was taken earlier, the capital is sunk so that the equation does not contain a capital recovery term. Although it looks similar to the short-term equation it is not equivalent because it takes into account more than one period and therefore includes price expectations instead of known prices. However, the time horizon is shorter than under the long-run perspective. To distinguish the perspectives, the price expectations are marked with an apostrophe. Equation (26) provides the situation before the carbon constraint is introduced:

$$\hat{\Pi}' = \hat{p}' q - C(q) \tag{26}$$

$$\hat{p}' = {\partial C}/{\partial q} \tag{27}$$

Differentiating equation (26) delivers in equation (27) the FOC for the closure of an installation: An installation will be closed if the marginal costs of production exceed the expected product price.

Following the introduction of emissions trading, the situation with and without a closure provision needs to be distinguished. Without a closure provision, the operators can retain the allowances so that the allowances are not contingent on production. Therefore, the allowance allocation does not appear in the respective profit maximization equation (28):

$$\hat{\Pi}' = \hat{p}'q - C(q,r) - \hat{v}'rq \tag{28}$$

Differentiating this equation towards q and r provides the FOCs for the situation without a closure provision.

$$\partial\hat{\Pi}'\big/\partial q = \hat{p}' - \partial C\big/\partial q - \hat{v}'r = 0,\ \hat{p}' = \partial C\big/\partial q + \hat{v}'r \tag{29}$$

$$\partial\hat{\Pi}'\big/\partial r = -\partial C\big/\partial r - \hat{v}'q = 0,\ \hat{v}' = -\left(\partial C\big/\partial r\right)\big/q \tag{30}$$

Comparing equation (29) with (27) reveals that the marginal costs for continuing production must be lower than under the situation without a carbon constraint. Thus, more installations, those with marginal costs above the reduced margin, will be closed compared to the situation without emissions trading. Emissions trading results in a crowding out of installations (in most cases old ones) which operated at the margin.

If closure provisions exist, they usually apply when the permit of an installation is returned. In some countries[24] they are already applied if the production falls below a threshold (t), often expressed as a certain share of the installation's capacity, independently of whether the permit is returned or not. Since the latter case includes the first case $(t = 0)$, the amount of allowances $\tilde{a}$[25] which are forfeited if the production falls short of the closure threshold can therefore be expressed as a function of q:

$$\tilde{a}(q) = 0 \text{ for } 0 \le q \le \text{t and } \tilde{a}(q) = \tilde{a} \text{ for } q > \text{t} \tag{31}$$

With:

t: closure threshold for q, $(0 \le t \le 0)$

The profit maximizing equation changes as follows:

$$\hat{\Pi}' = \hat{p}'q - C(q,r) - \hat{v}'rq + \hat{v}'\tilde{a}(q) \tag{32}$$

Since $\tilde{a}(q)$ is a discontinuous function, it can be differentiated only separately for the individual continuous sections ($0 \le q \le t$ and $q > t$). However, in both cases $\partial\tilde{a}\big/\partial q$ equals zero. The profit maximization equation thus has to be separated into two sections as well. For the section above the threshold t the FOC reads as follows:

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[24] For example in Belgium (Flanders), France, Greece, Hungary and Luxembourg (DEHSt 2005).

[25] To distinguish the amount of allowances from more than one of the short-term periods considered in section 3.3.2.1.1 it was marked with a tilde ($\tilde{a} > a$).

$$\partial \hat{\Pi}' \big/ \partial q = \hat{p}' - \partial C \big/ \partial q - \hat{v}' r = 0 \,, \ \hat{p}' = \partial C \big/ \partial q + \hat{v}' r \tag{33}$$

The profit maximization equation with regard to r did not change because the changes introduced due to the closure provisions did not affect terms which depend on r. The threshold for investment in mitigation technology is therefore in both cases identical with the threshold which was derived for the case without a closure provision and is given in equation (30).

Equation (33) is absolutely identical with the investment threshold in equation (29) which will be applied if no closure rule is provided for. This is not surprising because no allowances have to be returned if q exceeds t.

The differentiation for the section below t is basically identical. If q falls below t, an amount of $\tilde{a}$ allowances with a value of $\hat{v}'\tilde{a}$ has to be returned. The marginal profit must therefore not equal zero but the negative value of the forfeited allowances. However, since the FOC is a marginal consideration, the total value does not have to be compared but rather just the value per unit of production. The total value of the returned allowances has thus to be divided by the planned production q. The resulting FOC is shown below:

$$\partial \hat{\Pi}' \big/ \partial q = \hat{p}' - \partial C \big/ \partial q - \hat{v}' r = -\hat{v}' \tilde{a} \big/ q \,, \ \hat{p}' = \partial C \big/ \partial q + \hat{v}' r - \hat{v}' \tilde{a} \big/ q \tag{34}$$

The term $\hat{v}' \tilde{a} \big/ q$ is greater than zero. Therefore, the term $\hat{v}' r$ which caused a crowding out of marginal installations due to the introduction of emissions trading will be offset – at least partly. Accordingly, lesser marginal installations will be closed under an emissions trading regime with a closure provision. Ironically, the closure provision results in lesser closures of installations compared to the situation without such a provision. Under a closure provision, allocation of allowances is contingent on generation. The value of the allowances enters thus the profit maximization equations for determining on the closure of an installation. As a consequence, the provision results in a decreased price threshold for closures so that viewer installations will be decommissioned.

And even worse: under certain – not unlikely – conditions $\hat{v}' \tilde{a} \big/ q$ might be even greater than $\hat{v}' r$, for example if the production was reduced after the allocation of allowances was made: r is defined as emission per unit of output. Therefore, it is equivalent to the emissions in the base period (e_B) divided by the output of that period (q_B). Assuming grandfathering and – for simplicity reasons – no compliance factor, the emissions in the base period are equivalent to the allocation $\tilde{a}$. Accordingly, r is also equivalent to $\tilde{a} \big/ q_B$. If the planned output for the remaining periods q_R is lower than q_B, $\tilde{a} \big/ q_R$ is greater than $\tilde{a} \big/ q_B$ and thus also greater than r:

$$r = e_B \Big/ q_B = \tilde{a} \big/ q_B < \tilde{a} \big/ q_R \quad für\ q_B > q_R \tag{35}$$

Taking these considerations into account while comparing equation (34) with (27) and (33) reveals that the closure provision might not only result in fewer closures than under emissions trading without a closure provision but even in fewer closures than with no carbon constraint at all (Cames, Stronzik 2002: 9-10; Ellerman 2006: 11). In this sense a closure provision might not reduce the operational time of an installation as the name might indicate but, on the contrary, extend the operational period beyond the expected lifetime without emissions trading.

While a new entrant provision tends to promote investments in new technology and thus also fosters innovation, a closure provision provides disincentives for innovation because it extends the lifetime of existing installations which operate at the margin. Proponents of a closure provision argue that it is not fair for companies to retain allowances attained via free allocation when they have decommissioned their installations because they do not need them anymore. Some also denote the option to retain allowances in the case of plant closure as a “closure premium” which might also promote the dislocation of production to countries not covered by the EU ETS. However, whether production will be dislocated outside the EU depends on the degree of international competitiveness which again depends among others on the transport costs of a product. For electricity, which is responsible for almost two thirds of the EU ETS’s greenhouse gas emissions, transportability is – at least in the short and medium term – not given because the necessary transmission capacities are rather limited. The closure provision might thus cure this minor or non–existent problem. However, at the same time it undermines promoting innovation – one of the major goals of EU ETS (DG ENV 2004).

Gagelmann (2006: 21-22) as well as Schleich and Cremer (2007: 5) point out that the degree of the closure rule’s disincentive depends on the amount of allowances foregone due to closure. Extending operation of an existing plant will be the more attractive, the more allowances are foregone due to closure. Provided that an old installation would receive more allowances under grandfathering than under a BAT or average benchmark approach, they conclude that the closure rule provides stronger disincentives for innovation if it is applied together with the grandfathering approach. BAT benchmarking would, in contrast, provide the lowest disincentive of the closure. In this way allocation to incumbents indirectly affects the overall incentives to innovate of emissions trading although it does not directly affect innovation decisions (see section 3.3.2.1.2).

As a result it can be concluded that closure provisions definitely do not increase the innovation incentives of emissions trading. On the contrary, they decelerate the innovation process because they extend the lifetime of old installations which operate at the margin and increase the available generation capacities so that the expected electricity price will be lower. This again will decrease investment opportunities for new innovative generation technologies and thereby inhibit or delay the diffusion of advanced generation technologies into the market.

3.3.2.4 Transfer of allowances

In addition to the new entrant and the closure rules, a transfer rule was provided for in Germany's first NAP (ZuG 2007: § 10):[26] Operators which closed an old installation may have transferred the allowances of the old installation to a new installation provided that the new installation was not commissioned more than 2 years before or after the closure of the old installation. The NAP did not specify any conditions on ownership so that the transfer may have been applied between two installations of the same operator or between two installations of different operators.

This option was attractive if the allocation of the old installation was larger than the allowance allocation according to the new entrant provision, i.e. if the amount of the allowances ($\tilde{a}$) grandfathered to the old installation divided by the planned generation in the new installation (q^N) was larger than the benchmark ($\tilde{e}$) for the new installation ($\tilde{a}/q^N > \tilde{e}$).

If new and old installations have different capacity sizes, the installation with the share of capacity that exceeds the other will be treated as a regular closure or new entrant, respectively. The owner of the old installation will have to return a share of his allowances to the competent authority; this share has to be equivalent to the share by which the capacity of his old installation exceeds the new installation. If a new installation has a capacity which exceeds the old one, it will be allocated allowances like all other new entrants of the same type of technology. The incentives to close or invest in new technology for the exceeding shares are basically not different to the new entrant and the closure rules. In the further analysis, all cases in which the capacities of old and new installations do not match are excluded although that is the normal situation. However, for demonstrating the core incentives of the transfer rule, it is not necessary to take these exceeding shares into account.

3.3.2.4.1 Different owner

The total amount of allowances which will be transferred between an old and a new installation ($\tilde{a}$) can be analytically distinguished in a new entrant provision for the new installations ($\tilde{e}lK(q^N)$) and an add-on (m) which is equivalent to the difference between $\tilde{a}$ and the new entrant provision ($\tilde{a}-\tilde{e}lK(q^N)=m$).[27] The owner of the new installation would not be willing to compensate the owner of the old installation for those allow-

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[26] The NAP for the second trading period (ZuG 2012) no longer includes a transfer rule in order to make allocation less complex and in order to eliminate the problematic differential treatment of new entrants and incumbent utilities (BMU 2007a: 3).

[27] Since K is a function of q^N, m should also be a function of q^N. However, in this term K does not depend on q^N. It equals the capacity of the old installation K^O if the new installation's capacity is larger and it equals the capacity of the new installation K^N if the old installation is larger. Here the cases were analytically excluded where K^O and K^N do not fit in size so that $K^O = K^N = K$.

ances which he could otherwise receive free of charge from the competent authority. Accordingly, he will only be willing to pay a certain price for the amount of allowances exceeding the new entrant provision (m).

The value of the transferred allowances will basically be equivalent to the expected market price ($\hat{v}'$). However, those excess allowances are only fully fungible after they have been transferred between an operator of an old and a new installation. Thus, the operator of the new installations will accept only a reduced price $\hat{v}'x$ (with $0 < x < 1$) because otherwise he might buy the allowances from any other operator on the market. The operator of the new installation receives m additional allowances with a value of $\hat{v}'$ but pays only a price of $\hat{v}'x$ so that he receives an additional value $\hat{v}'(1-x)m$ due to making use of the transfer rule. This additional value appears in the profit maximization equation as shown below:

$$\hat{\Pi}'^{N} = \hat{p}'q^{N} - C^{N}(q^{N}, r^{N}) - \hat{v}'r^{N}q^{N} + \hat{v}'\tilde{e}lK(q^{N}) + \hat{v}'(1-x)m - \delta Z(r^{N})K(q^{N}) \qquad (36)$$

The old and the new installations use different technologies so that cost functions are not identical. To discriminate between both installations the cost function, the profits and the variables q and r are distinguished with the superscripts O and N for the old and the new installation, alternatively. To make the price terms comparable, the time horizon for both installations was normalized to the horizon of the old installation which is marked with an apostrophe at the price variables and profit signs.

The operator of the old installations reciprocally receives an additional payment of $\hat{v}'xm$ from the operator of the new installation if the old installation is decommissioned:

$$\hat{\Pi}'^{O} = \hat{p}'q^{O} - C^{O}(q^{O}, r^{O}) - \hat{v}'r^{O}q^{O} + \hat{v}'a(q^{O}) + \hat{v}'xm \qquad (37)$$

The terms which include r^{N} and r^{O} are – except for the superscripts – not different to the terms in the profit maximization equations for new entrants and for closures. Hence the partial derivatives towards r^{N} and r^{O} and with them the entry prices for the abatement decision are identical as well so that it can be concluded that transfer rule does not alter the incentives for abatement compared to those abatement incentives established by the new entrant and closure rule.

The partial derivatives towards q^{N} and q^{O} and the corresponding FOCs are shown in equations (38) to (42):

$$\partial \hat{\Pi}'^{N} \Big/ \partial q^{N} = \hat{p}' - \partial C^{N} \Big/ \partial q^{N} - \hat{v} r^{N} - \delta Z \, \partial K \Big/ \partial q^{N} + \hat{v}\tilde{e}l \, \partial K \Big/ \partial q^{N} = 0 \qquad (38)$$

$$\hat{p}' = \partial C^{N} \Big/ \partial q^{N} + \hat{v} r^{N} + \delta Z \, \partial K \Big/ \partial q^{N} - \hat{v}\tilde{e}l \, \partial K \Big/ \partial q^{N} \qquad (39)$$

$$\partial \hat{\Pi}'^{o} \Big/ \partial q^{o} = \hat{p}' - \partial C^{o} \Big/ \partial q^{o} - \hat{v}' r^{o} + \partial \tilde{a} \Big/ \partial q^{o} \tag{40}$$

$\partial \tilde{a} \big/ \partial q^{o}$ equals zero so that the FOC for the old installation would be basically identically to the situation without a closure rule as given in equation (33). However, the owner of the old installation has to transfer $\tilde{a}$ allowances with a value of $\hat{v}'$ to the owner of the new installation and receives a compensation of $\hat{v}'xm$ for this transfer. Accordingly, the marginal profit must equal the negative value of the transferred allowances plus the compensation. But since the FOC is a marginal consideration, the marginal profit must not be compared with the total value of the transferred allowances but just with the value per unit. $-\hat{v}'a + \hat{v}'xm$ therefore has to be divided by the planned production q^{o}.

$$\partial \hat{\Pi}'^{o} \Big/ \partial q^{o} = \hat{p}' - \partial C^{o} \Big/ \partial q^{o} - \hat{v}' r^{o} = -\hat{v}' \tilde{a} \big/ q^{o} + \hat{v}' xm \big/ q^{o} \tag{41}$$

$$\hat{p}' = \partial C^{o} \Big/ \partial q^{o} + \hat{v}' r^{o} - \left(\hat{v}' \tilde{a} - \hat{v}' xm \right) \Big/ q^{o} \tag{42}$$

Comparing the FOCs for the old and the new installation with those FOCs for the new entrant and the closure rules leads to several findings:

- The FOC for the new installation in equation (39) is – apart from the superscripts – absolutely identical with the equation (17); accordingly the transfer rule did not alter the incentives for new investments (Ellerman 2006: 12).
- The profit maximization equation (36) has, compared to equation (15), an additional element $\hat{v}'(1-x)m$ which is positive, signifying that the operator of the new installation is better off under the transfer rule than under the regular new entrant rule.
- The same applies to the owner of the old installation. Compared to the regular closure rule, the profit maximization equation for the old installation (37) contains the additional positive element $\hat{v}'xm$ so that the operator of the old installations is also better off than under the regular closure rule.
- However, the closure price for the old installation – given in equation (42) – has changed in comparison to the regular closure rule in equation (34). While $\hat{v}'\tilde{a}\big/q^{o}$ reduced the crowding out effect introduced by the carbon constraint, this effect is – at least partly – mitigated by the transfer rule through the additional term $\hat{v}'xm\big/q^{o}$ in the closure price equation (Ellerman 2006: 13). However, the mitigating effect is small; if it is assumed that operators of the old and new installations share the economic advantage of the transfer rule x should be 50 % (1/2); assuming furthermore that the allocation to old installations exceeds the new entrant provision by 100%

(very conservative), the capacity increasing effect would be mitigated by just 25 %. If the difference between the allocation to the old and new installation is below 100 %, the mitigating effect of the transfer rule is even smaller.

In essence, it can be concluded that the transfer rule is economically attractive for both the operator of the old and the new installation and that it mitigates the capacity increasing effect of the closure rules although only rather slightly.

3.3.2.4.2 Same owner

If the old and the new installation are under the control of the same operator, the profit maximization equations (36) and (37) of both installations can be added to an overall profit maximization equation $\hat{\Pi}' = \hat{\Pi}'^N + \hat{\Pi}'^O$:

$$\begin{aligned}\hat{\Pi}' = {} & \hat{p}' q^N - C^N(q^N, r^N) - \hat{v}' r^N q^N + \hat{v}' \tilde{e} l K(q^N) - \delta Z(r^N) K(q^N) \\ & + \hat{p}' q^O - C^O(q^O, r^O) - \hat{v}' r^O q^O + \hat{v}' \tilde{a}(q^O) + \hat{v}' m\end{aligned} \tag{43}$$

The partial derivatives towards q^N and q^O result in the same entry and closure price equations (39) and (42) as for the transfer between two different operators. The incentives for capacity increase or closure clearly do not depend on whether the transfer of allowances is made between installations of two different operators or between two installations of the same operator. However, comparing equation (43) with the profit maximization equations (15) and (32) for the regular new entrant and closure rules makes clear that application of the closure rule would increase the profits by $\hat{v}' m$. If the allowances are transferred between two installations of the same operator the additional revenues do not have to be shared so that the full economic advantage of the transfer falls to just one operator. This advantage is greater, the larger the difference between the allocation to old and new installations is.

The analysis shows that the capacity increasing effect of the new entrant provision is not affected by the transfer provision while the capacity increasing effect of the closure rule is mitigated but not completely eliminated (Ellerman 2006: 13). The joint incentive to increase capacities of the transfer rule is somewhat lower than in a situation with purely new entrants and closure provisions, particularly because the incentive to extend the lifetime of old installations is reduced. However, if would be an exaggeration to characterize the transfer rule as innovation friendly although it has reduced the innovation delaying effects of the closure rule.

3.3.2.5 Malus rule

Older installations usually show lower efficiencies and thus have higher emissions than newer installations. Accordingly, older installations are stronger affected by emissions trading and will be earlier closed than newer installations because they become economically inefficient sooner due to emissions trading. Since the decommissioning of old or inefficient installations is one of the options to reduce greenhouse gas emissions of the entire economy, incentives for an accelerated decommissioning can be taken into account.

The first German NAP for the period 2005-2007 applies a smaller compliance factor for older installations which do not exceed a certain efficiency threshold (ZuG 2007: § 7 (7)) so that they receive less allowances via free allocation than more efficient installations. The second German NAP for the period 2008-2012 includes a similar rule although it is applied in a more general manner: because the aggregated base period emissions of the installations which receive allowances via free allocation are larger than the available allowance budget for those installations, the allowance application are scaled down by a factor called "proportionate reduction" ("anteilige Kürzung" in German). However, this factor is not uniform for all installations but rather depends on the efficiency level of an installation. Less efficient installations generally receive less allowances than more efficient installations (ZuG 2012: § 4 (3)).

But do these rules actually accelerate the decommissioning of inefficient installations? To analyze this issue, a new factor y for the proportionate reduction is introduced in the profit maximization equation for the closure of installations. This factor y is less than one and scales the allocation down if its efficiency is comparatively low ($0 < y < 1$). Except from this factor y the profit maximization equation and the corresponding considerations are identical to those for the closure of installations in equation (32). The factor for proportionate reduction enters the profit maximization equation as follows:

$$\hat{\Pi}' = \hat{p}'q - C(q,r) - \hat{v}'rq + \hat{v}'y\tilde{a}(q) \tag{44}$$

The corresponding FOC is derived in equation (45):

$$\partial\hat{\Pi}'\big/\partial q = \hat{p}' - \partial C\big/\partial q - \hat{v}'r = -\hat{v}'y\tilde{a}\big/q, \ \hat{p}' = \partial C\big/\partial q + \hat{v}'r - \hat{v}'y\tilde{a}\big/q \tag{45}$$

A comparison of the closure price under the malus rule given equation (45) with the general closure price given in equation (34) elucidates that $\hat{v}'y\tilde{a}/q$ is lower than $\hat{v}'\tilde{a}/q$. While the closure rule has introduced an incentive to extend operation of old installations over the period which would be efficient without this rule, this effect is to some extent alleviated through the malus rule. However, since the factor for proportionate reduction y is rather closer to one than to zero and definitively larger than 0.5, the alleviating effect is rather small than large.

3.3.2.6 Impacts on emissions and innovation

The above analysis has illustrated that particularly the new entrants and closure rules provide incentives which result in increased generation capacities compared to the situation without these provision. The transfer and the malus rules mitigate these incentives but do not eliminate them at all so that the joint effect of these rules will be an increase of generation capacities. The impact of increased capacities on emissions and innovation incentives depends – inter alia – on the specific market conditions. In this regard, the configuration of the electricity market is substantially different to the market conditions of most of the other products covered by the EU ETS:

- Electricity is not (yet) storable on a large scale and has to be produced in real time. Excess capacities therefore compete on the market for stand-by power and on-demand use of electricity. In contrast to other products, electricity operators derive some revenues from their excess capacities by providing stand-by or balancing power and charge from large consumers in addition to the price per kWh also a price per kW of absorbed capacity.
- Electricity demand is rather inelastic, at least in the short and medium term (Lijesen 2007). This can be illustrated by an almost vertical demand curve which moves towards the left and the right side along the upwards sloping supply curve depending on time of the day, weather conditions and other, the electricity demand influencing factors (Ellerman 2006: 13). The electricity output would thus hardly increase even if the additional generation capacities resulted in lower electricity prices. In other sectors the demand and supply curves resemble more the standard x-shape usually assumed in neoclassical theory. Increased capacities will thus result in lower prices and higher demand and output.
- The transport of fuels is generally cheaper than transport of electricity. Electricity transmission capacities are thus rather limited and net electricity imports to the EU-25 have not gone above 1 % since 1990 (DG TREN 2007: Table 2.6.2). Since extending transmission capacities is expensive and above all time consuming (for example in order to receive the necessary permissions, etc.), electricity generation is virtually not faced with competition from outside of the EU ETS. Not so the other sectors: most of them are confronted with some degree of international competition (Grubb, Neuhoff 2006).

Due to these differences in the market condition, impacts of increased capacities have to be differentiated between the electricity industry and other sectors.[28] In mostly competitive and elastic domestic markets, increased capacity will result in lower prices. Lower prices, in turn, will result in both increased consumption and a crowding out of marginal installations, usually those with less efficient technologies and rather high emissions. The consumption effect will raise emissions whereas the crowding out effect will reduce them. Which of these effects will outweigh the other might vary between the different products or sectors respectively depending – inter alia – on the vintage structure of the production fleet and on the demand price elasticities. However, aggregate emissions are capped through the EU ETS so that the demand effect would in any case be curbed by increasing allowance prices which especially intensify the crowding out effect of old, inefficient installations.

On global competitive product markets, increased production capacities in Europe would also result in reduced prices, increased demand and output and hence also an

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[28] Except from electricity it is primarily district heat which is confronted with similar market conditions (product not storable, small demand price elasticity and no international competition).

increased market share of the European companies. However, it has to be taken into account that the introduction of emissions trading has already induced an increase of the European manufacturers' product prices. This has resulted in enlarged demand for products which are produced outside the coverage of the EU ETS and has thus reduced the market share of European companies. Depending on the nature of the market, the introduction of emissions trading might thus have induced some relocation of production towards companies which are not covered by the EU ETS. As a consequence some CO_2 emissions might have leaked from the EU cap. The new entrants and closure provisions, in contrast, weaken to some extent the undesired effects of the EU ETS on market shares, relocation of production and on CO_2 emission leakage.

The increased incentives to extend capacities foster in any case the crowding out of less efficient installations and provide investment opportunities for new CO_2 efficient technologies. From an innovation perspective it can be concluded that these allocation provision basically foster innovation towards CO_2 efficient installations in the industrial sectors.

In the electricity sector competition from outside of the EU ETS and CO_2 leakage can be practically neglected. Increased capacity stretches the shape of the electricity supply curve to the right side. Depending on where the new generation capacities enter the dispatch curve, the electricity price might be reduced for some or several hours of the day. If the new capacities enter the dispatch curve in its base load section, average electricity prices might be reduced to some extent. However, depending on the total operational hours per year, the impact on average prices will be marginal or almost negligible if the new plants are rather operated in cycling mode or at peak load.

The effect of new capacities on CO_2 emissions and demand for allowances depends on which installations are displaced by the new capacities. If old hard coal or lignite power plants are displaced by new installations of the same fuel with higher efficiencies or by natural gas plants or if old gas power plants are replaced by new plants, emissions and demand for allowances would decline. Yet, if the new entrant provisions are differentiated by fuel, as is the case in Germany, so that coal-fired power plants receive double as many allowances as gas plants (section 3.3.2.2.2) and/or if the relation of the clean and dark spreads are such that coal-fired power plants are – despite their higher costs of CO_2 emissions – economically more attractive (see Figure 16, p 162), CO_2 emissions might also considerably increase. As an effect, the demand for allowances and their prices would be higher. Since the overall emissions are capped, more abatement would have to be contributed by the industrial sectors. In other words, fuel specific new entrant provisions in the electricity industry foster a shift of abatement efforts from the electricity sectors to the industrial ones.

In addition to the impact on output market, the increased generation capacities result in an additional supply of stand-by and balancing power. Due to a more price elastic demand and comparatively intensive competition on these markets it can be assumed that the prices on these markets decline more strongly than on the output market. These price effects might, in turn, result in reduced charges per kW for absorbed capacity of large electricity consumers. It can thus be expected that the price effects of increased capacities due to the new entrants and closure provisions tend to affect the capacity rather than the output market of electricity (Ellerman 2006: 14).

In summary, the analysis of the various allocation provisions has demonstrated that the initial allocation to incumbent installations – independently of the specific allocation method – influences neither the companies' output nor investment decisions. From a theoretical perspective, the initial allocation has, therefore, no significant impact on the innovation incentives of the EU ETS. A new entrant provision, in contrast, has considerable impact on capacities and opportunities for innovation. It does not change the incentives related to the environmental performance of the planned investment but increases the incentives to extend capacities, thereby enabling more innovations in general. However, this only holds if the allocation to new entrants is not differentiated by fuel. If the per unit allowance allocations increase with the carbon content of the fuel – as is the case in Germany – the new entrant provision would promote those technologies which receive relatively more allowances per unit of output (kWh). A fuel specific benchmark, for example, creates the same incentives to extend capacities like an undifferentiated benchmark. However, it affects the selection of generation technologies towards those technologies which receive more allowances per kWh produced (coal plants) at the expense of comparatively CO_2 efficient technologies (natural gas plants).

A closure provision also contributes to an increase of generation capacities because it promotes the extension of the lifetime of existing installations operating at the margin. In this way, a closure provision tends to delay rather than promote the diffusion of innovative generation technologies. To some extent, a transfer rule mitigates the distorting effects of new entrants and closure provisions but does not eliminate these incentives entirely. The malus rule, again, curbs the lifetime extending effect of the closure rule but does also not remove the closure provision's distorting effect completely.

Altogether these specific allocation provisions will induce an increase in generation capacities which, due to the inelastic electricity demand, will in turn result in decreased prices on the capacity markets rather than on the output markets. The increase in capacities will be partly induced by the closure provision and partly by the new entrant provision. However, although the effects of both provisions act inversely, they do not cancel each other out; instead they result in there being more old and new installations compared to the situation without these provisions. The new entrant provision primarily provides incentives for investments in new installations, thereby enabling an additional reduction of CO_2 emissions through the diffusion of innovative technologies. This can, however, only be guaranteed if the new entrant provisions are not differentiated by fuel. Fuel specific new entrants allocations would eliminate incentives to shift towards generation technologies which use less carbon intensive fuels like natural gas. They would, conversely, tend to defer innovation towards CO_2 efficient technologies in the electricity industry but paradoxically promote such technologies in the other industrial sectors.

3.3.3 Framework and time plan

Given the long lifetimes and the irreversibility of power generation investments, time plan aspects are generally very important for investment and innovation incentives of an emissions trading scheme. Both the length of trading periods and the design of the international climate regime are thus rather sensitive for investment decisions. Comparing power plant lifetimes of 40 years and more (IEA 2007: 76) with commitment periods of five years and the Kyoto Protocol’s time horizon until 2012 clearly shows that the time frame of political regulation diverges substantially from the companies’ scope. From the firms’ perspective both issues determine policy or regulatory uncertainty which influences investment decisions (Buchner 2007; Sullivan, Blyth 2006).

Currently, it is uncertain which international climate policy regime will govern after 2012. According to the negotiation mandate agreed upon at the 13th Conference of the Parties in December 2007 in Bali, a follow-up to the Kyoto Protocol will not be approved before the end of 2009 (UNFCCC 2007). To enter into force, a new agreement needs to be ratified by the parties. Taking into account that it took more than seven years from December 1997 to February 2005 before the Kyoto Protocol entered into force, it seems quite ambitious that a follow-up agreement will enter into force before the end of the Kyoto Protocol’s first commitment period.

The EU ETS Directive does not directly depend on a follow-up to the protocol. Several articles of the Directive indicate that EU ETS is designed to continue after 2012 (2003/87/EC, for example Article 11 (2) or Recitals (29)). However, in section 22 of the Recitals it is also agreed upon that the Directive should be reviewed in the light of developments in the UNFCCC context. This may particularly apply to the overall cap of the EU ETS which might be more or less ambitious depending on agreements achieved under the UNFCCC framework.

In January 2007, the European Commission advocated that the EU should adopt domestic measures to ensure that the global climate temperature does not increase by more than 2°C compared to pre-industrial levels (COM(2007) 2: 2). To guarantee this, the EU should pursue in the context of the UNFCCC negotiations that developed countries reduce their emissions by 30 % compared to 1990 until 2020 and by 60 to 80 % until 2050. In March 2007, the European Union unilaterally committed itself to reducing its greenhouse gas emissions by at least 20 % compared to 1990 levels until 2020 and by 30 % if other developed countries commit themselves to comparable emission reductions (EU Council 2007: 12). Although this commitment gives a clear indication to the industries covered by the EU ETS that the greenhouse gas reduction policy generally and the EU ETS specifically will continue after 2012, it still leaves considerable uncertainty regarding the strength of the commitment (Blyth, Yang 2006: 6).

In general it can be assumed that a higher regulatory uncertainty results in the postponement of investment decisions and thus a slowdown of innovation. This can again be explained by the real option theory (see also section 3.3.4). Regulatory uncertainty may create incentives to postpone investment decisions until more regulatory information will be available which enables firms to make better-informed decisions (Ishii, Yan

2004: 31). In situations of regulatory uncertainty, the project payoff obtained by waiting until uncertainty has been resolved or reduced may be greater than the revenues foregone during waiting. Compared to a situation without uncertainty, the price of CO_2 must be higher to stimulate investments (Sullivan, Blyth 2006: 4-5). Both theoretical and empirical analyses provide evidence that increased uncertainty creates incentives to postpone investment decisions (Bloom et al. 2007; Botterud, Korpås 2004; Butzen et al. 2002; Ishii, Yan 2004; Kalckreuth 2000; Laurikka, Koljonen 2006).

Blyth and Yang (2006: 57) represent the effects of climate policy through the carbon price and differentiate between an underlying CO_2 price uncertainty about the costs of meeting the reduction targets and an one-off shock to prices which represents policy uncertainty. The latter uncertainty refers to decisions on a post-Kyoto agreement or an allocation decision. The point in time when these decisions are taken often tends to be foreseeable but that is not the case with regard to the outcome of the decision. Regulatory uncertainty is thus transferred into potential CO_2 price shocks.

In a simulation analysis, Blyth and Yang examine the effects of CO_2 price uncertainties on investment decisions for a pulverized coal (PC) plant and a CCGT. In their model, investment delaying option values are translated into additional gross margins over the capital costs which are required to fully compensate for waiting. They show that the effects of CO_2 price uncertainty are low compared to the fuel price uncertainty if both investment options are considered separately (Blyth, Yang 2006: 33-34). However, CO_2 price uncertainties have a significant effect if both plants are considered as alternatives, i.e. if it comes to the question of whether to build a PC or a CCGT plant. This is because the profitability of these projects goes in the opposite direction of changes in the CO_2 price. In the case of the options being considered separately, the value of waiting for more favorable CO_2 prices would have to be calculated from the difference between the increased revenues due to more favorable CO_2 prices and zero revenues of not constructing the plant. In the case of an investment alternative, the option value would have to be determined from the revenue variation of both plants by dint of the changes in the CO_2 price. Since the returns of both projects react in opposite directions to CO_2 prices changes, the value of waiting is considerably greater if the decision is whether to build a PC or a CCGT plant rather than whether to build one of these plants or not (Blyth, Yang 2006: 35-38).

The option value of postponing an investment decision also becomes larger, the shorter the time span to the potential CO_2 price shock is. This is because waiting for longer reduces on the one hand the value of additional information due to discounting and increases on the other hand the revenues forgone due to the postponed investment. The option value of waiting is thus considerably smaller at the beginning of a commitment period than at the end of that period. Investment decisions which are basically sensitive to CO_2 price uncertainties are therefore more likely to be taken at the beginning of a commitment period. Since both the Kyoto Protocol and the EU ETS have been designed using regular commitment periods to date, such incentive structure might result in a sawtooth shaped investment cycle (Blyth, Yang 2006: 34).

The above considerations illustrate that regulatory or political uncertainty may contribute significantly to the postponement of investment decisions and thus to a slowdown of the innovation process in the electricity industry. Measures that would reduce regulatory uncertainty may thus foster both investment and innovation. Potential measures include, first, the definition of binding long-term reduction targets and, second, time plan aspects of the target path. Measures at both the UNFCCC and the EU level could contribute to reducing political uncertainty for the EU ETS. Measures at the UNFCCC level would also tend to improve the predictability within the EU ETS. However, the predictability of the EU ETS does not solely depend on improvements at the UNFCCC level but can be increased independently of the UNFCCC.

3.3.3.1 Long-term target

The EU has already committed to reducing greenhouse gas emissions by 20 or 30 % respectively by 2020 and has envisaged a 60% to 80 % reduction of emissions by 2050 compared to 1990 levels (EU Council 2007: 12). Such a clear target is an important contribution to reducing climate policy uncertainty. However, a considerable amount of uncertainty remains since the 2020 target is contingent on the agreements achieved under the UNFCCC framework. Dissolving this contingency would further reduce the political uncertainty within the EU ETS but is not likely to be politically enforceable due to potential negative effects on the EU's international competitiveness. Moreover, agreeing upon a target for the EU as a whole does not directly translate into a clear target for the EU ETS. Therefore, the EU ETS' predictability still considerably depends on progress made towards binding, long-term targets under the UNFCCC.

The time horizon at the UNFCCC level currently only continues until 2012. Negotiations on a follow-up to the Kyoto Protocol were only commissioned in December 2007. The aim of these negotiations is to achieve an agreement by the end of 2009 at the latest. However, this is still ambitious since the perceptions of the individual parties regarding the future climate regime are still rather divergent.[29] These negotiations will hardly decrease but will rather increase the political uncertainty for the EU ETS. A contribution to reducing the regulatory uncertainty of the EU ETS from the UNFCCC process can thus not be expected in the short term but only in the long term.

3.3.3.2 Target paths

Besides binding long-term targets, the political uncertainty might also be reduced by the design of the detailed path towards these long-term targets. This mainly refers on the one hand to the length of commitment periods and on the other hand to the point in time when decisions on short-term targets are taken.

Longer commitment periods would reduce the impact of regulatory uncertainty on investment because the option value of postponing investments increases particularly

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[29] A comprehensive overview on the post 2012 debate and the concepts of individual parties is provided by Ecofys (2007).

towards the end of each period. Doubling the length of a commitment period from, for instance, five to ten years would thus provide longer periods with a small option value of delayed investment and thus foster investment and innovation. In addition, longer commitment periods would provide more flexibility to companies to offset short-term fluctuations resulting from economic cycles, weather conditions, etc. and might also reduce transaction costs due to fewer negotiation processes. However, shorter commitments periods also have advantages which have to be balanced with the advantages of longer periods. Shorter commitment periods allow policy makers to better adjust targets to scientific, technological, economic or political developments. More frequent compliance checks would also increase the transparency of emission reductions already achieved (Buchner 2007: 5-6).

This discussion illustrates that extending commitment periods would improve the predictability of climate policy but at the cost of reducing flexibility and transparency. Several suggestions are made to mitigate this trade-off between longer and shorter commitment periods:

- Rolling commitment periods: “commitments are subject to an automatic adjustment process that extends and makes them more stringent on, for example, an annual basis whilst retaining the assessment of compliance at multi-year intervals. The process of automatic annual extensions means the annual commitments … are always known with reasonable certainty for a next set of years – thus reducing the uncertainty created by periodic re-negotiation of commitments.” (MoE 2007: 12)[30]
- Multi-period decision-making: The length of the commitment period remains unchanged at five years but the targets are decided, for example, three periods in advance on the background of a long-term target path. This approach would considerably extend the predictability without downgrading the transparency with respect to emissions and achieved reductions.[31]
- Gateways: Australia’s National Emissions Trading Taskforce suggested combining firm targets for a period of 10 years with upper and lower bounds of possible future targets (‘gateways’) for the subsequent 10 years (NETT 2006). Since the firm targets would be extended every year by another year, this approach is basically an extension of the rolling commitment periods.

A common element in all these approaches is that a long-term emissions reduction perspective is combined with firm short-term and adjustable medium-term targets. In this way, they might reduce regulator uncertainty for potential investors while maintaining the flexibility and transparency of shorter commitment periods and might thus foster investment and innovation.

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[30] An automatic adjustment procedure of commitments has, for example, been introduced in BASIC’s (2006) Sao Paulo Proposal for an Agreement on Future International Climate Policy.

[31] This approach became known as ‘carbon budgets’ and was suggested in the draft UK Climate Change Bill (defra 2007).

3.3.4 Banking

Compared to traditional environmental command and control policy, emissions trading provides companies with additional flexibility in terms of the areas in which they reduce their emissions. Due to the fact that companies only have to surrender their allowances at the end of each five year compliance period, they are also granted some flexibility in terms of when to reduce emissions. However, “when flexibility” (Stephan, Müller-Fürstenberger 1999) is restricted to each compliance period. Using an allowance valid for a future period in the current period is usually referred to as borrowing while using a current period’s allowance in future periods is referred to as banking. The EU ETS Directive does not allow for borrowing but requires Member States to allow for banking (2003/87/EC, Article 13 (3)).[32]

In general, it can be expected that banking increases the efficiency of emissions trading because the additional “when flexibility” enhances the number of options how companies may react on the carbon constraint (Buchner et al. 2004: 4). Companies have an incentive to bank allowances if the growth rate of the allowance price is greater than the interest rate (Cronshaw, Kruse 1996) or “when marginal abatement costs are rising, marginal production costs are falling, emission standards are declining, or output prices are rising" (Kling, Rubin 1997: 114).

Cronshaw and Kruse (1996) show that banking reduces the aggregated compliance cost of emissions trading. However, particular borrowing may not lead to a social optimum because firms discount the future and tend to emit more at present than in the future (Kling, Rubin 1997). Godby et al. (1997) point out that in cases where firms cannot control emissions precisely during a compliance period, banking provides additional benefits in smoothening the functioning of the allowances market.

The first studies on intertemporal allowance trading have focused on flow pollutants, such as SO_2 and NO_X, whose environmental damages stem mainly from the current concentration. Most greenhouse gases, however, are rather stock pollutants because their damage depends on their accumulated stock in the environment. Leiby and Rubin (2001) include stock pollutants in their model and show that in the case of a non optimal allowance allocation path, welfare would be increased if the exchange rate for trading allowances between periods equals the discount rate minus the desired rate of change in the allowance price.

While in the above mentioned studies perfect information was assumed, Phaneuf and Requate (2002) include imperfect information in their analysis and find that abatement cost uncertainty and irreversibility are additional arguments for banking. They focus their analysis on investment incentives provided by banking. With a three period model they demonstrate that banking might reduce a firm’s incentive to invest in abatement technology.

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[32] From the pre Kyoto period (2005 to 2007) to the first Kyoto period (2008-2012) Member States are not required to allow for banking because banking between these periods might cause distortions in the Kyoto registries (Schleich et al. 2006: 113-114).

Period 0 is a pre-regulation period in which firms invest in abatement technology to reduce emissions in period 1 and 2. In period 1 firms decide on investment which reduces emissions in period 2 and – if allowed – on banking which reduces the need to reduce emissions in period 2. From a firm's perspective banking is attractive if the discounted allowance price of a subsequent period is higher than the current period's price. If banking is allowed, firms will adjust differences in the allowance price by banking allowances until period 2's discounted allowance price is equivalent to the allowance price of period 1.

Banking will occur if the aggregated period 1 reduction target is expected to be weaker than period 2's reduction target. If banking is allowed, firms can decide in period 1 whether to achieve the period 2 target by investing in abatement or by banking allowances. If banking is not allowed, firms do not have the alterative so that they can only invest in abatement to achieve their period 2 targets. Banking enables companies to reduce their investment in abatement and can thus be considered a disincentive for investment.

Phaneuf and Requate show that banking does not provide the socially optimal solution if abatement costs are certain since banking allows operators to deviate from the optimal target path determined by the regulator. However, abatement costs are uncertain because they depend on stochastic factors. In electricity generation, for example, abatement costs depend on the weather, which influences both electricity demand (heating in winter, cooling in summer, etc.) and supply (hydro power, lack of cooling water for thermal power plants, etc.) and input prices (gas price, dark and spark spread, etc.). Even so, the regulator has to determine the allowance allocation upfront, i.e. before those price uncertainties are resolved. Taking into account these abatement cost uncertainties, banking might improve social welfare since it would be efficient to advance abatement if it is cheap instead of increasing pollution to make use of the low permit price. But in the case of flow pollution, where the social damage depends only on current emissions, banking might result in hot spots so that the private level of banking might not coincide with the social optimal level (Requate 2002: 3).

Greenhouse gases in general and CO_2 in particular can be regarded as stock pollution. The social damage depends only on the accumulated stock of the pollutant so that the damage does not temporarily coincide with the emissions. Banking of stock pollutants will not change the social damage and can thus increase the social welfare (Requate 2002: 21-22) if it reduces the aggregated compliance costs. However, it would still substitute investment in abatement technology and can thus be considered a disincentive for environmental innovation.

Phaneuf and Requate (2002) assume continuous abatement cost functions. In reality, though, abatement investment is not continuous but rather to a large degree indivisible. Firms might not be able to scale the size of their investment to the expected abatement costs. Without banking it might be more attractive to select the investment option which is smaller than their optimal size and to "fill" the remaining gap with operational abatement (changing the merit order, fuel switch, etc.). If banking is allowed and discounted future allowance prices are expected to be higher than current allowance prices, firms could select the investment option larger than their optimal size and bank excess allowances for future periods. This way banking might increase investment incentives.

Banking will, however, also result in a decreased supply of allowances in a current period and an increased supply in future periods. In this way, it contributes to a smoothing of the allowance price over time and, thus, to a lower variance of the allowance price. The variance is a measure of risks associated with the stochastic allowance price (Sharpe, Alexander 1990: 136, 140). Provided that agents are in aggregate risk-avers[33] and that investments are virtually irreversible, banking contributes to reduce the allowance prices risk which in turn increases the propensity to invest.

The latter effect can be explained by the real option theory,[34] which highlights that investment decisions are usually not a "now or never" decision but can be postponed. Postponing an investment decision can maximize profits even if the net present value of an investment is positive. This might be the case if the discounted gains of additional information relevant for the return on investment are larger than the discounted profits foregone due to postponing the decision. Waiting might, for example, reveal more information relevant for decisions on the appropriate design of an investment (size, technology, input factors, etc.). In addition to the net present value of the returns, an investment has an option value which will be deleted when the investment is decision is taken. An investment should thus only be commissioned if the discounted returns plus the option value exceed the costs of this investment.

The option value of an investment increases with the risk. Investments which are exposed to higher risks have a higher option value and are thus more likely to be postponed. Banking would, conversely, reduce the risks since it smoothes allowance prices and diminishes their variance. Correspondingly, it would reduce the option value of investments and thus result in advanced investments compared to the situation without banking.

The overall effect of banking on investment and innovation is ambiguous. On the one hand banking enables firms to substitute investment in abatement technology by banked allowances and contributes in this way to postpone investment. However, this result particularly holds if firms' investment functions are continuous. In electricity generation investment is to a large degree indivisible so that the size of the investment cannot be perfectly adapted to the expected allowance price. Banking would enable firms to opt for the larger investment option and to bank allowances if the discounted expected prices are lower than current allowance prices. On the other hand, banking reduces the variance and thus the risk associated with the allowance price. This, in

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[33] Historically, riskier securities had on average higher returns. If investors would not be risk-avers they would not have required higher yields to compensate their risks (MacCrimmon, Wehrung 1984; Sharpe, Alexander 1990: 141, 151).

[34] In the real option theory, methods for assessing financial options are transferred to real investments. This transfer is based on considerations by McDonald and Siegel (1985), by Brennan and Schwartz (1985) and by Dixit and Pindyck (1994). A detailed overview is provided by Trigeorgis (1995).

turn, diminishes the option value of investment options and would, compared to the situation without banking, encourage firms to bring forward their investment decisions.

Which of these conflicting effects outweighs the other has not yet been determined. Electricity companies covered by the EU ETS generally highlight the risk reducing effect of banking and report that banking would encourage their investments. However, in a ranking of the importance of various design options for their company banking was ranked last in the 12 options (section 4.3.5, p 143). Another piece of evidence that banking is not considered a central design option can be derived from that fact that it was hardly mentioned in the review process of the EU ETS.[35] Indeed, only in six of the 46 stakeholder contributions[36] banking is mentioned at all. In the report of the third meeting[37] it was alluded to marginally and merely in the report of the fourth meeting[38] it was addressed several times, however not as a contentious issue within the EU ETS but as a design feature which has to be clarified before linking trading schemes. Thus, even if banking in aggregate might improve the propensity to invest, it might do so only to a minor extent.

3.4 Conclusions

With the introduction of emissions trading an entirely new approach to environmental policy has been introduced. The new approach broke with the strong link between pollution and polluter and provided more flexibility to polluters by focusing on differences in mitigation costs without abolishing the responsibility for their pollution entirely.

Compared to traditional environmental command and control policy the new approach has several advantages: Provided that a comprehensive monitoring and compliance scheme is established, it guarantees that the aspired environmental targets are indeed achieved. Moreover, the increased flexibility enables achievement of the same targets as under a command and control approach at lower costs or achieving more emission reductions at the same costs. In other words, emissions trading yields a higher static efficiency than traditional command and control policies. And last but not least, emissions trading also provides stronger incentives to develop and implement more efficient technologies because efficiency gains are fully rewarded to the innovator and not cut off if a certain emission level is achieved. Besides a higher static efficiency, emissions trading also guarantees higher efficiencies in the future so that its dynamic efficiency is also superior to command and control policies.

Although emissions trading generally provides stronger incentives for innovation than command and control policies, the stringency of these incentives may still vary depending on the specific design of an emissions trading scheme. Hence, determination of the innovation incentives of individual design options and their potential configurations was

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[35] http://ec.europa.eu/environment/climat/emission/review_en.htm

[36] http://ec.europa.eu/environment/climat/emission/list_review.htm

[37] http://ec.europa.eu/environment/climat/emission/pdf/070521_22_final_report_m3_tc.pdf

[38] http://ec.europa.eu/environment/climat/emission/pdf/070614_15finalreport.pdf

the key goal of the previous chapter. However, since innovation incentives themselves are difficult to identify, the analysis was focused on incentives to invest in new capacities. This approach follows the considerations in more detail which were elaborated in chapter 2 (see specifically section 2.2): In the electricity industry the responsibility for the entire innovation process is divided between technology manufacturers and research institutes on the one hand and the core electricity industry on the other hand. The first two sectors are responsible for the invention and the development of marketable products while the latter sector is predominantly responsible for the diffusion of those innovative technologies provided by the other two sectors. Investment is a precondition for the diffusion of new technologies and hence a good proxy indicator for innovation incentives induced by the various design options and their potential configurations.

Following Ellerman (2006), the analysis was largely based on a comparison of the firm’s profit functions and the corresponding first order condition for profit maximization which would be applied under each of the alternative configurations of the design options. The size of the overall cap, various allocation options and issues related to the overall framework and the time plan of emissions trading have been identified as design options that are rather sensitive to innovation incentives. Moreover, the issue of whether banking provides additional incentives to innovate or not was analyzed since this issue was intensively debated in the literature.

For the overall cap it can be concluded as a rule that the innovation incentives are stronger, the more stringent the overall cap is. This is because a more ambitious cap will result in higher allowance prices which, in turn, allow for more advanced technologies, which are still more expensive, to enter the market.

Not surprisingly, the type of allocation to incumbent installations does not directly interfere with the diffusion of innovative technologies. For the question of whether to invest in new capacities or not, it does basically not matter whether allowances are auctioned off to existing installations or allocated free of charge according to the grandfathering or benchmarking approach. However, the allocation rules for incumbents might have an indirect impact on the diffusion of advanced technologies, particularly if new entrants or closure rules are established.

New entrants or closure provision, in contrast, may significantly affect decisions on new investments. If free allocation of allowances to new entrants occurs, it can be considered a subsidy to capacity extension. Quite naturally, this would foster investments more strongly as new entrants would have to buy all allowances on the market. A new entrant provision thus provides additional opportunities for innovation. However, these opportunities might not result in environmental innovation if fuel specific benchmarks are applied instead of uniform benchmarks. Fuel differentiated benchmarks which allocate more allowances to those fuels with higher carbon content, would discriminate switching towards less carbon intensives fossil fuels (particularly natural gas) and thus eliminate an important option from the portfolio of potential mitigation measures. A fuel specific benchmark may, nevertheless, be applied to cure concerns with regard to the security of supply because natural gas will increasingly be imported from countries which are considered instable or untrustworthy. However, this remedy does not come for free but results in higher emissions of the electricity sector which have to be offset by more reductions in the industrial sectors induced through on average higher allowance prices.

A closure provision, which requires installations to return their allowances upon closure, does not – as one would suspect from the term – promote the closure of installations but paradoxically provides incentives to extend the lifetime of existing installations. If operators of closed installations have to return the allowances allocated to them, the allowances become contingent on generation and are therefore considered in the closure decision. In this way, a closure provision increases the threshold price for market exit so that some of the installations which would be crowded out due to the introduction of emissions trading will continue to operate until the closure price has further decreased.

Both the new entrant and the closure provision provide thus incentives to increase generation capacities. Particularly the distorting effects of the closure provision could be alleviated through a transfer and a malus rule. The transfer rule provides additional incentives for closure while the malus rule penalizes continued operation of old and very inefficient installations. Yet, the alleviating effect of both rules is rather small compared to the “life extending” effect of the closure provision so that they do not eliminate the distorting incentives entirely.

In addition the indirect incentives of the allocation rules for incumbents have to be taken into account: if new entrants are treated as incumbents after a certain period of time, investors would anticipate the expected allocation to the then incumbent installations in their investment decisions. Provided, for example, that an average benchmark would yield more allowances to the planned installations than a BAT benchmark, the average benchmark would encourage investment in new capacities more strongly than a BAT benchmark. Depending on the length of the period, during which an installations is considered a new entrant, this indirect effect may be comparatively small due to discounting.

A similar indirect incentive of the allocation rules for incumbents affects the closure provisions. Provided that an old installation would receive more allowances under a grandfathering than under a benchmarking approach, the “life extending” effect of the closure provision would be stronger under a grandfathering approach than under a benchmarking approach because the number of forfeited allowances is greater. In contrast to the indirect effect which affects the new entrant provisions, this effect will not be extenuated through discounting but develops instead its incentives immediately.

All in all, these allocation provisions will contribute to an increase of generation capacities. The closure provision would result in a higher number of old, inefficient installation compared to the situation without this provision. The new entrant provision would foster investment in new installations, thus providing additional opportunities for the diffusion of innovative generation technologies. Unless the new entrant provisions are differentiated by fuel, this would result in additional CO_2 reductions because newer power plants are usually substantially more efficient than old installations. However, if the allocations to new entrants depend on the fuel, they would eliminate incentives to shift towards fossil fuels with lower carbon contents such as natural gas. The electricity industry's CO_2 emissions would, accordingly, decline to a lesser extent under a fuel specific approach than under an undifferentiated approach and might even rise if unfavorable developments on the fossil fuel market make coal-fired power plants much more attractive than gas plants. Fuel specific new entrant provisions might thus rather delay the transformation towards a more sustainable and less carbon intensive electricity supply but indirectly promote such technologies in other sectors.

Besides the overall cap and the various allocation provisions, issues related to the *general framework* and the *temporal issues* in particular are rather sensitive in terms of the innovation incentives of the EU Emissions Trading Scheme. Regulatory or political uncertainty about the future of the scheme reduces companies' propensity to invest because the option value of waiting until the uncertainty is resolved increases, leading to delays in innovation. An international agreement on a long-term follow-up to the Kyoto Protocol under the UNFCCC framework would substantially reduce the political uncertainty and improve the environment for innovative investments. However, negotiations on a follow-up to the Kyoto Protocol began only in December 2007 and it will take several years before a new protocol becomes genuinely legally binding.

Nevertheless, the political uncertainty does not only depend on progress at the UNFCCC level but could also be reduced through measures at the EU level. The EU's unilateral commitment to reducing greenhouse gases by at least 20% and possibly 30% if other developed countries take comparable targets is an important step to reducing the regulatory uncertainties of European climate policy. Longer trading periods would be another option to establish an investment and innovation friendly environment. Yet, longer trading periods would limit policy makers' flexibility to adjust targets to scientific, technological, economic or political developments and would result in less frequent compliance checks which, in turn, would reduce the transparency of the trading scheme. A common element of suggestions to escape from this dilemma is that a long-term emission reduction perspective is combined with firm short-term and adjustable medium-term targets.

Finally, it was analyzed how *banking* might influence the companies' propensity to invest and to innovate. Basically banking provides companies with more flexibility in the management of their allowances. This enables firms, on the one hand, to substitute investment in advanced technology by banked allowances with the result that innovations are rather postponed. On the other hand, however, banking would reduce the variance in the allowance prices and hence the associated risks. This again would reduce the option value of postponing investment and encourage companies to bring forward investments in advanced technologies. Which of these effects outbalances the other has not been determined up to now. However, from the companies' perspective, the survey has shown that banking is of minor importance. Thus, even if banking might encourage innovation on average, its effect will be rather small than large.

From an innovation perspective, several conclusions can be drawn for the optimal design of an emissions trading scheme. In the first place, it is essential that the trading scheme is embedded in a comprehensive climate policy with a binding long-term target and firm medium- and short-term commitments. Trading periods should not be extended for transparency reasons but might be fixed several years in advance to provide more reliable perspectives for investors. As long as at least a share of the allowances is allocated to incumbent installations free of charge, a new entrant provision might be reasonable to spur innovation. However, if all allowances are auctioned off to incumbents, it will be difficult to justify free allocation to new entrants. If innovation should still be encouraged under auctioning, it seems to be more adequate to apply the usual tools of innovation policy beyond the EU ETS.

To guarantee that the CO_2 scarcity signal is not disturbed, it is also essential that all new installations receive the same per unit allocation and that new entrant provisions are not differentiated by fuel. Closure rules should be completely abolished so that operators can retain allowances of closed installations until the end of the trading period. This would make specific transfer rules obsolete and would reduce the importance of a malus rule. By taking these considerations into account, the trading scheme would not only improve its innovation incentives but also become less complex and more transparent for all participants.

4 Electricity industry – incentives and innovation

The previous chapter has illustrated that emissions trading induces innovation incentives in the electricity industry and that the extent of these incentives depends on the specific design of the trading scheme. The aim of this chapter is to analyze whether the theoretically derived innovation incentives can effectively be observed in the electricity industry.

For this purpose, a panel analysis with two surveys in the German electricity industry has been carried out. The first survey was conducted in autumn 2004, only a few months before the EU Emissions Trading Scheme started. The second survey was completed in summer 2007. By then the companies had already gathered two and a half years of experience with the new instrument. The results of the first survey are considered as the baseline to which the results of the second survey are compared in order to identify the impact on innovation incentives in the electricity industry.

The chapter is organized as follows: in section 4.1 the approach of the empirical investigation is elucidated in detail. The results of the first and second survey are described and analyzed in sections 4.2 and 4.3. A summary and conclusions are provided in the final section (4.4).

4.1 Approach

Each of the two surveys consisted of a series of face-to-face, in-depth interviews with the company representatives in charge of dealing with emissions trading. The interviews were based on a semi-structured interview guide with a number of open questions and some closed questions. To guarantee comparability of the surveys it was intended that both surveys be conducted with the same companies and representatives. However, companies disappeared or changed their business and responsibilities were modified within the companies. Nevertheless, 90 % of the companies and 60 % of the representatives who participated in the first survey were also available for the second survey.

The interview guide for the first survey comprised 39 main questions and 62 sub-questions (see section 8.1). As for the companies and the representatives it was intended that most of the questions be repeated in the second survey. However, the analysis of the first survey revealed that some questions could be omitted in the second survey while other questions had to be refined or amended. The interview guide for the second survey covered 50 main questions and 51 sub-questions (see section 8.2). Despite some changes in the interview guide more than three quarters of questions in the first interview guide were repeated in the second interview guide. The interview guides were organized around five topics:

1) **Innovation strategy**: To identify the impacts of emissions trading on innovation in the electricity industry it was essential to learn more about the general approach towards innovation in the covered companies. They were thus asked how they establish innovations in their company (see also section 2.3.4) and how these proc-

esses might change or already have changed in response to emissions trading. In addition, expectations in terms of different innovative technologies for power supply were addressed.

2) **Institutional innovations**: Based on the broad concept of innovation (see section 2.2) not only technological change but also organizational changes and alterations in the business process are considered potential innovations. Correspondingly, the companies were queried about changes in their organizational structure or in their business processes which they expect or have already implemented by dint of emissions trading.

3) **Changes in operation of existing installations**: In this section companies' expectation about changes in the operation of power plants are investigated. Changes in the merit order, such as shifts of operational hours from coal or lignite to gas power plants, would undoubtedly affect the environmental performance of the electricity systems but would, in the first instance, not contribute to the long-term environmental innovation of the electricity system. However, according to the theory on the formation of expectations (Felderer, Homburg 1987: 251-261) and according to empirical evidence (DB 2001) individuals base their expectations – at least partially – on current and past experiences. The experiences gained from the operation of power plants under the new emissions trading regime might thus influence companies' expectations on electricity, fuel and CO_2 prices as well as their expectations on average operational hours for individual technologies. And since investment decisions for new power plants or efficiency improvements are strongly determined by the companies' expectations, it can be assumed that the operational experiences gained under the new emissions trading scheme also indirectly affect investment and long-term innovation in the electricity industry.

4) **Changes in investment strategies**: Investment is a precondition and thus an important indicator of technological innovation (see section 2.4). Under this topic companies were requested to describe their plans for investments in electricity supply technologies and efficiency improvements and how these plans might be or have already been affected by emissions trading. Moreover, general expectations on the competitiveness of different supply technologies and fuels as well as issues related to project based Kyoto mechanisms were addressed.

5) **Assessment of design options**: Specific configurations of individual design options might have considerable impacts on the innovation incentives of the EU Emissions Trading Scheme (see chapter 3). In this section it was, therefore, asked which design options are most important to individual companies and how these design options should be configured from the company's perspective to foster innovation. Furthermore, the way in which the electricity industry as a whole might be affected by different configurations of individual design options was inquired.

Since the interviews addressed several sensitive issues, it was essential to guarantee confidentiality and that no company specific data or information would be published in the analysis. Without this agreement several questions would have been answered less openly or not at all. Some of the interviewees would have even refused to participate in the interviews.

All in all, 22 companies participated in the surveys. The covered companies are a representative cross-section of the German electricity industry, despite its small number. The electricity generation of the covered companies in Germany adds up to more than four fifths of Germany’s total power production, though the five largest companies already account for more than three quarters of electricity generation. Nevertheless, the surveys covered several middle-sized and a number of small utilities. Despite the coverage, the sample is also representative in terms of the regional distribution (east and west) and the business type (public utilities, industrial auto-producers, independent power producers). In addition, the sample includes companies with old and new power plants and companies with different generation portfolios (coal, lignite, gas, nuclear, renewables, etc.). Table 2 provides an overview of the sample.

Table 2 Sample of companies covered by the surveys

	Survey		Large	Middle-sized	Small	West	East	Public utilitiy	Industrial auto-producer	Independend Power Producer
	1^{st}	2^{nd}								
BASF		X		X		X			X	
BTB	X	X			X	X		X		
Concord Power	X	X			X	X				X
E.on	X	X	X			X		X		
Electrabel	X	X			X			X		
EnBW	X	X	X			X		X		
Henkel	X	X			X	X			X	
InterGen	X				X	X				X
KMW	X	X		X		X		X		
MohnMedia	X	X			X	X			X	
MVV	X	X		X		X		X		
RWE	X	X	X			X		X		
Stadtwerke Duisburg	X	X		X		X		X		
Stadtwerke Finsterwalde	X				X		X	X		
Stadtwerke Frankfurt/Oder	X	X			X		X	X		
Stadtwerke Hannover	X	X		X		X		X		
Stadtwerke Leipzig	X	X			X		X	X		
Stadtwerke Schwäbisch Hall	X	X			X	X		X		
Statkraft		X			X	X				X
Steag	X	X	X			X				X
Vasa Energy	X	X			X	X		X		
Vattenfall Europe	X	X	X				X	X		
	20	**20**	**5**	**5**	**12**	**17**	**4**	**15**	**3**	**4**

Sources: Author’s own summary

The interviews of the first survey lasted one hour and 10 minutes on average while the interviews of the second survey lasted 10 minutes longer on average (1:20 h). However, the duration varied substantially from 40 minutes to two hours and 20 minutes. Altogether more than 50 hours of interviews were recorded comprising some 4,000 answers. The substance of all answers was carefully interpreted and summarized. Based on these summaries, categories of answers were identified and their frequency determined (Mayring 2003: 13-15). These frequencies again were used to draw conclusions regarding the impact of emissions trading on innovation in the electricity industry. The results of this analysis were – if necessary – complemented by specific viewpoints of individual companies to illustrate the spectrum of the standpoints.

One difficulty was to single out the impacts of emissions trading from impacts of other instruments which might also have influenced innovation incentives in the electricity industry. This was particularly true of the Renewable Energy Sources Act (EEG) and the Cogeneration or CHP Act (KWKG). Both acts were passed long before the EU Emissions Trading Scheme began. However, the EEG's last amendments became effective just one year before the start of the EU ETS. Some interference of these acts can definitively not be ruled out.

Basically, it is not possible to precisely separate the influence of the different laws. Nevertheless, in cases of potential interference of these instruments the interviewees were always asked whether they attribute the reported changes to emissions trading or to other instruments. But even the interviewees could not always give a clear answer to such questions. In the analysis below, effects were only attributed to emissions trading if several companies had explicitly stated that the respective effect was undoubtedly caused by emissions trading. If the effects could not clearly be attributed to emissions trading, the ambiguity is explicitly stated.

4.2 Results of the first survey

4.2.1 Innovation strategies

To identify the impact of the introduction of emissions trading on innovation the companies were asked how they address innovation in general. A separate set of questions tackled their attitudes and strategies towards innovation.

Interestingly, only one third of the companies – mainly the larger ones – stated that they had something like an innovation strategy. They often had a specific department or staff unit which in most cases reports to the technical management board member. Their tasks comprise identification of new technologies relevant to the company, identification of (technical) optimization potentials within the companies or management of specific funds for innovation. However, the share of employees which deal with innovation in one way or another was around 1 % of all employees in each company or much smaller. The same applies to innovation related expenditures.[39] In all those companies that were able to quantify their expenditures on innovation in relation to the total turnover, the share of innovation expenditure was much lower than 1 % (see also section 2.3.3).

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[39] Such expenditures include expenditures for own staff, innovation funds, demonstration projects, subsidies to universities, etc.

In those companies which do not have a specific department for innovation, the task to implement innovative technologies within the company is often fulfilled on the management or the board level. Some made clear that they occasionally observe innovative activities on the market; others admitted that their decisions on innovation are often based on instinct. However, some of the smaller companies considered themselves as innovators since they applied only innovative technology, such as cogeneration, or since they were independent power producers which competed with large established companies. Others explained that they always applied the most advanced technology and considered this – even though they did not have a specific innovation department – as their contribution to the innovation process.

Basically, four different forms of innovation strategies in the electricity industry can be distinguished:[40]

1) **Joint research projects**: basic research, for instance on advanced materials and high pressure power plants, are often carried out in joint ventures with power plant manufacturers, technology providers and research institutes;
2) **Onsite development**: cooperation with technology or power plant providers, for instance in the first years after a plant is commissioned;
3) **Venture capital**: acquisition of small, innovative companies, often with a minority share, in order to get access to those companies' know how (patents);
4) **Search policies**: systematic identification of new technologies or process innovations within or outside the own company; such strategies include tenders for mitigation measures, seminars and workshops or cross-company benchmarking approaches.

Joint research projects

The larger companies were all involved in basic research projects which were carried out together with other utilities, plant manufacturers, technology providers and research institutes. A typical example of such an approach is the so-called reference power plant of North Rhine-Westphalia (Referenzkraftwerk NRW), a study on the economic and technical optimization of a future hard coal-fired power plant (VGB 2004). The results of this study provided the basis for the implementation of such a power plant, called COMTES700, which is currently under construction in the city of Scholven in the German federal state North Rhine-Westphalia (COMTES700, VGB 2007). In both projects several power producers, plant and technology manufacturers and research institutes are involved. Their contributions are coordinated by the association of large power plant operators (VGB PowerTech). Apart from coal technologies, such cross-company research projects typically address technologies like nuclear power or fuel cells. Most of the medium sized and smaller companies are not involved in such kind of projects. However, some of them made clear that they gain and generate knowledge about in-

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[40] For a more detailed description, see section 2.3.4.

novative technologies or processes through participation in and contributions to respective working groups of the electricity sector’s associations (e.g. VDEW, AGFW, VGB).

Onsite development

The second strategy is rather common in the German electricity industry. More than four fifths of the companies stated that they cooperated with technology providers either after the commissioning of a new power plant or on a continuous basis. Sometimes technology providers approach power plant operators with new technologies or concepts and offer these technologies or strategies to be tested on their sites under “real life conditions” free of charge. Due to teething problems of such technologies or strategies, plant operators face the risk of interruption in generation which result in reduced operation of their plant. Nevertheless, this strategy is attractive since it enables generators to achieve a technology advantage against their competitors.

Venture capital

The venture capital strategy is also very common, at least within the larger and medium sized companies of the German electricity industry. However, half of the companies (mainly smaller ones and some medium-sized companies) stated that they did not apply this strategy. But still for the larger and medium sized companies the venture capital strategy is not a cornerstone of their innovation strategies. Some stated that they follow this strategy more for image reasons than for promoting innovation within the company and admitted that they “burn” a lot of money with this strategy. In addition, it has to be taken into account that the acquired innovations not only address climate mitigation issues but also a wide range of issues from internet access through electricity cables or automated metering to fuel cells.

Search policies

Specific search strategies for innovations within and outside of the company were only established in one fifths of the companies. Systematic screening and cross-company benchmarking approaches had already been applied for some time. One company had carried out a tender for mitigation projects within the company to learn more about the internal CO_2 reduction potential. The tender was considered rather successful and revealed several new potentials within the company. Nevertheless, the majority of the companies did not apply such systematic search strategies for innovations.

Technology clusters

As regards individual technologies, more than half of the companies – mostly the smaller or middle-sized ones – considered cogeneration a technology with an important innovation potential. Slightly less than half of the companies mentioned the innovation potential of clean coal technologies including advanced power plants and CCS. However, since all the larger companies highlighted the potential of the clean coal technology cluster, this cluster might be considered even more important for the future electricity supply in Germany than cogeneration. While the clean coal and cogeneration clusters were considered interesting by several companies, other clusters, such as virtual power plants, fuel cells or renewable energy sources, are followed only by a few companies. However, each company has its individual profile. Some considered the potential of renewable energy sources very important whereas others focused on fuel cells or virtual power plants.

Some companies also explained that clean coal and cogeneration technologies would particularly gain from the introduction of emissions trading. However, other companies stated more generally that all technologies with comparatively small CO_2 emissions (renewables, decentral technologies, etc.) would profit from emissions trading. Others again made clear that their innovation strategy would not be influenced by emissions trading although most innovation activities would be useful by and large with regard to emissions trading as well.

Altogether, some 60% of the companies believed that emissions trading would not influence their own innovation activities. Only one company explained that emissions trading had already altered their innovation strategy. Some others stated that impacts would depend on the price of CO_2 allowances which was absolutely unknown before the start of the trading scheme and that the uncertainty about the CO_2 price resulted in waiting rather than in taking investment decisions.

Signaling effects

Econometric analysis of 2000 companies of the commercial and services sector in Germany by Gruber and Schleich (2003) reveals that carrying out an energy audit resulted in a reduction of energy consumption by some percentage points in those companies which had carried out such an audit. The energy consumption was reduced because the audits identified potentials which had been previously overlooked. If even a voluntary measure like an energy audit resulted in a statistically significant reduction of energy consumption, the same or even stronger reductions might be expected from the introduction of emissions trading as a mandatory measure. Emissions trading might induce signaling effects (Gagelmann, Frondel 2005) because companies become aware of their overall greenhouse gas emissions and their composition with the result that new abatement options are identified or already known options are considered in a different light.

Two fifths of the surveyed companies did not expect such signaling effects from emissions trading. Since utilities as supply side companies already focus on energy efficiency such potentials were considered well known but not economically efficient at the respective price levels. Signaling effects and reduction potentials can rather be identified in companies of the electricity demand side which do not value energy efficiency as highly. However, three fifths of the companies believed that such reduction potentials might be revealed through the introduction of emissions trading. Some stated that they had occasionally identified formerly unknown reduction potentials in the past. Others explained that the introduction of emissions trading would shift the focus towards the discovery of new reduction potentials. They, however, believed that the impact of such a signaling effect would be of minor importance since the electricity industry's energy costs account for a large share of the total cost. Correspondingly, the electricity industry already focuses on energy and cost savings.

The expectations regarding impacts on the innovation strategy of the electricity industry were generally quite dispersed. Some companies expected the same impacts for the industry as for their own company while others expected some influence on investment decision but no quantum leaps. Some assumed slightly increased attention on reduction potentials whereas other believed that emissions trading would not influence innovation strategies at all. Finally, some companies highlighted that the introduction of emissions trading would delay investment, and thus innovation, due to increased uncertainty at the beginning of the scheme.

Summary

As a result it can be concluded that only the larger electricity companies have an elaborated innovation strategy. Innovations are, nevertheless, incorporated through strong cooperation with technology providers and plant manufacturers. The larger utilities are all involved in joint research projects with these companies while the middle sized and smaller utilities participate in joint working groups of the respective business associations. Moreover, the utilities contribute to the electricity industry's innovation process by providing test site facilities and options for onsite development of advanced technologies. Some of the larger and middle sized companies also incorporate innovations into their business processes through acquiring pioneering start ups. However, none of the utilities considered this venture capital approach as central to achieving their innovation or their business goals.

While the larger companies attached the greatest importance to the clean coal technology cluster which includes inter alia supercritical coal-fired power plants and CCS, several smaller and middle sized utilities highlighted the innovation potential of combined heat and power. The majority believes that emissions trading will not substantially influence their innovation activities because they are already focusing on increasing energy efficiency. Moreover, some expect that the introduction of emissions trading might defer some investments until more practical experiences with the new instrument have been gained.

4.2.2 Institutional changes

After the European Council had passed the Emissions Trading Directive (2003/87/EC) in October 2003, Member States started to transpose the Directive. Some Member States, including Germany, realized that they were lacking the data they would need to allocate allowances according to historic emissions (grandfathering). Therefore, they contacted the operators of the covered installations as early as December 2003 (BMU 2003) and asked them to provide the data on a voluntary basis. At this point in time at the latest the operators of the covered installations in Germany were confronted with the new requirements of emissions trading. However, several companies had started the discussion on the internal consequences of the introduction of emissions trading much earlier. Some of them, mainly the larger ones, were already involved in the debate since the European Commission had published its green paper on emissions trading in March 2000 (COM(2000) 87). In late 2004, the introduction of emissions trading had correspondingly induced several institutional changes within the companies such as changes in organization and management.

Administration

Only in a few companies was the introduction of emissions trading the reason for a reorganization of their structures or for the creation of new positions. More than 80 % of the companies did not create new divisions or departments. The new tasks which emerged by dint of the introduction of emissions trading were rather addressed by specific task forces in which experts from different divisions of the company were gathered. Smaller companies stated that they did not establish such a task force since only one or two persons would be concerned with the new requirement of emissions trading.

In two thirds of the companies, generation or production would be one of the divisions most affected by emissions trading, closely followed by trading and fuel procurement. Two fifths of the companies also expected that resource planning and one third assumed that the environment division would be affected by emissions trading more strongly than other divisions. More than half of the companies also explained that they had not established other institutional changes in their organization nor were planning to do so. A quarter of the companies, however, stated that the responsibility for emissions trading was reorganized, some also explained that they had already created or were planning to create a new position for the coordination of all emissions trading related tasks.

Monitoring and reporting

One precondition for the allocation of allowances in 2005 was that companies provided certified data on their historic emissions by mid-September 2004 (TEHG; ZuG 2007). Not surprisingly, all companies stated that they had compiled detailed inventories of their historic and current emissions. However, only half of the companies had adapted or were planning to adapt their information technology infrastructure in such a way that all CO_2 emissions could be traced continuously. Also, only half of the companies had already established or were planning to establish a procedure which allows for regular comparison of their accumulated emissions with their allowances. Some of them were planning to carry out these comparisons on a daily basis while others wished to include these comparisons in their monthly reports of key performance figures of individual installations and the company as a whole.

Avoidance cost cures

The aim of emissions trading is to reduce the CO_2 emissions of the companies covered under the scheme. However, allowance trading allows them to decide whether it is more efficient to carry out reduction measures within the company or to purchase additional allowances from other companies. To address this question it would be necessary to have a clear picture of the cost and potential of internal reduction measures. By 2004, a third of the covered companies stated that they had compiled an avoidance cost curve in order to identify the most cost effective internal reduction measures and to compare them with the price of allowances. One of these companies went even further and carried out an internal tender in which all units of the company could offer certain amounts of EUA for the price they needed to finance these measures. The offers needed to be substantiated with a detailed project description and cost calculation on a standardized spreadsheet provided by the company's headquarters. Typically offered measures were turbine retrofit, fuel shift, etc. The company stated that they learned a lot about the internal reduction potential in this process even though no real trading was carried out in contrast to the earlier pilot cases of BP or Shell[41].

Emission scenarios

Except for the smaller companies with few power plants, most companies had developed emissions scenarios which enabled them to analyze the impact of emissions trading. In the larger companies, the scenarios also enabled modeling of the impact of different allocation rules (auctioning, grandfathering, benchmarking, etc.) and the impacts of the company's own strategies such as a fuel switch to less carbon intensive fuels. In medium sized and smaller companies, these scenarios were less elaborated and comprised sometimes only economic efficiency calculations which included different CO_2 prices or just some worst case calculations to determine the risks of emissions trading.

Trading floor

Before the start of trading almost 60 % of the companies, mainly the large and middle-sized ones, had already established or were planning to establish a trading floor for CO_2 allowances. In all cases CO_2 allowance trading was or was planned to be integrated in existing trading floors for electricity and other commodities. The largest companies also highlighted that the trading position of all their national or international business units would be consolidated at one trading floor so that all CO_2 allowances for the company would be traded at just one point. Smaller companies which usually do not have a trading floor were not planning to establish one solely for CO_2 allowance trading. Some stated that they would not trade much or that they would outsource trading to consultants or brokers; others wanted to decide at a later stage whether to establish a trading floor or not. It was also mainly the largest companies in the survey which had already established or were planning to establish a hedging strategy for CO_2 prices. In most cases the risk heading would be carried out together with risk heading for electricity trading. The middle sized and smaller companies did not establish such risk heading although some wanted to check whether such a strategy would be re-

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[41] In 2000, BP and Shell had introduced internal emissions trading schemes to reduce CO_2 and methane emissions by 10 % compared to 1990 levels. In Shell's voluntary scheme with 30 involved business units 4.5 million tons of CO_2e were traded. BP's scheme was mandatory; it covered 112 business units and resulted in a total of 7.2 million tons of CO_2e being traded (Philibert, Reinaud 2004: 16-17).

quired in the future. One of the smaller companies highlighted that CO_2 allowance trading was not considered a risk to the company since it received sufficient allowances to cover all emissions. Correspondingly, a risk heading strategy was not considered necessary.

Cooperation

Less than one fifth of the companies were planning to provide emissions trading related services to other companies, such as carrying out emissions trading for clients with a third party financing contract (contracting clients) or bundling of CO_2 with electricity contracts, remarking that demand for such services before the start of emissions trading was very small. In contrast, some of the companies were planning to engage other companies for such services themselves. In addition to independent certifiers, which all operators had to cooperate with in their application for allowance allocation, more than half of the companies – both smaller and larger ones – also planned to acquire support from external consultants for preparing for and carrying out emissions trading. A fifth to a quarter of the companies planned to engage software providers or brokers. Interestingly, the companies did not expect much support from plant manufacturers and technology providers such as Siemens, Alstom, etc. in their preparation for or realization of emissions trading. However, some of the municipal utilities highlighted that they would check options for organizing emissions trading jointly with other municipal utilities.

Summary

Overall the survey revealed that the status of institutional preparation shortly before the start of the EU ETS was quite varied amongst the individual companies. Effectively all companies had already fulfilled the fundamental requirements such as compiling a certified emissions inventory, establishing a secure internet connection with the German Emissions Trading Authority (DEHSt) or preparing the submission of the application for being allocated allowances. However, many of the smaller companies did not carry out much further preparation for the new instrument. On the one hand, they did not have further financial and personal resources for such an undertaking. Since several of them expected to be allocated sufficient allowances, they do not, on the other hand, consider emissions trading to be a major risk for their business. For the larger and some of the middle-sized companies the situation is quite different. Virtually all of such companies had established a task force for coordinating the preparation to the EU ETS. They consider emissions trading to be a new challenge with opportunities and risks and have put a lot effort into developing simulation models, scenarios, calculating avoidance costs, appropriate risk hedging and preparing their existing trading floors to include CO_2 in their trading routines. Despite the stated differences between smaller and larger companies, all companies seemed to be sufficiently prepared for the challenges of the new instrument if the available resources and the risks faced are taken into account.

4.2.3 Operation of power plants

With the start of emissions trading in January 2005, a price for CO_2 was introduced in Europe. Correspondingly, CO_2 had to be regarded as an additional input factor in electricity generation from fossil fuels. Depending on the price of CO_2, the merit order of the power plants might change substantially (section 5.1).

Merit order

However, before the start of the trading scheme in 2004, only about two fifths of the surveyed companies really expected a change in their merit order. Some expected that the operational hours of gas powered plant might increase whereas other companies highlighted that the price of CO_2 is just one (additional) factor determining the short-term operation decisions. Therefore, they expected only small shifts between the different fuels due to the introduction of emissions trading.

One third of the companies did not expect a change in their merit order because they depend on just one fuel or because they are smaller utilities with just one power plant in their generation portfolio. However, if switching off a power plant and purchasing electricity from competitors instead is considered an option of the merit order, some of the smaller companies expected changes, too. Particularly if CO_2 prices increase substantially while electricity tariffs do not sufficiently reflect this trend, the switching off of one's own power plants might result in being the most attractive alternative.

Several companies explained that before the start of EU ETS it was difficult to estimate whether their merit order would change and if so into which direction it might be changed. They assumed that it would be easier to answer this question in two years time.

Fuel shift

Apart from changing the merit order of their own generation portfolio, power plant operators might also change the fuel input to individual power plants to reduce CO_2 emissions. Bivalent power plants basically allow, for example, for switching from oil to gas. For coal and lignite power plants, shifting to less carbon intensive coal or lignite qualities or co-firing of substitute fuels, such as sludge, carcass meal or waste wood can also be considered. Co-firing of biomass (wood chips, etc.) – at least partly – might be another option for operators of coal and lignite power plants to reduce CO_2 emissions without investing in alterations of the plant configuration.

Regarding the shift to less carbon intensive coal qualities, only a few of the companies considered this option. They argued that the availability of such qualities might be difficult and that the advantage of such qualities might be levelized by their higher prices. Most of the other companies could not apply this option either because they were already using the least carbon intensive fuel available or because they have only oil or gas fired power plants in their generation portfolio.

Only a few of the surveyed companies have bivalent power plants which enable an easy shift from one fuel to another. Most of these plants can be fuelled with oil or gas. Gas is about 25% (DEHSt 2004) less carbon intensive then oil. Correspondingly, a shift from oil to gas might be an attractive option for reducing CO_2 emissions without additional investment. However, most of the companies that have such bivalent power plants already predominantly use gas. Oil is often only used to cut off the expensive capacity peaks of the gas supply or as a backup fuel for cases of interrupted gas supply. Therefore, the share of oil in such power plants is as low as 1 or 2%. If it exists at all, the potential of this option is correspondingly small.

Co-firing of substitute fuels in coal and lignite power plants was, by contrast, considered an interesting option which had already been applied by several operators before the start of emissions trading. A third of the companies stated that they were checking options to intensify the use of such substitute fuels, but also mentioned that the potential of this option might be restricted through the availability of these fuels. Some also assessed a complete fuel shift from coal or lignite to biomass. This, however, would not be possible without additional investment.

With regard to the question of which of the above mentioned measures might be triggered by emissions trading, most companies assumed that emissions trading would not change the operation of power plants substantially since the electricity industry was already continuously focused on efficiency improvements. They expected that emissions trading would introduce a price for CO_2 which had to be taken into account as an additional factor, beside others, for deciding whether to run a power plant or not. Some companies also highlighted that particularly substitute fuels and biomass might become more attractive through emissions trading. Several companies also stated that they were reexamining all projects in their files in the light of emissions trading and expected that emissions trading would have more impact on long-term investment projects than on the short-term operation of power plants.

4.2.4 Investment strategies

"EU Emissions Trading – An Open Scheme Promoting Global Innovation to Combat Climate Change" is the title of a brochure which the European Commission published shortly before the start of the trading scheme (DG ENV 2004). Undeniably, innovation is one of the major goals or even the key goal of the trading scheme. In the medium- and long-term this goal requires investment in efficiency improvements and new generation capacities in the electricity industry. Therefore, the effects which operators expect emissions trading will have on their investment strategies are important.

Portfolio

The surveyed companies planned several changes in their power plant portfolio. The larger power producers highlighted that they had to renew up to a quarter of their power plants until 2020. Some explained that they were planning investments in hard coal or lignite power plants or in CCGT plants. Some also assessed whether they should make use of the transfer rule (see section 3.3.2.4). Others made clear that they were planning to close down power plants while increasing generation in existing plants. Some also stated that they were planning to invest in renewable technologies or cogeneration. In general, there was no clear picture with regard to investment strategies or generation technologies; instead there was a sense of disorientation before the start of the trading scheme. Correspondingly, some of the companies also made clear that they had discussed various investment options but were planning to take decisions only in 2005. Moreover, most companies underlined that their investment plans and strategies had not been influenced by emissions trading to date. Investments in renewable technologies, cogeneration or CCGT plants were rather induced by the EEG and the KWKG.

Efficiency

Regarding efficiency improvements, the situation was quite similar. The companies specified a lot of measures which they were planning in their power plants, such as the topping of a gas turbine, turbine retrofit, optimization of steam generation, increasing steam temperature, reduction of own electricity use through the introduction of regulated instead of curbed pumps, improved sprinkling devices in the cooling tower or shortened maintenance intervals in combined cycle power plants. Some also planned improvements in their district heating net which would allow them to make a fuel switch as well. One of the larger companies described that all these potential measures were gathered and coordinated in their so-called “CO_2 bureau”. Some of the smaller companies explained that improvements were not economically efficient either because their plants were too old or because they were rather new and did not therefore have much of an improvement potential. Moreover, nearly all companies emphasized that efficiency improvements were part of their daily business anyway and that most of these measures were not induced by emissions trading. However, some admitted that these measures might become more attractive through emissions trading and that they might become more important in the second trading period or if a substantial share of allowances are auctioned after 2012.

Replacement

Only one quarter of the companies saw no need for power plant replacement within the next 10 years. Correspondingly, three quarters expected that they had to replace at least a share of the power plants. Nevertheless, some of the companies did not expect that their investment decisions would coincide with those of other operators. However, the majority of the surveyed companies were aware of the problem and expected that the individual investment decisions of the different players in the market would result in a new investment cycle within the next ten years. They supported their position by pointing to the phasing out of nuclear energy until 2022 and by the fact that – particularly in West Germany – virtually no new power plants have been commissioned since 1989. One company explained that the technology providers and power plant manufacturers had already identified the corresponding demand pressure and that they were going to react with price increases.

Project based Kyoto mechanisms

Irrespective of investments in efficiency improvements or new power plants, operators might also invest in reduction projects within the JI or CDM framework. In addition to the generation of carbon credits, such projects might be used to get access to new markets or new business fields. However, almost three fifths of the companies had not examined this option in greater detail, sometimes because they assumed that they would be provided with sufficient allowances. The remaining companies, particularly the larger ones, had investigated the potentials of JI and CDM in more detail. Some were already engaged in various JI or CDM projects. Nevertheless, all companies explained that these project based flexible Kyoto mechanisms would play at best only a minor role in their compliance strategies. Some pointed to the high transaction costs of these projects due to unclear framework conditions in the host countries and to exchange rate risks. Carbon credits of such projects tended to be considered side effects of projects which were initiated for other reasons. Other companies made clear that they preferred investments in carbon funds such as the Prototype Carbon Fund (PCF)[42] of the World Bank or the so-called “Klimaschutzfonds”[43] (climate protection fund) of the German KfW bank to direct project investments.

Fuel mix

When asked about their expectations in terms of the impact of emissions trading impact on the competitiveness of the different electricity generation technologies and fuels in the electricity industry as a whole, about half of the companies assumed that emissions trading would generally improve the competitiveness of natural gas. However, some companies were concerned about the availability of natural gas and expected that a price increase of natural gas might cancel out the advantage. Others assumed that hard coal would still remain attractive. Individual companies expected that other technologies emitting less CO_2, such as nuclear power, biomass or other renewable plants as well as CCS would increase in attractiveness. However, about two fifths of the companies thought that emissions trading would have little impact on the competitive position of individual generation technologies, at least as long as the allowance price did not exceed a not yet known threshold.

Even though three quarters of the companies would need to replace some of their generation capacities within the next ten years, all were reluctant about taking decisions before the start of the EU ETS. Instead, they delayed their decisions until first experiences with the new instrument had been gathered. In this sense, the introduction of emissions trading clearly contributed to a postponement of investment and innovation.

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[42] http://carbonfinance.org/Router.cfm?Page=PCF&FID=9707&ItemID=9707

[43] http://www.kfw-foerderbank.de/DE_Home/Klimaschutzfonds/index.jsp

However, this effect should be attributed to the introduction of emissions trading rather than the instrument emissions trading as such.

4.2.5 Design options

Alongside the question of whether emissions trading induces innovation in the electricity industry or not, the question of which particular design options of emissions trading foster or hinder innovation was addressed in the survey. The overall cap, the allocation method, rules for dealing with closures, new entrants and transfer of allowances between old and new installations as well as banking and several specific rules were already identified as being important in terms of innovation effects (chapter 3). In the first survey, which was carried out before trading started, the companies had expressed their views on which design options were especially relevant to them and which design options would be more important for innovation in the electricity industry than others.

Company perspective

Almost two thirds of the companies considered the method of allocation very important to them and half of the companies judged both the overall cap and special rules, for example for cogeneration or process related emissions, crucial for their company. Not surprisingly, the cogeneration rule was particularly often mentioned by several smaller companies which have cogeneration plants in their generation portfolio. The rules for closures or new entrants as well as banking and borrowing were, on the contrary, only mentioned by very few companies.

With regard to the question of which design options trigger innovation effects in their companies, almost half of the companies answered that emissions trading would not induce any innovations, for example because investment decisions for the next ten years had already been taken long before emissions trading had begun or because their room for maneuver is limited due to restrictions of their heat supply obligations. However, slightly more than half of the companies identified one or more rules important to innovation in their company. The rule for transferring allowances from old to newly built installations was mentioned most often in this regard (two fifths), followed by rules for new entrants (one fifth) and allocation rules for cogeneration. One company also considered rules on closures and a long-term stability of the allocation for 14 plus 4 years as crucial.

Industry perspective

Asked which of the design options would trigger innovation in the electricity industry as a whole, half of the companies stated that the overall cap would have a major impact on innovation. If the cap is strong, allowances would be scarce and their price high which would induce more innovations than a low allowance price. Regarding the other design options the situation is quite diffuse: one fifth of the companies highlighted the importance of the transfer rule in terms of innovation while only a few companies considered rules for new entrants, the allocation method or the long-term stability of the allocation important to innovation in the electricity industry. Furthermore, some companies believed that particularly the specific rules would hinder innovation effects or that emissions trading would not trigger innovation at all.

Finally, the companies were asked how emissions trading should be designed to foster innovations. Interestingly, the companies had very few ideas concerning an innovation friendly design for emissions trading unless they were provided with some examples. Three fifths of the companies, independently of their size, estimated that a stronger allowance cap would improve the innovation effects of emissions trading. More than half of the companies considered the allocation method to be rather important to innovation whilst the large majority of companies preferred fuel specific or general benchmarks to auctioning since the latter would increase the financial burden of the companies. A third of the companies also assessed the elimination of specific allocation rules, such as for cogeneration or process related emissions, essential in terms of innovation effects of emissions trading since it would increase the overall transparency of the scheme. One company also underlined the need for an EU-wide harmonized allocation approach to eliminate distortions between Member States.

Summary

Before the start of the EU ETS, the majority of the surveyed companies recognized the importance of individual design options such as the overall cap, the methods of allowance allocation or specific rules for the use of combined heat and power for their own companies. However, the understanding of the different design option’s impact on innovation in the electricity industry as a whole was rather limited. On the contrary, most companies believed that emissions trading does not induce innovation at all since investment decisions were taken before the start of the trading scheme or because their room for maneuver is rather limited due to heat supply requirements. The companies did not attach much importance to the particular innovation impact of specific rules for new entrants or closures, as identified in chapter 3. It remains to be seen whether the companies’ attitudes will change after first experiences with the new instrument emissions trading have been gathered.

4.2.6 Conclusions

Innovation strategy

Although elaborated innovation strategies are rather rare in German utilities, they contribute substantially to the innovation process in the electricity industry as a whole. They participate in joint research projects with plant manufacturers, provide test facilities and invest in new, advanced technologies so that those technologies can enter and finally penetrate the market. In addition to this cooperation in the innovation process which has already been practiced for a long while, the introduction of emissions trading generated new requirements for institutional innovations within the companies.

Institutional changes

Although the level of institutional changes varied substantially between larger and smaller utilities, most companies seemed to be sufficiently prepared before the start of the trading scheme. While the larger firms had already established advanced tools for managing emissions trading such as continuous emission controls, integrated electricity and CO_2 trading floors or CO_2 price risk hedging strategies, such tools could hardly be found at smaller companies. The latter established only the minimal requirements like developing certified emission inventories and submitting the application for being allocated with allowances to the German emissions trading authority (DEHSt). However, due to the generous allocation in the first period they considered their risks and their potential revenues from selling allowances to be too small to justify establishing more advanced tools.

Signaling effect

Most companies expected that emissions trading would just add the CO_2 price as another factor to their operation and investment decisions but would not change their business fundamentally. Since fuel costs traditionally depict a large share of the utilities' overall cost function, they were already fairly focused on efficiency. They expected that the price for CO_2 would intensify this focus further but would not change the incentive structure fundamentally. Correspondingly, the companies expected that the introduction of emissions trading would tend to trigger the discovery of unknown abatement potentials (signaling effect) in industrial sectors rather than in the electricity sector.

Operational changes

Most companies, nevertheless, expected some changes in the merit order although they did not have a clear picture of how the merit order might change because it was unclear how the introduction of a price for CO_2 would actually affect electricity and fuel prices. However, several companies highlighted that particularly substitute fuels and biomass might gain attractiveness through the introduction of emissions trading to a certain extent.

Investment strategy

As for the operation of power plants, the CO_2 price was merely regarded as an additional influencing factor in a set of several parameters which are taken into account for decisions on investment in new power plants or efficiency improvements. Some firms did not expect that this single factor would change their investment decisions substantially. Several companies stated, however, that they were scrutinizing all projects in their files in the light of emissions trading and that final decisions will be postponed until first experiences with the new instrument have been gained.

Timing of innovations

Therefore, the innovation effects before the start of the EU Emissions Trading Scheme can be divided into two sorts of dimensions: before the start of the emissions trading mainly "soft" institutional innovations which did not require large investment decisions were commissioned. The companies established regular task force meetings, calculated avoidance cost curves, sketched scenarios and adapted their trading floors and risks hedging strategies. In addition, the ways in which the merit order might change and to what extent the use of substitute fuels or biomass might be increased were scrutinized. However, "hard" innovations which involved larger investment decisions were actually postponed for at least one or two years. Investment plans for new power plants or larger efficiency improvements were reinvestigated under the new conditions of the upcoming emissions trading scheme. The final decisions were, however, delayed until a clearer picture of emissions trading's impact on the prices for power, fuels and CO_2 had become available. In this respect, the introduction of emissions trading had ambiguous innovation effects: it fostered "soft" institutional innovations but tended to contribute to a delay of "hard" technical innovation.

4.3 Results of the second survey

The second semi-structured survey was conducted in summer 2007, about three years after the first survey and two and a half years after the EU ETS had begun in 2005.

4.3.1 Innovation strategies

The first survey had revealed that detailed innovation strategies are rather rare in the German electricity industry. Although the share of companies which have some kind of innovation strategy has slightly increased since then, half of the companies still do not engage in systematic treatment of innovation. The existence of such innovation strategies is strongly correlated to the size of the companies: while the great majority of the larger utilities state that they have such strategies, only a few of the smaller companies place a specific focus on innovation. Clearly smaller companies have fewer financial and personal resources available to develop such strategies and apparently do not consider such strategies as essential to achieving their business goals.

Forms of innovation

Despite the lack of elaborate innovation strategies almost all companies incorporate innovations in some way into their business processes. The situation with regard to the forms of innovation strategies, which were already identified and described in section 2.3.4, is basically quite similar to the one arising from the first survey. However, some differences between the first and the second survey can be identified.

- Predominantly the larger utilities are involved in **joint research projects** together with power plant manufacturers, technology providers and research institutes. Only a few of the middle sized and none of the smaller companies are involved in such projects. However, a quarter of the companies explained that they contribute to the electricity industry's innovation process through participation in joint working groups on new technologies and standards of the respective business associations.

- About two thirds of the firms also enabled technology providers and power plant manufacturers to test and further develop new and innovative technologies on their sites (**onsite development**). This share is slightly lower than in the first survey. However, such cooperation can be found in all kind of utilities independent of their size.
- While in the first survey half of the firms stated that they have a **venture capital** fund aimed at acquiring knowledge from innovative start up companies, this share had substantially decreased to just a fifth of the firms in the second survey. Several companies explained that they have ceased using this approach and even some of those companies which still have funds available to this end stated that the importance attached to acquiring knowledge from innovative start up companies has considerably decreased since the last survey. The venture capital approach had gained much attention in the last boom of the computer industry around the year 2000 ("dot.com hype"). In the follow up this approach had transferred to other sectors. Several of the companies in the electricity sector adopted this strategy as well but had apparently also realized since the last survey that this approach contributed less to the companies innovation process than they was originally expected.
- Only a fifth of the companies stated in the first survey that they identify innovations through systematic **search policies** within their company. In the second survey the share of companies which applied this strategy was slightly higher at one third. Most of these companies regularly organize workshops with those employees involved in issues relevant to innovation. Some also develop detailed innovation plans in which the different innovation options are assessed and prioritized. In those companies which do not have such a systematic search approach, the identification of innovation options happens more diffusely so that most of the potential options are identified by chance.

Technology clusters

The focus on technology clusters which are considered to have a large innovation potential has considerably changed since the first survey. Except for the very small companies, virtually all companies highlight the innovation potential of clean coal technologies such as integrated gasification combined cycle (IGCC) plants or **CCS**. The attention paid to this technology cluster has substantially increased through the introduction of emissions trading.

The attention given to renewable energy sources has also increased. In the first survey only a few companies intended to increase their activities in this innovation cluster. In the second survey four fifths of the companies mentioned the important innovation potentials of renewables. However, some companies stated that increased attractiveness had been more induced by the **EEG** than by emissions trading.

As in the first survey, mainly the smaller and middle-sized companies but also some of the larger utilities with a high share of cogeneration plants expected further innovations in the **cogeneration cluster**. Virtual power plants and decentralized supply structures have also been given more attention since the first survey while fewer companies expect innovative progress in the cluster of hydrogen and fuel cells. In addition to those clusters, several companies mentioned the increased importance of compressed air energy storage (CAES) and pumped storage power stations.

Apparently the introduction of emissions trading has already altered the focus of innovation activities of several companies. This is also directly confirmed by half of the surveyed companies, mainly the larger ones. A third of those affirmed the higher importance of the clean coal technologies, particularly CCS, and a quarter pointed to the increased attention towards renewable energies due to emissions trading. The majority of the smaller and middle-sized firms, however, did not realize any changes in their innovation activities due to the introduction of emissions trading. For the future, only a quarter of all companies expect that emissions trading will have no impact on their innovation strategies. A third of the companies assume that emissions trading will affect all innovation clusters and another third believe that particularly CCS will receive much more attention by dint of emissions trading. A quarter of the firms, finally, presume that their innovation activities in the cogeneration and renewable energy clusters will be affected by emissions trading in the future.

The expectation of change induced by emissions trading in the innovation strategy of the electricity industry as a whole correlates more or less with the expectations they have for their own companies. Almost all companies expect that emissions trading will have an influence in this respect in the future. CCS, cogeneration and renewable energies are expected to be the innovation clusters which benefit most from the introduction of emissions trading.

Signaling effects

While in the 2004 survey only two fifths of the companies did not expect a signaling effect to come about on the basis of the introduction of emissions trading (see section 4.2.1), practically all companies stated that emissions trading had not had any such impact in the 2007 survey. Several emphasized that the incentives for efficiency improvements tended to already be strong before the EU ETS began. Most of the greenhouse gas reduction potentials were well known in the past but were not economically viable. In the course of experiencing emissions trading for almost two and a half years, the companies had apparently not identified undiscovered abatement opportunities so that they had to revise their earlier expectations towards the signaling effect. For the electricity industry a signaling effect of emissions trading can therefore not be confirmed. However, several companies guessed that emissions trading might have triggered a signaling effect in those industrial sectors in which the incentives for energy efficiency are less pronounced than in the electricity industry.

Summary

It can be concluded that the introduction of emissions trading did not alter the companies' general approach towards innovation. Some of the differences which have been identified between the first and the second survey (such as the substantially decreased importance of the venture capital approach) cannot be attributed to the introduction of emissions trading but are rather caused by changes in preferences or trends and fashions. However, the introduction of emissions trading has significantly changed the focus within the respective innovation strategies. Innovations in the CCS, renewable energies and demand side efficiency clusters receive much more attention from the companies while the attractiveness of the cogeneration cluster is still considered to be strong.

4.3.2 Institutional changes

In 2004, a few months before the EU ETS came into force, all companies had already effectively implemented a number of institutional changes. The changes in larger utilities were, however, more essential then those in smaller companies. Therefore, it can be expected that only a few additional institutional changes have been implemented since then. This is basically true but, nevertheless, some additional changes deserve to be highlighted.

Administration

As in 2004, only very few companies stated that they had established an additional department for the administration of emissions trading. The large majority of the firms surveyed had integrated the new tasks into departments that already existed. In the larger companies, the personal resources of the affected departments were usually increased, although only slightly. In the smaller and most of the middle sized companies, the additional tasks now have to be accomplished by the already existing personnel.

Flexible mechanisms

The only exception to this rule was the establishment of specific departments for project based Kyoto mechanisms in most of the larger utilities. These departments aim at identifying and developing attractive CDM or JI projects and/or acquiring low-cost emissions credits from the mechanisms. Such departments may comprise up to 20 employees and have a budget of up to € 150 million at their disposal. In 2004 these companies had giveb CDM and JI much less attention. This can, on the one hand, be explained by the fact that the international market for project based mechanisms was certainly less developed in those days (Schneider 2007). On the other hand, the attractiveness of those mechanisms had considerably increased since the CO_2 future prices for the second commitment period remained constantly above the threshold of € 20 per EUA. In this light and despite the basically higher risks, credits from project based mechanisms seemed considerably more attractive to the companies than in 2007 than in 2004.

Task force

Three quarters of the companies had launched a task force in which experts from different departments were brought together to coordinate the new administrative and strategic task generated by the introduction of emissions trading. In all companies which had already launched such a task force before the start of the trading scheme, the task force continued to exist in 2007. But since several of the new tasks caused by the introduction of emissions trading were already integrated into the regular business routines in 2007, the frequency of task force meetings was much smaller in most companies in 2007 than in 2004.

Emission scenarios

The share of companies which had developed emissions scenarios was already quite high in 2004 but has further increased to more than four fifths of the companies in 2007. However, CO_2 avoidance cost curves, in which the internally available options for CO_2 abatement are plotted according to their potential and their projected costs, were still being compiled in a minority of the companies. However, the share has slightly increased from roughly one third to more than two fifths.

Emission reporting

The share of companies which register their emissions data electronically has slightly increased since the first survey. In 2007, almost two thirds of the companies had installed devices to record fuel inputs continuously or established routines to manually enter the data in a timely manner. Only a quarter of the companies – predominantly the smaller ones – record their emission data on a monthly basis only. All other companies record emissions data either continuously or on a daily basis. However, only a few of those companies compile reports on that data to the management on a daily basis. The majority of firms compile the emissions reports on monthly bases, and a few of them do this on a quarterly basis only.

Market analysis

All companies, independently of whether they are small or large, have one office where the data of all emitting units controlled by the respective company are collected so that short or long positions in the carbon market can be basically identified. While in the 2004 survey only half of the firms stated that they have installed a tool which enables them to regularly compare their current emissions with their emission allowances, all companies had established such a tool in 2007. In the larger utilities this comparison is carried out in real time or on a daily basis whereas the smaller and middle-sized utilities execute such comparisons on a monthly basis only.

Information technology

Predominantly the larger and middle-sized companies have also adapted their business software to the new requirements under the EU Emissions Trading Scheme. In most of the cases these software upgrades included the extension of the metering tools, the integration of CO_2 prices into the dispatch tool and the trading software or a graphical representation of the current CO_2 market position. The smaller utilities and some of the middle-sized ones instead developed company specific software tools on the basis of standard software such as Excel to comply with the new requirements of the EU ETS.

Trading

More than half of the companies – again the larger and middle-sized ones – integrated CO_2 trading into already existing trading floors for electricity and other commodities. Some of the smaller companies stated that they had organized their trades on their own without an advanced trading floor or that they traded only once a year. Others made clear that they had gained market access through services which are provided by some of the larger utilities. Despite market access, some of the larger firms also offer portfolio management or emissions trading related consulting services to other companies. However, apart from for CO_2 market access these services were rarely used by other companies so that CO_2 market interface services were effectively the only kind of emissions trading related cooperation taking place between companies in the electricity industry.

Risk hedging

In the 2004 survey, less than two fifths of the companies explained that they had already established a hedging strategy for CO_2 price related risks or were planning to do so in the near future. In 2007, more than half of the companies had now established such a strategy and another 15 % were planning to start risk hedging so that more than two thirds of the companies will apply specific tools to hedge CO_2 price risks. The remaining companies are all small companies which – thanks to a generous allocation of allowances – consider their CO_2 related risk so small that it can be neglected.

The larger companies which intensified their efforts in project based mechanisms have also started to develop tools for analyzing the specific risks of these instruments. With publically available data on the performance of individual projects in the registration process and from the difference between planned and actually issued credits the risk of specific country, project developers or project categories can be identified. The results of these risk assessments are integrated into the overall risk hedging strategy and are simultaneously used for deciding whether to develop their own CDM or JI projects or not and, if so, which category should be preferred.

Summary

The above analysis confirms that – as stated at the beginning of this section – the majority of institutional changes and innovations had already been established before the trading scheme began in 2005. Since then, mainly smaller institutional changes have been undertaken. Nevertheless, some of the changes are more fundamental such as the establishment of specific departments for project based mechanisms. In 2004, the mechanisms were on the one hand not yet sufficiently developed to be considered an attractive and reliable alternative to internal abatement measures or to the trading of allowances within the EU. In 2007, the attractiveness of these mechanisms has, on the other hand, considerably increased since the allowance futures for the second commitment period stayed more or less continuously above the threshold of € 20 per EUA. Therefore, particularly the larger companies assigned substantially more effort to the project based mechanisms in 2007 than in 2004.

Furthermore, since 2004 the companies have integrated most of the emissions trading related administrative tasks into their normal business routines. The share of companies which record their emission data in some way electronically has slightly increased and virtually all companies have now established a tool which enables them to compare their current emissions with the allowances they have at their disposal. A final institutional change worthy of highlighting is the increased share of companies which have elaborated or are planning to develop a risk hedging strategy. The first experiences gained with the new instrument and the expected further development of the emissions trading scheme has clearly increased the importance of such strategies. In 2007, only the smallest companies did not apply any risk hedging because they consider the risks they face – thanks to a generous allocation of allowances – as relatively small.

4.3.3 Operation of power plants

When the EU ETS came into force in January 2005 a price for CO_2 was introduced which the utilities had to take into account as an additional cost factor in their decisions as to whether to operate a fossil power plant or not. From the start of the scheme until mid-2005 the CO_2 price rose continuously and unexpectedly to almost € 30 per EUA; it then dropped slightly to values between € 25 and € 20 per EUA before it peaked in April 2006 at € 31.50 per EUA. After the publication of the first verified data in April 2006 it became obvious that too many allowances had been allocated. The publication of the emission data caused a sharp drop of the price to values of € 10 per EUA and a further decline thereafter. Since mid-2007, the price for an EUA stayed continuously below € 1 per EUA (Figure 11, p. 156). In 2005, the trade weighted average exceeded € 20 per EUA. In 2006 it was – despite the sharp decline in April – only slightly lower at € 17 per EUA (EEX 2007). In 2007, however, the trade weighted averaged fell well below € 1.50 per EUA so that the impact on the merit order was certainly rather small. Nevertheless, the average prices in 2005 and 2006 exceeded levels which might have caused some changes in the merit order.

Two fifths of the companies, though, reported that their merit order has not changed since 2004. This was mainly because these companies had predominantly must-run cogeneration plants or only plants with the same fuel in their portfolio or just one plant and thus no real merit order. The share of companies which reported no change is identical with the share of companies which expected in 2004 that their merit order will not change. Clearly, the companies already had a clear picture in 2004 of whether their operation of power plants will be affected by the introduction of emissions trading or not.

Fuel shift

Those companies which confirmed changes in the merit order reported different experiences. Some had initially observed a shift from coal to natural gas. However, due to steeply increasing natural gas and decreasing CO_2 prices this trend was later reversed. Others reported a shift from lignite to hard coal plants, particularly when the CO_2 prices were above the level of € 25 per EUA. Several companies also explained that they had shifted generation from older to new plants and that some of the hard coal plants which were usually operated throughout weekends were now shut down on Fridays and only started up again on Mondays. Under the emissions trading regime several coal powered plants have therefore substantially more startups per year than before. One of the smaller companies with mainly gas fired cogeneration plants also reported that it had increased its electricity generation thanks to increased electricity prices.

Biomass

The share of companies which consider intensifying the use of biomass or substitute fuels in bivalent power plants has considerably increased. While in 2004 only about a third of the companies took this option into account, almost two thirds of the companies regard this option rather attractive in 2007. Several also reported that the co-firing of substitute fuels has already remarkably increased since 2004 and is likely to increase further due to emissions trading. Most of the companies that stated that this was not case, explaining that their installations held no permit for co-firing substituted fuels or that the use of substitute fuels or biomass was technically not feasible without larger changes in the design of the installation.

Future changes

The expectations with regard to changes of the merit order in the future are rather similar to those held in 2004. A third of the companies still did not expect any changes in the merit order for the above mentioned reasons. Those which assumed changes in the merit order explained that the changes mainly depended on the development of the CO_2 price and on the coal-gas spread. Several expected larger shifts from coal to gas if the CO_2 price constantly exceeded the threshold of € 25 or € 30 per EUA. Some companies also guessed that the load factors of all technologies with low or no CO_2 emissions such as nuclear, hydro or biomass will be further increased in the future.

Price expectations

In 2004, the companies had expected on average a CO_2 price between € 11 and € 15 per EUA[44] for the first trading period and between € 19 and € 21 per EUA for the period from 2008 to 2012. In 2007, the companies anticipated an allowance price between € 20 and € 25 per EUA for 2010, a price between € 21 and € 30 per EUA for 2020 and a price between € 28 and € 40 per EUA for 2050. However, while for 2010 more than four fifths of the companies are prepared to give a price estimate, less than a third are willing to do so for 2050.

The 2004 estimates for the first period are – despite the high volatility of the allowance price in the first period – fairly congruent with the market outcome of € 12 to € 13 per EUA (weighted average, EEX 2007). It remains to be seen whether this is a pure coincidence or whether the companies develop a rather realistic price estimate on average. The price estimate for 2010 was slightly increased from € 19/21 per EUA in 2004 to € 20/25 per EUA in 2007. This reflects by and large the price range for EUA futures for 2008 to 2012 during the period from May to July 2007 (Figure 11, p. 156) at the time when the interviews where carried out. The companies' price expectations are apparently influenced by the prices for allowance futures and vice versa. Compared to the 2004 estimates, the estimates had to be increased in 2007 after the European Commission's decision in early 2007 made clear that the second period's allowances market will be significantly scarcer than the first period's market.

Summary

Two and a half years of experience with emissions trading illustrate that the scheme is basically working as intended. Power plant operators integrated the CO_2 prices into their operation decisions and shifted load from coal to biomass, substitute fuels and natural gas, from lignite to hard coal or from older to new plants in times when CO_2 prices where high. Quite naturally, these load shifts were reversed again when the CO_2 price dropped later to levels close to zero. Due to a rather generous allocation of allowances the spot market did not generate a sufficiently stable CO_2 price signal, which would have encouraged investments in new generation capacities and thus innovation. However, the companies' price expectations in 2007 for the second trading period are in a price range where both more substantial shifts in the merit order and a higher propensity to invest can be expected in the future.

4.3.4 Investment strategies

In 2004, many firms already had mentioned that the CO_2 price is just one factor among several which determine investment decisions. In the 2007 survey the companies were therefore explicitly asked to select and prioritize the five most important investment

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[44] Arithmetic average of the lower and upper bounds of the price estimates.

decisions influencing factors out of a set of 11.[45] The expected fuel price was the most important factor. It received almost a quarter of all priority points (24%). The second most important factor was the expected electricity price (18%) followed by the expected CO_2 price (15%) and the expected investment costs (13%).[46] Out of the remaining factors – which all received less than 10% of the priority points – the companies devote more attention to only national legislation (8%) and fuel diversification (7%) in their investment decisions.

Apparently the expected CO_2 price is an important influencing factor in the companies' investment decisions. However, it is only the third most important factor. The expected fuel and electricity prices clearly have more impact on investment decisions than the expected price of CO_2. One reason for this priority is that the costs for hard coal and natural gas are still much higher than the costs of CO_2 allowances. At current fuel prices of some € 2.5 per GJ for hard coal and some € 8 per GJ for natural gas, the allowance price would have to increase to € 27 per EUA or to more than € 140 per EUA, respectively, to cause the same costs to generate 1 MWh as the cost of the fuel input. However, since the companies expect such price levels only in 2020 or much later it is consistent that they consider the fuel prices as the most sensitive factor in the investment decision. Nevertheless, the CO_2 price is not irrelevant and is considered on average to be more important than the core investment costs or other factors like national legislation and fuel diversification.

Regarding the impact of emissions trading on investment strategies it can be concluded that the CO_2 price is – despite its low level at the end of the pilot period – already the third most sensitive factor in the companies' investment decisions. With higher CO_2 prices in the future it might become an even more important influencing factor.

Power plant investments

One third of the companies, mainly the smaller ones and some of the middle-sized, explained that they will not invest in new generation technology until 2020. This is roughly the same share as in the 2004 survey. Most of the remaining companies had detailed plans for future investments. In 2007, all known investment plans amounted to 35 GW of new generation capacities up to 2016. For another 5 GW, commission dates have not yet been determined (bdew 2007). The public debate on power plant investments substantially intensified between 2004 and 2007. The hesitant attitude towards power plant investments, which prevailed among the utilities before the start of emissions trading in 2004, has largely disappeared. Several investment decisions have thus already been taken. However, several decisions are still pending. They will presumably

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[45] The following factors were provided: fuel diversification, expected investment costs, expected electricity demand, expected fuel price, expected CO_2 price, expected electricity price, international climate regime, national legislation, technological diversification, security of supply and other.

[46] Laurikka and Koljonen (2006: 153) report similar priority rankings of influencing factors.

be taken after first experiences with the second commitment period have been gathered.

Several of the large companies also explained that they intend to exploit economies of scale by constructing two or three virtually identical power plants at different sites. By means of this convoy type of construction, they plan to reduce both construction and operational costs. Some of the international operating utilities also explained that they perceived Germany as a comparatively coal friendly country which provides attractive conditions for the construction of coal-fired power plants. This aspect was an important argument in their considerations of where to place the different types of investments. Coal-fired power plant investments are, therefore, located in Germany, while investments in other generation technologies are placed in other places in Europe.[47] However, some of the international operating utilities stated that such considerations did not play a major role in their investment decisions.

Nevertheless, an assessment of the Platts World Electric Power Plants Data Base (Platts 2007) reveals that some 240 GW of power plants are planned or under construction in the EU's 27 Member States. On average, almost half of them (46 %) will be gas power plants while renewables account for 23 % and coal-fired power plants only for 22 %. For every MW invested in coal there will be more than 2 MW invested in gas power plants. In Germany, this ratio is the other way round: for every MW invested in gas (25 %) there will be 2 MW invested in coal-fired power plants (54 %). Apart from Germany only in Poland, the Czech Republic, Bulgaria and the Slovak Republic are more coal than gas power plants planned. In all other EU Member States where coal or gas power plants are planned, the larger share of planned investments will go to gas based generation capacities. Although investment plans are changing quite frequently and rapidly, the ratios are such pronounced that they clearly back the position the Germany has developed one of the most coal friendly power plant investment strategies, particularly within the group of the 15 old Member States.

Some firms knew that they have to invest until 2020 because some of their plants will reach their economic lifetime but did not yet have detailed plans for the replacement of those installations. Almost three quarters of the companies explained that emissions trading had an impact on their investment decisions although more than two fifths made clear that the impact of emissions trading had a lower priority. Some companies stated that emissions trading increased the uncertainty of investment decisions and tends to affect the choice of technology and fuel rather than the scale of their investments. Others also explained that renewable energies have become more attractive through emissions trading or that emissions trading tends to affect closure decisions rather than their investment decisions.

In 2007, four fifths of the firms expected that their investment decisions will coincide with the investment decisions of competitors so that one can speak of an investment

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[47] See for example Electrabel's press release on 10 May 2007: Electrabel will invest in 5 new power stations in the Netherlands and Germany at http://hugin.info/133965/R/1126144/208932.pdf.

cycle. Interestingly, in 2004 only two quarters of the surveyed companies expected such an investment cycle although it was well known at that time that many power plants would reach the end of their economic lifetime in the years ahead and that few capacities had been constructed since the mid-1990s. Several studies estimated that up to 60 GW generation capacities have to be constructed in Germany up to 2030 (BMWA 2003: II; Deutscher Bundestag 2002: 235-237; Ernst & Young 2006: 8; EWI, Prognos 2007: 105-109). It remains unclear why so many companies did not anticipate this situation in 2004. In 2007, by contrast, only a few of the smaller companies expected that they will not be affected by an investment cycle, mainly because their generation capacities are new so that it is not necessary to replace them and because the market segment for smaller power plants is less cyclical than for large generation capacities. Of those firms which expect to be affected by an investment cycle some made clear that they had already recognized the consequences: investment costs and delivery periods have risen significantly.[48] Several companies mentioned that this situation was – at least partly – caused by the so-called 14 year rule of the first German NAP. According to this provision new installations would have been the recipients of free allocation for 14 years without applying a compliance factor during that period. The first version of the second NAP still included this rule (BMU 2006). But since many operators expected that this rule would be abolished after 2012, they intended to commission new power plants before the end of 2012. However, the European Commission rejected this provision so that it had to be deleted in the final version of the NAP (ZuG 2012). Several companies explained that the deletion of this provision has relaxed the situation in the power plant market although it still remains tense. Only a few of the companies assumed that they will be less affected by those consequences because they had contracted options for the construction of a plant well before the start of this investment cycle. Various firms also pointed out that the extended delivery periods of the power plant manufacturers could specifically cause a dramatic delay in the commissioning of new plants with respective consequences for the available capacity and power prices.

Efficiency improvements

Nearly four fifths of the companies reported of plans to improve the efficiency of existing plants or had already implemented such efficiency improvements. Typical measures which are planned or were already implemented aimed at reducing the power plants' internal electricity consumption, for example by installing more efficient frequency-controlled feed pumps. Several companies also planned to retrofit some of their turbines and to replace bladings or entire turbines if they reached the end of their economic lifetime. Some companies also mentioned measures like the installation of additional exhaust heat exchangers, shifting a district heating network from vapor to hot

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[48] For example, the specific investment costs for a coal-fired power plant have increased from € 820 per kW in 2004 to € 1,500 per kW in 2007 (Flauger 2007). However, in addition to more stringent climate mitigation policies this trend is also caused by Germany's nuclear phase out policy and substantially increased steel prices.

water, improving preheating of feed water, expansion of sewage co-firing or shortening of revision cycles as potential measures which are taken into consideration. Several companies reported that they had achieved an increase in efficiency between 0.5 and 1.5% by means of those measures which had already been implemented. One company also explained that in terms of electricity generation there is always a trade-off between the availability of a plant and its efficiency. Emissions trading had shifted the attention in the balance towards efficiency. Thus, the CO_2 price had slightly increased the attractiveness of efficiency improvements compared to the availability of power plants.

A third of the companies which planned any efficiency improvements explained that none of the planned measures was induced or even influenced by emissions trading. In other words, those measures would still have been implemented without emissions trading. However, a third of the companies which had planned efficiency improvements made clear that virtually all their efficiency measures were induced or at least influenced by emissions trading while the remaining third declared that a least some of the planned measures were induced or influenced by emissions trading. One company clarified that specifically the German NAP's malus rule (see section 3.3.2.5, p. 94) had induced major investments in efficiency improvements: by investments of € 70 million the efficiency of six hard coal-fired power plants had been increased by 1 to 1.5%, meaning that they no longer fall below the 36% threshold of the malus rule anymore.

As in the 2004 survey, more than half of the companies believed that natural gas gained in attractiveness due to emissions trading. However, even more companies (three fifths) assumed that renewable energies will improve their competitive position through emissions trading – particularly biomass and wind power. Particularly with regard to CCS expectations have considerably changed. In 2004 only very few companies believed that emissions trading would improve the competitive position of CCS. In the 2007 survey, the share of companies which expected that CCS' competitiveness would increase was still small (one fifth). However, expectations in terms of the economic potential of CCS strongly depend on the size of the company. While the smaller and middle sized companies did not expect much progress in this option, all the larger companies supposed that the economic conditions for CCS will be improved through emissions trading.

Flexible mechanisms

With regard to activities in the field of project based mechanism the picture has substantially changed since 2004. In 2007, three fifths of the companies, mainly the smaller and middle-sized ones, regarded these instruments as being unsuited to their situation. Some of them had not even screened the options of these instruments in detail while others had scrutinized their potential role in their avoidance strategy but had rejected them as too risky or too complicated. However, two fifths of companies planned to invest in CDM or JI projects or had already invested in such projects. The share of companies which considered project based mechanisms attractive or not has indeed not changed. As was the case in the 2004 survey, it was mainly the larger and some of the middle-sized companies which were involved in these instruments. However, the attitude of the larger companies towards CDM and JI has changed considerably since 2004. Before the start of the EU ETS they remained rather reluctant and did not assign high priority to these instruments. In 2007, however, most of the larger companies had already established separate departments for project based mechanisms and assigned notable budgets for the acquisition of reduction credits or the development of CDM or JI projects. The focus of these activities is clearly to get access to low-cost reduction credits while potential side effects such as access to new markets are negligible. In parallel some companies have intensified their involvement in programs such as the “Klimaschutzfond” of the German KfW banking group or the Prototype Carbon Fund of the World Bank (see section 4.2.5, p. 126).

Summary

The debate on investing in new power plants considerably intensified between 2004 and 2007. The utilities have abandoned their reluctance to investments. Up to 40 GW of new capacities are in the pipeline and some of them are already under construction. The companies try to exploit synergies by applying a convoy type of construction and some of the international operating utilities prefer to place coal-fired power plants in Germany because Germany is basically considered to be a coal friendly country.

In contrast to 2004, the large majority of the companies in 2007 believed that they are confronted with an investment cycle which results in substantially higher investment prices for generation technologies and much longer delivery periods of the power plant manufacturers. This situation is at least partly caused by the so-called 14 year rule in the German NAP which gave incentives to commission new plants before 2012. However, the abolishment of this rule has eased this situation but has not eliminated it completely.

The CO_2 price has also induced several efficiency improvements such as installing frequency controlled feed pumps or the replacement of bladings. In one case the German NAP’s malus rule – according to which power plants with lower efficiency had received relatively fewer allowances than more efficient installations – had specifically triggered investments which resulted in up to 1.5 % increased efficiency.

In addition, emissions trading has considerably changed the attitudes towards CCS. In 2004, most companies devoted relatively little attention to this mitigation option. In 2007, the larger companies in particular were putting significant effort into that option and are convinced that emissions trading will increase its attractiveness.

A similar change can be observed with regard to project based mechanisms. In 2004, most companies were rather hesitant about this option while in 2007 most of the larger companies had substantially intensified their efforts in this area. Experiencing CO_2 prices of more than € 30 per EUA in the first period has apparently made clear that this option no longer can be neglected.

4.3.5 Design options

With the 2004 survey in mind, the companies were asked to prioritize the design options of the EU ETS which are most important to their company in 2007. The ranking of the three most important options in 2007 tends to be basically similar to the ranking in 2004. Provisions on the initial allocation, the definition of the overall cap and specific rules for cogeneration[49] are considered in both surveys as the first, second and third most important design options. However, for some of the remaining options the position of importance has shifted. Provisions regarding the base year and the consideration of early action and the transfer rule were in fourth position in 2004 but are considered less important in the 2007 survey (position 7 and 8, respectively). Instead provisions for new entrants and the international climate regime are considered more important in 2007 (positions 4 and 5, respectively). Rules on the closure of installations and for banking were interestingly considered least important to the companies in both surveys.

Company perspective

The priorities assigned in the 2007 survey also facilitate analysis of the relative importance of each option. The rule for initial allocation and the overall cap both receive about one fifth of the priority points. Specific rules for cogeneration and provisions for new entrants received 15 and 14 % respectively of the priority points. All other design options received only 6 % or less of the priority points. This result clearly shows that the initial allocation and the overall cap are considered by the companies to be very sensitive.

In 2004, nearly half of the companies had expected that none of the design options would induce incentives for innovation in their companies. In the second survey less than a fifth of the companies – exclusively smaller ones – assumed that none of the mentioned rules would encourage innovation in their own company. Two fifths – primarily the larger firms – estimated that especially the overall cap would foster innovation in their company. Rules for the initial allocation and for new entrants are also considered by one fifth of the companies to be relevant to innovation in their own companies.

In 2004, two fifths of the companies also believed that the transfer rule would trigger innovation in their firm. In the 2007 survey, the transfer rule was mentioned by only a few of the smaller companies. The importance of the transfer rule was clearly overestimated before the start of the trading scheme. First experiences with the trading scheme have apparently revealed that this rule is applicable only in a very few cases so that in 2007 it was considered less important.

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[49] In Germany, cogeneration plants receive allowances for electricity and heat generation according to a so-called double benchmark (ZuG 2007: § 14; ZuG 2012: § 7 (3)). Most of the companies pointed out the importance of this rule to them but explained that they do not consider it to be a specific treatment of cogeneration.

Industry perspective

With respect to the question of which design of the individual options would best foster innovation, the replies are quite clearly in favor of some options but somewhat ambiguous about others. The share of companies which assumed that a stronger cap would basically promote innovation has increased from three fifths to three quarters between the 2004 and the 2007 survey. Yet, some companies pointed out that a too stringent overall cap might delay innovations because it would tend to result in reduced generation than innovation because companies might lack the financial resources to finance the necessary investments in new technologies.

Several firms hold the view that innovation incentives would be stronger, the higher the share of allowances to be auctioned off. Nearly half of the firms assumed that auctioning off all allowances would encourage innovation while roughly a third advocated only up to 40 % of the allowances to auction, believing that a higher auctioning share might result in significantly higher electricity prices and thus an unbearable burden for the economy. Some companies also suggested differentiating between the electricity industry and the other sectors covered by the EU ETS. Some of the other sectors would be more affected by a higher share of auctioned allowances because they are more exposed to international competition so that they cannot pass through the additional costs of allowances as easily as the electricity industry. Therefore, the electricity industry should be allocated fewer allowances free of charge than the industrial sectors which are principally more affected.[50] One company also believed that auctioning off all allowances would eliminate the electricity industry's windfall profits. Using the auction revenues to promote innovative technologies in the EU ETS sectors would substantially increase the innovation incentives for the entire trading scheme.

Initial allocation

As long as all allowances are not auctioned off it is still necessary to apply rules in the case of free allocation. All companies assumed that from an innovation perspective benchmarking should be preferred to the grandfathering of allowances to incumbent installations. Half of the companies believed that fuel specific benchmarks would foster innovation more strongly than uniform benchmarks while nearly a third of the companies thought that uniform benchmarks would induce more innovation incentives. This difference can be traced back to the different concept of innovation. Those which believed that fuel specific benchmarks would promote innovation more strongly than uniform benchmarks mainly considered innovation as technological improvements within a certain technology whereas the other group of companies had a much broader concept

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[50] This consideration is already implemented in the second German NAP which provides for auctioning of 38 million EUA. This amount is exclusively deducted from the electricity industries budget so that the utilities receive roughly 20 % lesser allowances than they need while the companies of the industrial sector receive almost all allowances they need free of charge (ZuG 2012: § 7).

of innovation, which also included structural changes between competing technological options such as a shift from coal to gas power plants.

New entrants rule

For the allocation to new entrants the picture is somewhat similar. Less than a quarter of the surveyed companies thought that new entrants should not receive any allowances via free allocation. But more than half of the firms believed that fuel specific benchmarks would best foster innovation while less than one fifth of the companies preferred uniform to fuel specific benchmarks from an innovation perspective.

Closure rule

More than half of the firms believed that returning allowances immediately after closure of an installation would be beneficial to innovation. Some firms also stated that returning allowances immediately would result in delayed closure of installation but still advocated for this option perhaps because retaining the allowances in the case of closure is considered unfair. However, more than a third of the companies thought that closed installations should retain their allowances at least until the end of the respective period.

Transfer rule

The transfer rule was initially introduced to spur new investments and thus innovation. However, the large majority of the companies (two thirds) believed that it does not comply with this intention and that it should be abolished. Half of the companies – mostly the larger ones – expect instead that trading periods of 15 years would improve innovation incentives because it would reduce the uncertainties, thereby improving the propensity to investment. Some admitted, however, that the shorter trading periods at the beginning of the trading scheme are useful for having the option to review the scheme after first trading experiences have revealed the weaknesses of the scheme.

Specific rules

Three quarters of the firms supposed that specific rules such as for the decommissioning of nuclear power plants or the consideration of early action make the trading scheme more complex. They advocated the elimination of all special rules since a simpler trading scheme would increase transparency and thereby foster innovation. Double benchmarking for cogeneration plants was, however, not considered a special allocation rule but rather a normal one since such installations generate two products. Therefore, they should also receive allowances according to the output of both products.

Climate regime

Taking into account installation lifetimes of 40 years and more, the lack of a long-term and binding climate regime can be considered a major obstacle to investment and innovation. Correspondingly, the large majority of the companies expected that an agreement upon such a climate regime would substantially increase the innovation incentives. A number of firms explained that the innovation incentives of a climate regime would be the greater, the longer the regime would last. Half of the companies assumed that an agreement which continues up to the year 2050 should be aimed for and some companies added that an extended geographical coverage would also be beneficial to innovation.

Innovation sensitivity

The priorities with regard to the question of which of these design options is most sensitive in terms of innovation incentives in the electricity industry as a whole are somewhat different to the priorities from the company perspective. The cap is considered most important from both perspectives. However, the rules for allocation to incumbents ranked second from the company perspective but are considered less important from the aggregated viewpoint. Allocation to new entrants, a long-term international climate regime and longer trading periods were instead ranked in second to fourth positions from the industry standpoint. The closure and the transfer rules are considered to be the least sensitive in terms of the innovation incentives of the EU ETS in the electricity sector as a whole.

Summary

Overall the analysis has revealed that the companies attach by far the greatest importance to the overall cap and the initial allocation in terms of approaches to innovation. The relevance of early action and the transfer rule have declined between the first and the second survey. It seems that the transfer rule can only be applied in a few specific cases, making it of lesser importance to most of the companies.

Since the share of companies expecting that none of the design options would trigger innovation in their company has declined, it can be assumed that several companies have already experienced some innovation incentives of the EU ETS. The utilities also believe that the overall cap, the rules for initial allocation and the rules for allocation to new entrants induce the strongest innovation incentives in their own companies.

As regards the specific configuration of individual design options, the majority of firms think that a more stringent target and a higher share of auctioned allowances would generally trigger more innovations. As long as all allowances are not auctioned off, rules for initial allocation are still necessary. Most companies preferred fuel specific benchmarks to uniform ones, both for the allocation to new entrants and to incumbents, because they think that fuel specific benchmarks would specifically foster technical innovations and efficiency improvements while uniform benchmarks would foster fuel switch to fuels with lower carbon contents. Finally, several companies pointed to the long investment cycles in the electricity industry of 40 years and more. Against this background they emphasized that longer trading periods and a reliable long-term international climate regime would be essential for sustained innovation.

4.3.6 Conclusions

Innovation strategy

The introduction of emissions trading has not fundamentally changed the electricity industry's approach towards innovation. Nevertheless, it has influenced innovation activities in most of the companies and considerably modified the focus of their innovation activities. The large majority of surveyed utilities intend to intensify their innovation activities, particularly in the field of renewables energies. In addition, the larger utilities have already started devoting considerably increased effort to CCS and research on materials and processes while the middle sized and smaller companies plan to intensify their innovation activities with regard to cogeneration technologies.

Institutional changes

Not surprisingly, most of the institutional changes and innovations had been already established before the start of the trading scheme. In 2007, the majority of the emissions trading related tasks and functions had already been perfectly integrated into the daily business routines of previously existing departments. The only exceptions to this rule are the project based flexible Kyoto mechanisms. Several of the larger companies have only recently begun to set up specific business units or their own subsidiaries for the acquisition of credits from CDM and JI projects or for the development of such projects. Experiencing carbon prices of more than € 30/EUA has considerably increased the importance of this option. Moreover, the mechanisms are institutionally much further developed in 2007 with the result that they are more reliable and can thus be better managed by the companies. Correspondingly, the companies have begun to develop tools for analyzing the specific risks of these mechanisms and to integrate them into their overall CO_2 risk hedging strategies.

Operational changes

Emissions trading has also altered the operation of power plants in most of the companies. Loads were shifted from plants with lower efficiencies to those with higher efficiencies and from fuels with higher carbon content to fuels with lower carbon content when the CO_2 price was high enough. Hard coal-fired power plants, which usually were operated throughout the weekends, were then shut down on Friday evening and only started again on Monday morning. Of course, these changes were shifted in the reverse direction when the CO_2 price declined to levels close to zero.

Investment strategy

The introduction of a CO_2 price has not only modified operation decisions but investment decisions as well. Despite its high volatility and its collapse in 2006, the CO_2 price is already the third most sensitive parameter in the investment decisions of utilities, following fuel and electricity prices. While most companies where rather reluctant with regard to power plant investment in 2004, this attitude was almost no longer apparent in 2007. Several companies have already taken investment decisions on new power plants and some have already begun construction. A number of other investment plans are in the pipeline – many of them involving coal-fired power plants (see Figure 19, p. 167). The new momentum on the power plant market has already triggered a strong upturn of the investment cycle with the consequence that investment costs are strongly rising. This situation was exacerbated by the German NAP's rule according to which new power plants commissioned before the end of 2012 would have been allocated with allowances free of charge for 14 years. However, the Commission's rejection of this rule has relaxed the situation remarkably. Some of the international utilities consider Germany coal friendly due to its NAP and prefer, therefore, to locate their coal-fired power plants in Germany whereas gas power plants, for example, are located elsewhere in Europe. However, other international operating utilities refute such considerations.

Many companies have also already implemented several measures for efficiency improvements in virtue of the introduction of emissions trading. Some firms even argue that the CO_2 price has shifted the balance between the availability and efficiency of a power plant in favor of efficiency. Compared to efficiency, availability has thus lost importance due the introduction of emissions trading. The measures which have already been implemented resulted in efficiency improvements of up to 1.5 percentage points. Particularly the German NAP's malus rule has induced significant efficiency investments in 6 coal-fired power plants so as to raise these plants' efficiency above the malus rules' 36 % threshold.

Design options

Despite the fact that the first innovation effects of emissions trading are noticeable, many firms believe that the innovation incentives could be intensified by improvements in the design of the EU ETS. The stringency of the cap is crucial to innovation. Many firms are convinced that a more rigorous cap would trigger additional innovations in their own company and in the electricity industry in general. Besides, the companies assume that free allocation to new entrants contributes substantially to innovation and that an increased share of auctioned allowances to existing plants would also enhance incentives to innovate. Finally, many utilities underlined that a long-term international climate regime and longer trading periods would considerably improve the conditions for innovative technologies.

4.4 Summary and conclusions

To scrutinize whether emissions trading has promoted innovation in the electricity sector, two semi-structured surveys of a representative set of companies of the German electricity industry were conduced in the form of a panel analysis. The first survey was carried out in the autumn of 2004 in order to grasp the utilities' attitudes towards both emissions trading and innovation as well as their status of operation shortly before the trading scheme went into force. The second survey was carried out in the summer of 2007 when the covered companies had already gained some two and a half years of experience with the new instrument. Comparing the results of both surveys provides some interesting insights. Table 3 provides an overview of the main findings of this comparison.

Table 3 Results of the survey

	1st survey	2nd survey	Comments
Innovation strategy			
Share of companies with innovation strategy	rare	rare	unchanged
Importance of innovation activities			
Research projects	mainly large companies	mainly large companies	unchanged
On-site development	very common	very common	unchanged
Venture capital	large & middle-sized companies	large & middle-sized companies	considerably reduced importance
Search strategies	few companies	few companies	largely unchanged
Potentials of technological innovation clusters	clean coal (CCS, IGCC, etc.), renewables, cogeneration, fuel cells	clean coal (CCS, IGCC, etc.), renewables, cogeneration, storage (CAES, pumped, etc.)	fuel cells less, storage more important
Signaling effect	likely	no, reduction potentials were known but economically not feasible	decreased
Changes in innovation strategy due to ETS			changed expectations
Innovation independent of ETS	yes		
CCS and Renewables more important		yes	
Institutional innovations			
New departments	none	CDM/JI in large utilities	
Task force ET	most	fewer meetings	ET tasks integrated in daily business routines
Emission scenarios	large majority	almost all	slightly increased
Avoidance cost curves	few	more	slightly increased
Continuous emission monitoring	half	more	slightly increased
Tool for comparing allowances and emissions	half	all	substantially increased
Trading floor for allowances	integrated in existing trading floors	integrated in existing trading floors	unchanged
Risk management	minority	majority	slightly increased
Cooperation with other utilities	none	large utilities: market access for small companies	
Changes in operation of power plants			
Expected changes in merit order	minority	majority	no change possible in utilities with only cogeneration, one plant or only similar plants
Experiences changes in merit order		half, e.g. load shift from older to newer plants and from coal to gas (and reverse); shutting down hard coal plants on weekends	shift in trade-off between availability and efficiency in favor of efficiency
Increase co-firing of biomass or substitute fuel	minority	majority	
Expected allowance prices			
2005-2007	€ 11-15/EUA		
2008-2012	€ 19-21/EUA	€ 20-25/EUA	
2020		€ 21-30/EUA	
2030		€ 28-41/EUA	

Continued on next page …

Table 3 Results of the survey (continued)

	1st survey	2nd survey	Comments
Changes in investment strategies			
Most sensitive parameters in investment decisions		1) expected fuel price, 2) expected electricity price, 3) expected CO_2 price	
Decisions on power plant investments	delayed	construction of several plants started, many projects in the pipeline	
Investment cycle expected	no	yes, prices for power plant investments already increased	German NAP's 14 year rule has contributed to the problem
Efficiency improvements due to ET		yes, several (pumps, bladings, etc.), effici-ency improvements up to 1.5%	German NAP's malus rule has encouraged improvements in several hard coal power plants
Improved competitiveness of fuels/technologies	natural gas	renewables (biomass, wind), natural gas	
Investments in project based mechanisms	minority	minority	financial and personal resources substantially increased
Assessment of design options			
Design options which induce innovation in own company	1) none, 2) transfer rule, 3) treatment of new entrants	1) overall cap, 2) me-thod of allocation, 3) treatment of new entrants	understanding of ET substantially increased
Innovation friendly configurations of design options			
Overall cap		a more stringent cap induces more innovations	
Auctioning		a higher share of auctioning induces more innovations	
Allocation to incumbents		fuel specific benchmarks	
Allocation to new entrants		fuel specific benchmarks	
Closure provision		return allowances immediately after closure	
Transfer rule		none	
Specific rules (early action, CHP, nuclear, etc.)		CHP (double benchmark)	
Duration of trading periods		the longer the better	
Climate regime		reliable, international climate regime, the longer the better	
Design options which induce innovation in electricity industry as a whole	1) overall cap, 2) transfer rule, 3) treatment of new entrants/climate regime	1) overall cap, 2) treatment of new entrants, 3) climate regime 4) duration of trading periods	importance of transfer rule was overestimated
CAES: compressed air energy storage; CCS: carbon capture & storage; CDM: clean development mechanism; CHP: combined heat & power; ET: emissions trading; ETS: emissions trading scheme; EUA: European Union allowance; IGCC: integrated gasification combined cycle power plant; JI: joint implementation; NAP: national allocation plan.			

Sources: Authors' own summary

Timing of innovations

Before the start of the trading scheme it was mainly “soft” institutional innovations which did not require large investment decisions that were carried out. The companies had to prepare for the new instrument and had to adapt their business routines to the new challenges (for instance, emission inventories and scenarios, monitoring, tools for comparing current allowances and emissions, integrating CO_2 in existing trading floors and adapting risks hedging strategies). “Hard” technological innovation which involved larger investment decisions were, however, postponed for a few years, returning to the agenda only after the first experiences with the instrument had been gained. In this respect the introduction of emissions trading entailed rather ambiguous innovation effects. It has indeed spurred soft institutional innovations but has at the same time delayed hard technical innovation. However, similar effects would have occurred if a tax instead of emissions trading had been introduced. The postponement of investments in technical innovations should therefore be attributed to the introduction of any economic instrument rather than to emissions trading specifically.

Merit order

The CO_2 market had by and large worked as intended and induced some changes in the merit order during the times when the allowance price was rather high: load shifts from older, inefficient to newer plants with higher efficiencies, shifts from lignite to hard coal or from coal to gas or biomass, shutting down hard coal-fired power plants on weekends, etc. The fact that these changes were reversed when the CO_2 price collapsed to levels close to zero affirms the proposition of a well working CO_2 market.

Investment decisions

The utilities resumed their investment plans after first experiences with new instrument were obtained despite some volatility and the collapse of the CO_2 price at the end of the pilot period. However, investment decisions tend to depend more on expected allowance prices than on spot market prices. Prices of allowance futures, though, increased considerably and have undergone a less volatile development since the end of 2006 after the European Commission rejected the first NAPs and made clear that generous allowance allocations would not be accepted for the next trading period. Not surprisingly, the expected carbon price has a lower priority than the expected fuel and the expected electricity price is ranked the third most sensitive parameter in power plant investment decisions.

The debate on where to locate which type of power plant has gained considerable momentum since the autumn of 2006. Some of the international operating utilities intend to locate hard coal-fired power plants in Germany due to Germany's basically coal friendly NAP while natural gas based generation technology will be located in other European countries.

The increased demand for new power plants has already resulted in significantly higher investment costs for power plants. This situation was – at least partly – tightened by the so-called 14 year rule in Germany's NAP which promised 14 years of free allocation to new generation capacities if they were commissioned before the end of 2012. The European Commission's rejection of this rule has somewhat relaxed the situation on the power plant market without eliminating it completely.

The CO_2 price has also accelerated investments in efficiency improvements. With various measures (frequency-controlled feed pumps, bladings, etc.) the companies have increased the efficiency of a number of plants by up to 1.5 percentage points. Particularly the German NAP's malus rule has promoted efficiency improvement in older coal-fired power plants in order to raise their efficiency above the 36 % penalty threshold.

Design options

Gaining the first years of experiences with the new instrument has also changed assessment of the scheme's design. The stringency of the overall cap, the treatment of new entrants and the existence of an international, long-term and reliable climate regime are considered the most essential factors in terms of innovation in the electricity industry. The expectations which many companies had placed on the transfer rule were, however, not fulfilled. Its importance had seemingly been overestimated before the start of the trading scheme.

Technology clusters

The most noticeable changes between the first and the second survey refer to the project based mechanism, clean coal technologies and renewables. CDM and JI were, without doubt, significantly less developed in 2004 than in 2007. Experiencing carbon prices of € 30 per EUA in 2006 and the prospect of more stringent caps in the future have additionally contributed to a different attitude towards these instruments in 2007. Most of the large utilities have established new departments for the acquisition of credits from these mechanisms and for the development of CDM and JI projects; considerable financial and personal resources have also been allocated to these new departments.

Clean coal gained considerably more attention following the start of the EU ETS. Most of the larger companies have increased their research and development efforts in this cluster. First demonstration plants for CCS and IGCC power plants are either already under construction or in preparation. The large majority of the companies – not just the larger ones – believe that such technologies would not receive the attention they receive today without the introduction of a price for CO_2.

The increased attractiveness of renewables at first seems surprising because renewables are – besides biomass – not directly affected by the EU ETS. The competitiveness of biomass has directly increased because it can be used as a secondary fuel in bivalent coal-fired power plants. In this way it may contribute immediately to CO_2 reduction in this plant. Correspondingly several companies have increased the co-firing of biomass where technically feasible. Moreover, the large majority of the surveyed companies think that not only biomass has gained attractiveness but renewables in general, most notably through the Renewable Energy Sources Act. Several companies have supported this view by referring to increased investments in renewables. However, the development of the CO_2 price in the trading scheme has additionally illustrated that climate policy has already begun and that it is effective and might "hurt" in the future if not all options for climate mitigation are pursued.

Conclusions

The above analysis of the two surveys clearly demonstrates that emissions trading has already induced innovations in the electricity industry. However, the analysis has also identified some indications of how the scheme could be refined to improve incentives for long-term innovations towards a sustainable electricity system.

5 Empirical evidence – environmental and economic impacts

Since emissions trading is a so-called quantity control instrument, it is theoretically simple to determine its contribution to achieving a more sustainable electricity system. Provided a strong monitoring and enforcement regime is implemented, emissions will not exceed the agreed caps. The contribution of emissions trading to reducing emissions could thus be determined by comparing these caps with historic or business as usual emissions. In practice, however, it is more difficult to identify the environmental and economic impacts of emissions trading because the impacts of emissions trading need to be separated from the impacts of other policy instruments.

In the next sections it will be examined whether emissions trading has worked well in the German electricity industry to date. The analysis opens with a brief overview of allowance allocation for the first and second trading period and the corresponding development of the carbon market (section 5.1). Based on this, various indicators for short-term impacts on the operation of power plants and potential reasons for the observed results will be identified (section 5.2). With regard to investment decisions, the analysis is even more difficult. Following only three years of experiences with emissions trading, investment decisions are still very much in flux and may change substantially once the final decision on the review of the EU ETS or on the post 2012 climate regime has been taken. Therefore, the analysis can only detect first indications for the impact of emissions trading on long-term investment decisions (section 5.3).

5.1 Allocation and allowance prices

The environmental and economic impact of an allowance trading scheme depends to a large extent on the scarcity of allowances which is determined by the cap. The impact of the EU ETS on the operation of power plants and decisions to invest in new generation capacities can therefore only be understood against the background of a clear picture of the scarcity of allowances and of the resulting price developments on the carbon market.

Table 4 provides an overview of the agreed caps in the EU ETS and each Member State's verified emissions in 2005. On average, CO_2 emissions were reduced by 3% between the Member State specific base periods and 2005. In the new Member States the emissions declined by 7% while they only declined by 2% in the old Member States. Table 4 also illustrates that in 2005 substantially more allowances were allocated than were needed. For the first year of the trading period, an excess of 8% allowances were allocated to the installations. In 2005, Austria, Ireland and Italy were the only Member States with some, and Spain the only Member State with substantial scarcity in allowances.

In the new Member States the over-allocation was even stronger than in the old Member States. In 2006 CO_2 emissions were even slightly higher than in 2005. This might be explained by the somewhat lower average allowance price in 2006 (€ 17/EUA compared to € 22/EUA in 2005). However, verified emissions in 2006 are basically in the same order of magnitude as in 2005. In 2007, the average allowance price dropped substantially to less than € 1/EUA. If all allowances would have been used, emissions would have been some 4.5 % higher than in the base periods.

The assessment of the impact of the EU ETS during the pilot period therefore turns out to be somewhat ambiguous. On the downside it has to be taken into consideration that allowance allocation was too generous and that the emissions have been reduced only slightly compared to the base periods. However, on the upside it should be taken into account that the CO_2 prices temporarily rose to levels of more than € 30/EUA and that the EU ETS in these periods has illustrated what the scheme might look like if allowances would be scarcer in the future.

Table 4 Allocation and verified emissions in the EU ETS

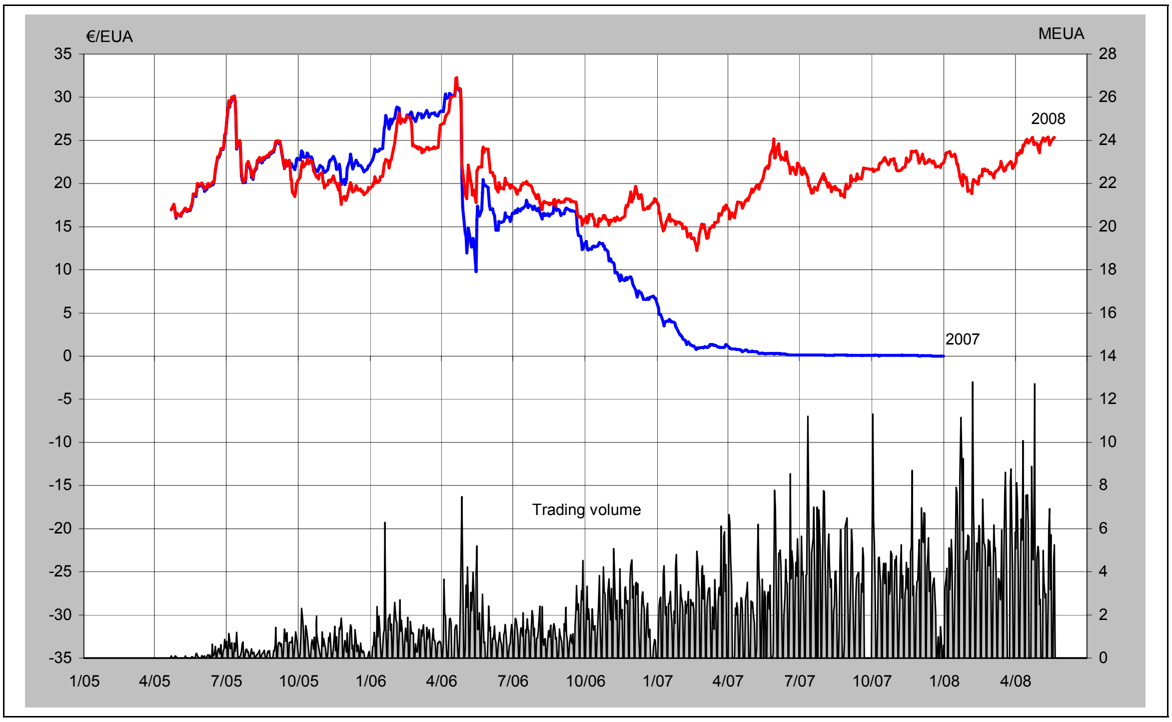
	Cap 2005-07	Verified emissions 2005	Verified emissions 2005 to base periods emisssion 1998-03 [a]	Verified emissions 2005 to cap 2005-07	Share of ETS in total GHG emissions 2005	Allowed cap 2008-12	Allowed cap 2008-2012 to verified emissions 2005	Allowed use of CER/ERU as share of the allowed cap 2008-12	Share of ETS in Kyoto or burden sharing target 2008-12
	MEUA/a	Mt CO_2		%		MEUA/a		%	
EU-27	**2.299**	**2.124**	**-3%**	**-8%**	**41%**	**2.083**	**-2%**	**13%**	**40%**
EU-15	**1.730**	**1.639**	**-2%**	**-5%**	**39%**	**1.569**	**-4%**	**14%**	**40%**
Austria	33	33	10%	1%	36%	31	-8%	10%	45%
Belgium	62	55	-12%	-11%	38%	59	6%	8%	43%
Denmark	34	26	-14%	-21%	41%	25	-7%	17%	45%
Finland	46	33	-9%	-27%	48%	38	14%	10%	53%
France	157	131	-7%	-16%	24%	133	1%	14%	24%
Germany	499	475	-5%	-5%	47%	453	-5%	20%	47%
Greece	74	71	2%	-4%	51%	69	-3%	9%	51%
Ireland	22	22	7%	1%	32%	22	-1%	10%	36%
Italy	223	226	1%	1%	39%	196	-13%	15%	40%
Luxembourg	3	3	-10%	-23%	20%	3	-4%	10%	27%
Netherlands	95	80	-10%	-16%	38%	86	7%	10%	43%
Portugal	39	36	0%	-6%	43%	35	-4%	10%	46%
Spain	174	184	12%	5%	42%	152	-17%	20%	46%
Sweden	23	19	-4%	-15%	29%	23	18%	10%	30%
United Kingdom	245	242	-1%	-1%	37%	246	2%	8%	36%
EU-12	**569**	**485**	**-7%**	**-15%**	**49%**	**514**	**6%**	**10%**	**41%**
Bulgaria	42	41	-6%	-4%	58%	42	4%	13%	40%
Cyprus	6	5	16%	-11%	51%	5	8%	10%	
Czech Republic	98	82	-7%	-16%	57%	87	5%	10%	48%
Estonia	19	13	2%	-34%	61%	13	1%	0%	32%
Hungary	31	26	-19%	-17%	32%	27	3%	10%	29%
Latvia	5	3	-23%	-38%	26%	3	20%	10%	14%
Lithuania	12	7	-27%	-46%	29%	9	33%	20%	20%
Malta	3	2	10%	-32%	57%	2	7%	0%	
Poland	239	203	-8%	-15%	51%	209	3%	10%	46%
Romania	75	71	0%	-5%	46%	76	7%	10%	33%
Slovakia	31	25	-5%	-17%	52%	33	29%	7%	49%
Slovenia	9	9	-4%	-1%	43%	8	-5%	16%	49%

[a] Member State base periods varied between 1998 and 2003

Sources: EU COM (2007a; 2007b; 2007c), EEA (2007a), author's own calculations

The generosity of the Member States in terms of allowance allocation for the pilot period is clearly reflected in the development of allowance price (Figure 11). Over-allocation became clear to all market participants in April 2006 when verified emissions were published for the first time. Before the release of the verified data, nobody really knew what the amount of CO_2 emitted by the covered companies was because it was not mandatory to meter it properly. The companies thus developed rather conservative risk strategies. Those companies short of allowances intended to buy allowances for the emissions not yet covered by their allowance holding. Conversely, many companies who had surplus allowances were not willing to sell them for the same risk adversity. In this situation, the allowance price rose to levels of more than € 30/EUA in 2005 – despite conjectures about over-allocation. However, after the release of the first verified data it became clear that substantially more allowances were allocated than were needed; the allowance price dropped sharply to half of its peak value, declining further to levels close to zero in April 2007 because banking of allowances to the next period was not allowed (section 3.3.4).

Figure 11 Allowance prices and trading volume



Source: ECX (2008)

The allocation of allowances for the commitment period from 2008 to 2012 seems to be less generous than for the pilot period. This is owed to the European Commission's firm stance towards the Member States. Originally the Member States applied for the allocation of 10 % more allowances than the European Commission finally accepted. Compared to verified emissions in 2005 the emissions will decline further by 4 % in the old Member States while they will grow in the new Member States by 6 %. For the EU as a whole this results in a decrease of 2 % compared to verified emissions in 2005.

Compared to the Member States' base periods, emissions will be reduced by 5% on average (Table 4).

However, verified CO_2 emissions might indeed be higher in the period 2008 to 2012 than in 2005 because the companies covered by the EU ETS are allowed to use credits from project activities (CERs and ERUs) in addition to the allowances allocated to them. The use of such credits is restricted on average to 13% of the allowances allocated to the companies. All together the firms might use up to 278 million of such credits per year. Since the prices of these credits are usually lower than the prices of EUA it can be expected that companies will largely use this potential to save costs. Assuming an average price of € 15 per credit, the EU ETS would trigger a transfer of more than € 4 billion per year to greenhouse gas reduction projects in developing countries and countries in transition.

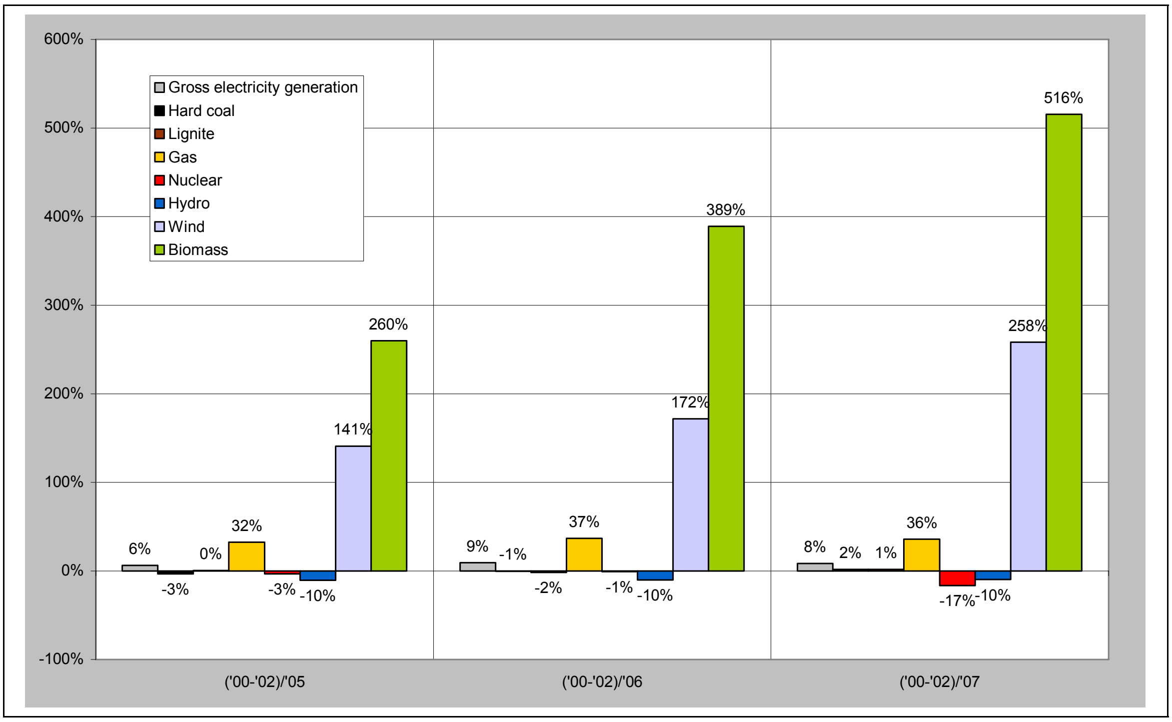
In 2005, verified CO_2 emissions of all EU ETS installations in the new Member States accounted for roughly half of the total greenhouse gas emissions while in the older Member States only two fifths of the total greenhouse gas emissions were covered by the trading scheme. In the period from 2008 to 2012 the EU ETS will contribute disproportionately to emissions reduction, particularly in the new Member States, so that EU ETS' share in total greenhouse gas emissions will decline to the level of the old Member States.

The price development of EUA 2008 futures mirrors that market participants expect more scarcity in the second trading period of the scheme (Figure 11). Until September 2006, the price followed more or less the price of pilot period allowances. Since then it decoupled from the price of EUA expected in 2007 and rose again to prices of more than € 20/EUA, particularly after it became clearer and clearer in the spring of 2007 that the Commission would reject all NAPs which were too generous.

5.2 Impacts on operation

Emissions trading has introduced a price to greenhouse gas emissions which now has to be considered in the production function of electricity generators (section 4.2.3). Unless the price of allowances is not zero or close to zero, this should be reflected in the structure of fuel consumption for electricity generation. The consumption of fuels with relatively high carbon contents such as hard coal and lignite should decline while the consumption of fuels with relatively low emission rates such as natural gas or renewables should increase. In Figure 12 the consumption of each fuel for electricity generation is compared to the consumption in the base period (2000 to 2002).

Figure 12 Change in fuel consumption for electricity generation compared to the base period

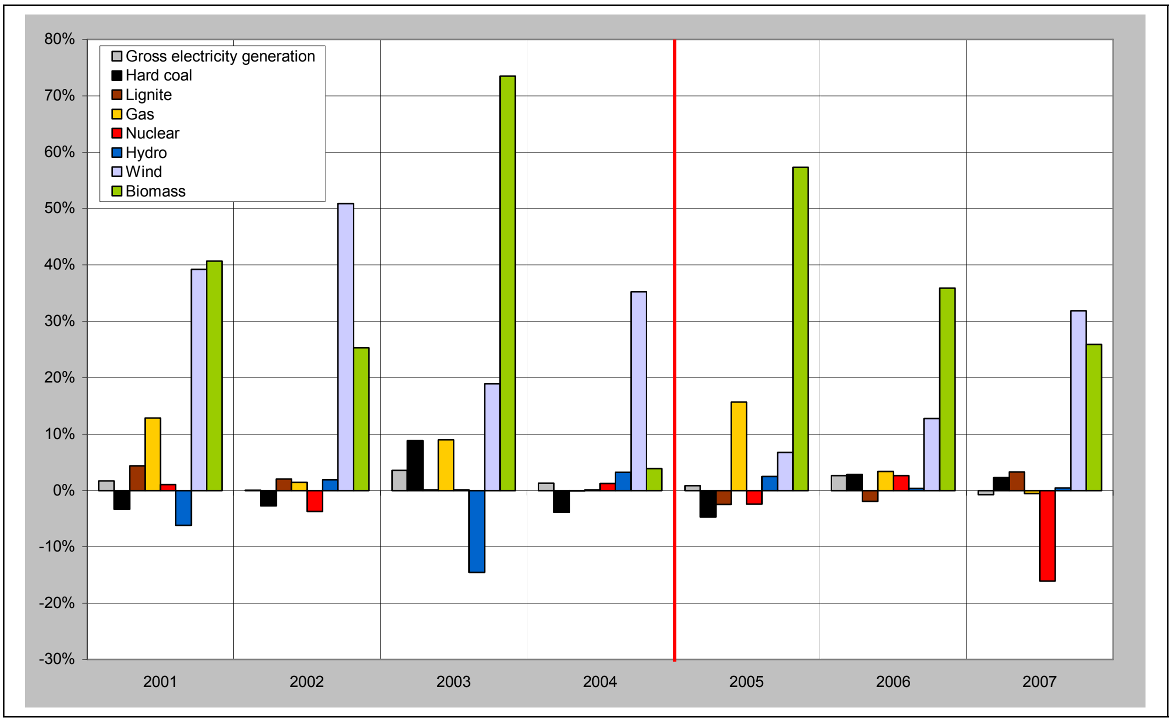


Sources: BMWi (2007b; 2008), author's own estimates

Indeed, the use of lignite and hard coal declined slightly – at least as long as the carbon price had not dropped close to zero – despite an increase of the electricity generation between 6 and 9%. At the same time, the consumption of natural gas has increased by about one third compared to the base period. The use of hydro and biomass for electricity generation has also increased. However, hydro cannot at all be attributed to emissions trading and biomass only to some degree. To a large extent the consumption dynamic for renewables is caused by the EEG. Nevertheless, at first sight it seems that emissions trading has actually induced a certain degree of change in the fuel structure towards less carbon intensive fuels.

However, a closer look at the fuel structure dynamics reveals that the first sight might be misleading. Figure 13 depicts the yearly changes in fuel consumption for electricity generation.

Figure 13 Change in fuel consumption for electricity generation compared to previous year

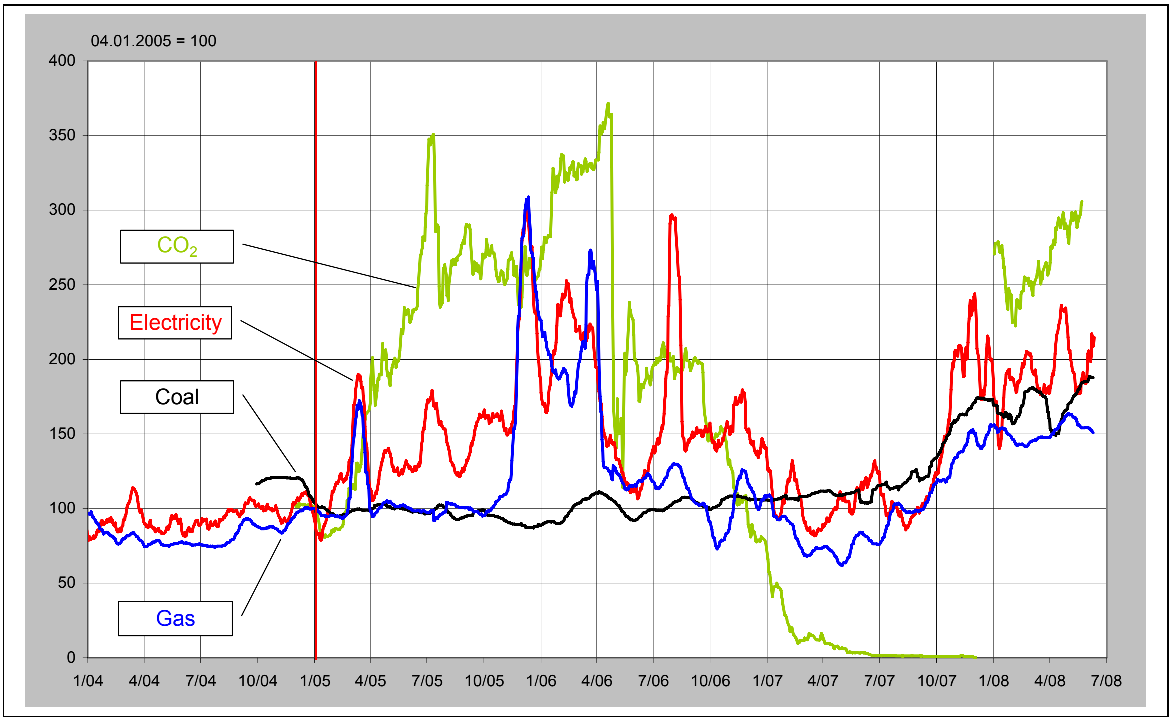


Sources: BMWi (2007b; 2008), author's own estimates

The pattern of the changes compared to the previous year during the first trading period from 2005 to 2007 is not substantially different to the changes compared to the previous year that occurred in the period before the EU ETS began. The 2005 increase in natural gas consumption by 16 % is only slightly higher than the 13 % increase in 2001 or the 9 % increase in 2003. Hard coal consumption declined by 5 % in 2005 but also by 3 % in 2001 and 4 % in 2004. Only for lignite the picture is as expected: lignite consumption rose in most years before the start of the EU ETS but decreased in 2005 and 2006 during the significant carbon price and increased again in 2007 when the price of EUAs came close to zero. The relative changes to the previous year are both in direction and extent apparently not so different to the situation before and after the start of EU ETS. The fuel structure for electricity generation is evidently influenced by other factors and changes in the fuel structure and can therefore not clearly be attributed to the carbon priced introduced by the EU ETS – at least not yet.

As was the case with investment decisions, for which companies rated the carbon price only the third most important factor after fuel and electricity prices (see section 4.3.4), operation and merit order decisions are also determined by the same factors. Together with the CO_2 price Figure 14 illustrates the developments of the main fuel and the electricity prices since the EU ETS began.

Figure 14 Development of energy and carbon prices



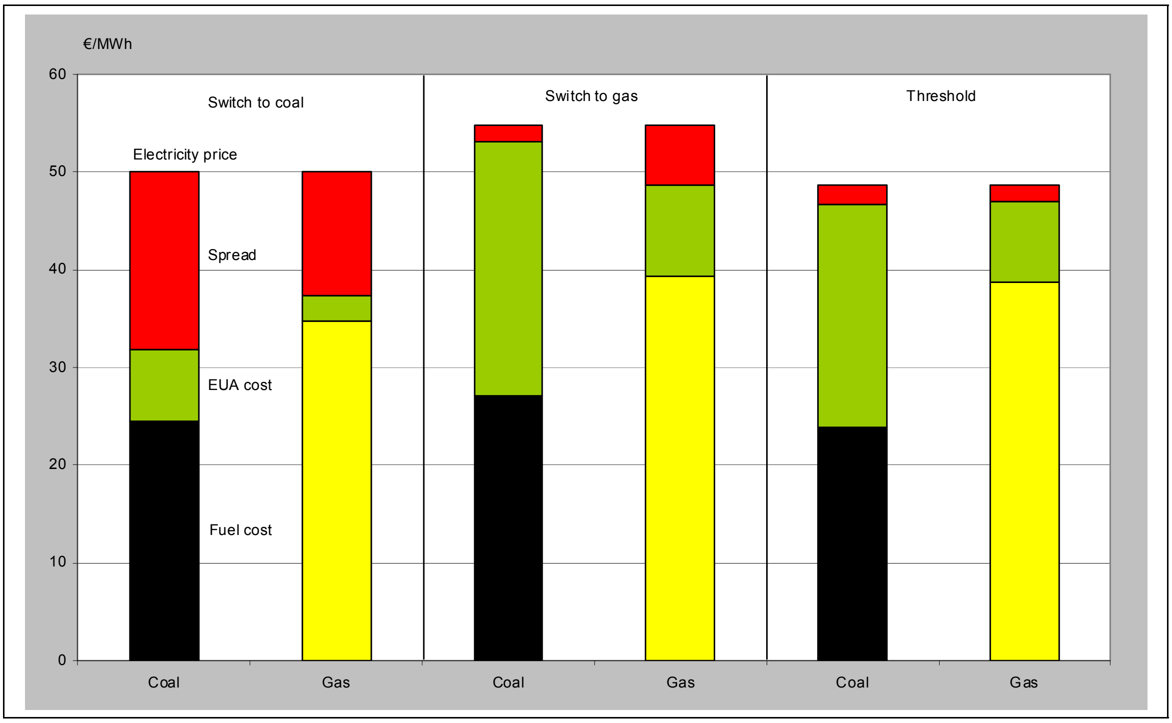
Sources: CO_2: PointCarbon (2008, EUA 2007 & 2008); electricity: EEX (2008, Phelix Base, 20 period moving average); coal: Spectron (2008, Rotterdam coal index, 20 period moving average); gas: SDT (2008, Zeebrugge day ahead index, 20 period moving average); exchange rate: Oanda (2008); author's own calculations

The figure illustrates that not only the carbon but also the electricity and the natural gas prices were quite volatile during the first trading period of the EU ETS. And although the coal price was less volatile, it still increased by more than 70 % at the end of the period. The figure also shows that the price of natural gas substantially increased in some periods (for example, winter 2005 to spring 2006) beyond the hard coal price. Such developments in relative fuel prices can considerably influence the merit order of electricity companies which have both types of plants in their portfolio. However, the electricity and carbon price developments also need to be taken into account for deciding whether a switch from coal to gas is profitable or not.

Such decisions on changing the merit order between a hard coal and natural gas plant are usually taken on the basis of the so-called dark and spark spread (Frémont 2006). The dark spread is the remainder when the carbon cost per MWh is subtracted from the electricity price while the spark spread is the same difference for natural gas. If the dark spread is larger than the spark spread, it is profitable to operate hard coal-fired power plants before natural gas plants are operated and vice versa.

Under emissions trading, the EUA cost additionally has to be taken into account. The clean dark and spark spreads, which include the costs of CO_2 emissions, are accordingly smaller than the dark and spark spreads (Frémont 2006). The developments of the clean spreads can be used to identify incentives to switch from coal to gas under the EU ETS. The left two columns in Figure 15 describe a fictive situation where the EUA costs are higher for coal than for gas. However, the fuel cost of coal is much cheaper than that of gas. The clean dark spread is thus larger than the clean spark spread. Operating the coal-fired power plant is therefore more profitable than the gas power plant. In the situation depicted in the two central columns all prices have changed. Particularly the EUA costs have increased substantially with the result that under this situation the clean spark spread is larger than the clean dark spread. Despite the fact that generation is generally less attractive in this situation because the spreads are much smaller than in the first situation, the clean spark spread is now larger than the clean dark spread. Operators who have the opportunity would shut down their coal-fired power plants in this situation and predominantly operate gas power plants for electricity generation.

Figure 15 Incentives for coal to gas switch

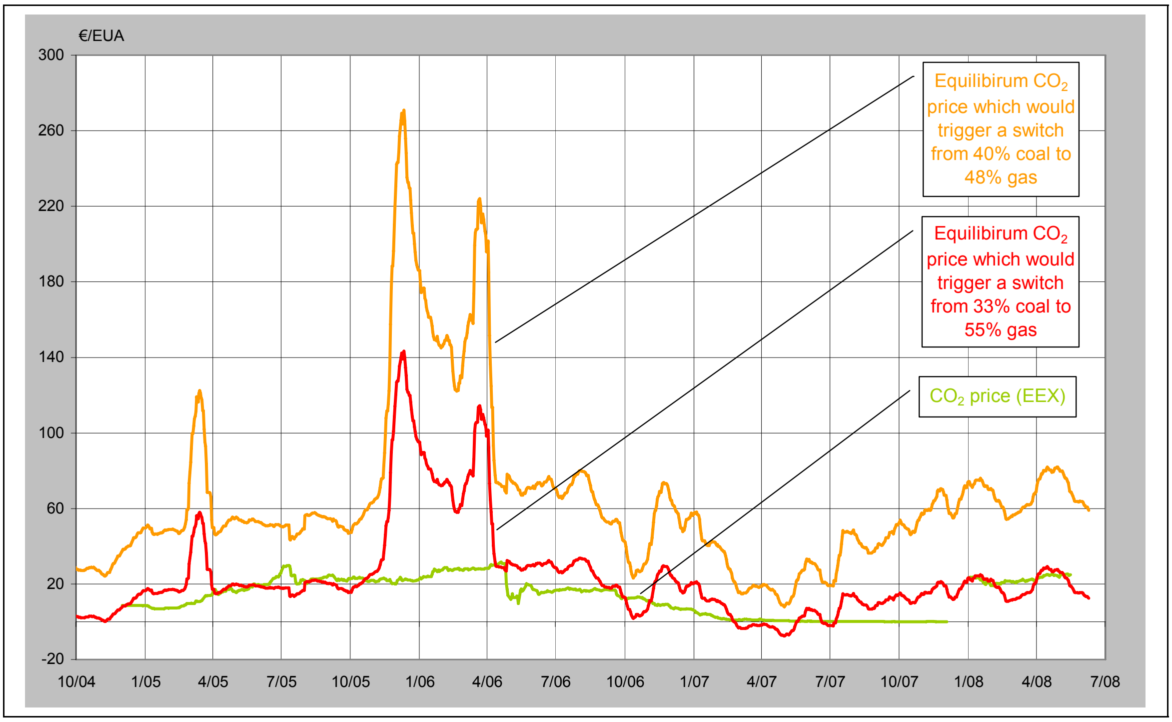


Sources: Author's own illustration

For each situation which is determined by the electricity, the coal and the gas price, a carbon price can be calculated which would balance the clean dark and spark spread (Figure 15, right two columns). This is the threshold price at which the direction of the fuel shift would change. If the real carbon price is lower than the threshold, coal plants are operated before gas plants while the opposite is true if the actual carbon price is higher than the threshold.

This threshold price can be used to determine the EU ETS's incentives for switching from coal to gas under the observed fuel and electricity price developments during the first trading period. For calculating the spreads the power plant's efficiency needs to be taken into account because it determines both the actual fuel and EUA costs. A power plant with a lower efficiency has higher fuel and EUA costs than a power plant with a higher efficiency. Shifting load from coal to gas will thus occur at first between a relatively inefficient coal-fired power plant (η: 33 %) and a rather efficient gas power plant (η: 55 %). Assuming these efficiencies for the coal and gas power plants and taking into account the observed electricity, coal and gas prices, a threshold EUA price for each day can be calculated and depicted. Assuming for the illustration that there would also be enough gas capacity to shift all load from coal to gas – which is definitively not the case in Germany – a second threshold could be calculated. All coal load would be shifted from coal to gas if the carbon price is so high that even the most efficient coal plant (η: 40 %) would be less profitable than a rather old gas plant (η: 48 %). These thresholds can now be compared with the observed carbon price (Figure 16).

Figure 16 Coal to gas switch band



Sources: PointCarbon (2008); Spectron (2008); SDT (2008); Oanda (2008); author's own calculations

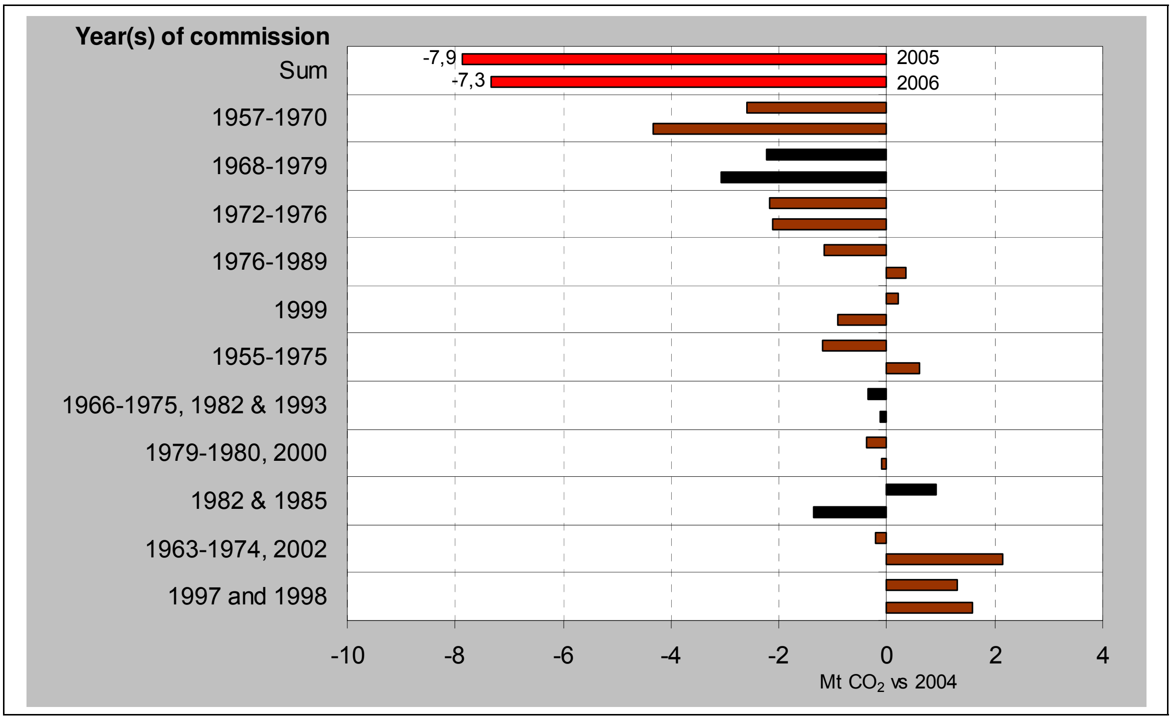
The area between the thresholds is the coal to gas switch band induced by the carbon price. If the EUA price exceeds the lower red line, it would be profitable to shift load from old inefficient coal-fired power plants to new and efficient gas plants. If the carbon price also exceeded the upper orange line, it would be profitable to shift virtually all load from coal to gas fired plants.

Figure 16 clearly shows that the carbon price exceeded the lower red threshold price only during very short periods in the summer of 2005 and the autumn of 2006. In spring 2007 the lower threshold price even became negative, signifying that the shift of load from coal to gas was profitable even without taking into account the carbon price, which was already close to zero at this point in time. In all the other periods during the first trading period it was basically more efficient to operate coal plants and to shift – where possible – load from gas-fired to coal-fired power plants. It is therefore not surprising that no significant shift in the fuel consumption for electricity generation from coal to gas can be observed despite the introduction of a price for greenhouse gas emissions. Evidently the price developments for coal, gas and electricity have outbalanced the incentives which were established through the carbon price.

Emissions trading might, nevertheless, have induced a shift from lignite to hard coal plants or from old and inefficient to more efficient new lignite or coal-fired power plants. However, such incentives are difficult to identify because lignite is not traded as a commodity on the market. Lignite is exclusively used in vertically integrated electricity companies. The fuel costs of lignite are usually not published and would in any case be less reliable than market prices because the companies do not really compete on the basis of these prices.

Another option for identifying impacts of emissions trading on the operation of various lignite and hard coal plants is to scrutinize the emissions of individual power plants before and after the start of the EU ETS. The so-called European Pollutant Emission Register (EPER) provides CO_2 emission data for large power plants for the year 2004 (EEA 2007b). These emission data can be compared with the verified emission data of these plants for the years 2005 and 2006 which are registered in the Community Transaction Log (CITL) (EU COM 2007c). Such analysis has been carried out for selected German lignite and hard coal-fired power plants. The results of this analysis are depicted in Figure 17.

Figure 17 Emissions in large coal-fired power plants



Source: EEA (2007b); EU COM (2007c); author's own calculations

Figure 17 illustrates that there was clearly a shift from old and less efficient to newer and more efficient plants. However, a shift between lignite and hard coal-fired power plants cannot be identified – at least not in the plants covered by the analysis.[51] In addition, the overall emissions of the covered plants decline. This analysis provides at least a small indication[52] that emissions trading has encouraged the shift towards more efficient power plants even if the fuel price developments have avoided more significant changes in the fuel structure for electricity generation.

So far mixed results have been identified with regard to the impact of emissions trading on the fuel use for electricity generation and CO_2 emissions. A significant impact on the fuel use for electricity generation cannot clearly be identified but some indications support that emissions trading might have at least supported the shift of generation from old to new and more efficient power plants.

Taking into account the substantial fuel price changes depicted in Figure 14 it can also be questioned whether emissions trading has avoided an increase in emissions under the business as usual development without the EU ETS being in place. Using a detailed electricity market model of the German power market, the arrhenius Institute for

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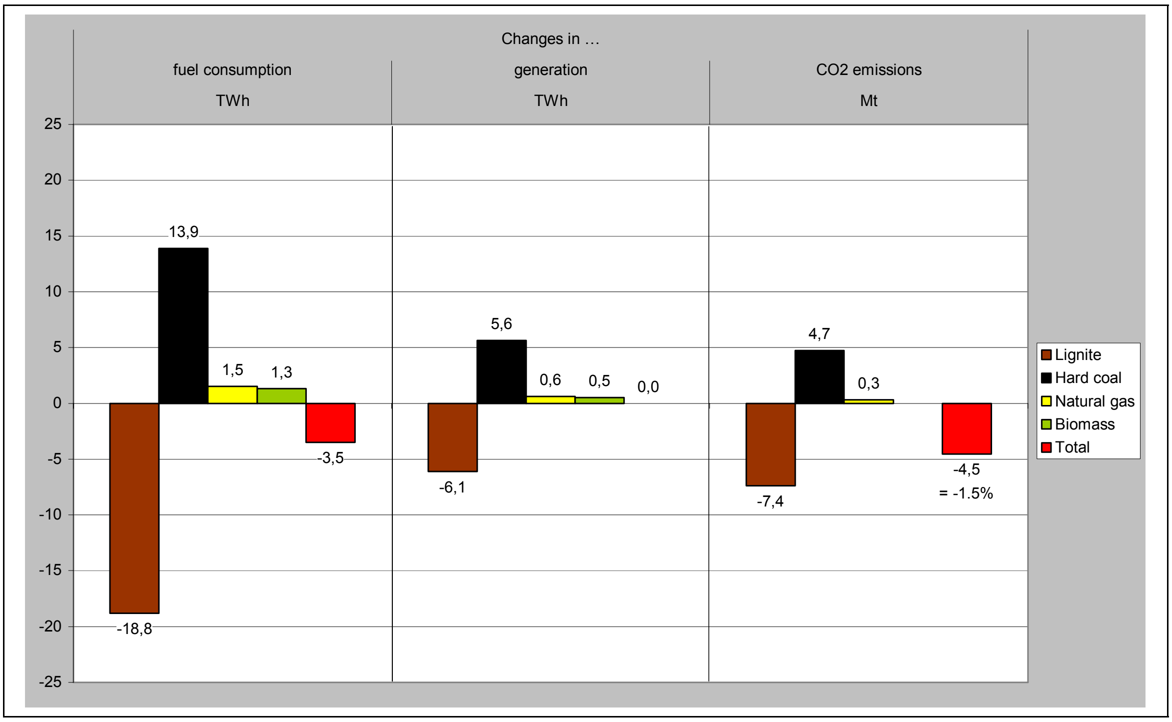
[51] The identifiers of individual installations are not harmonized between both data bases. Therefore, it was not possible to compare all lignite and hard coal plants but just those where the consistency of the identity could be determined with sufficient reliability.

[52] To consolidate this indication it would be necessary to compare the verified emissions in 2005 and 2006 with more years of historic emissions data. Unfortunately, the EPER data base only provides data for 2004.

Energy and Climate Policy (2007) has analyzed the impact of emissions trading on the electricity generation. The model is based on a database of all larger power plants in Germany and is able to reproduce the development of electricity generation, fuel consumption and CO_2 emissions of historic years as a benchmark while taking into account the average allowance price of the respective period. Such a model run has been conducted for the year 2006 using the average allowance price of 17 €/EUA. By setting the allowance price to zero, the business as usual development which would have occurred without the EU ETS in place can be modelled. The differences between the two model runs are presented in Figure 18.

Figure 18 Impact of emissions trading in 2006



Sources: arrhenius Institute (2007); author's own calculations

According to this model experiment, emissions trading has indeed induced some fuel shift but predominantly from lignite to hard coal and only to a minor extent from lignite to gas or biomass. Electricity generation from lignite decreased by some 6.1 TWh due to the EU ETS while production from hard coal, natural gas and biomass increased by 5.6, 0.6 and 0.5 TWh respectively. In addition, the overall efficiency of electricity generation was increased, resulting in 3.5 TWh less fuel consumption for electricity generation. CO_2 emissions changed correspondingly. Overall CO_2 emissions are according to the model results some 4.5 Mt or 1.5 % lower with the EU ETS in place than without it.

In summary, it can be concluded that there are some indications that the EU ETS has already developed some incentives to reduce CO_2 emissions in the electricity industry in its first trading period. And these incentives seem – as predicted – to promote both fuel shift and efficiency improvements. However, decisive facts that clearly substantiate the EU ETS's impact on the CO_2 emissions of electricity generation are not yet available.

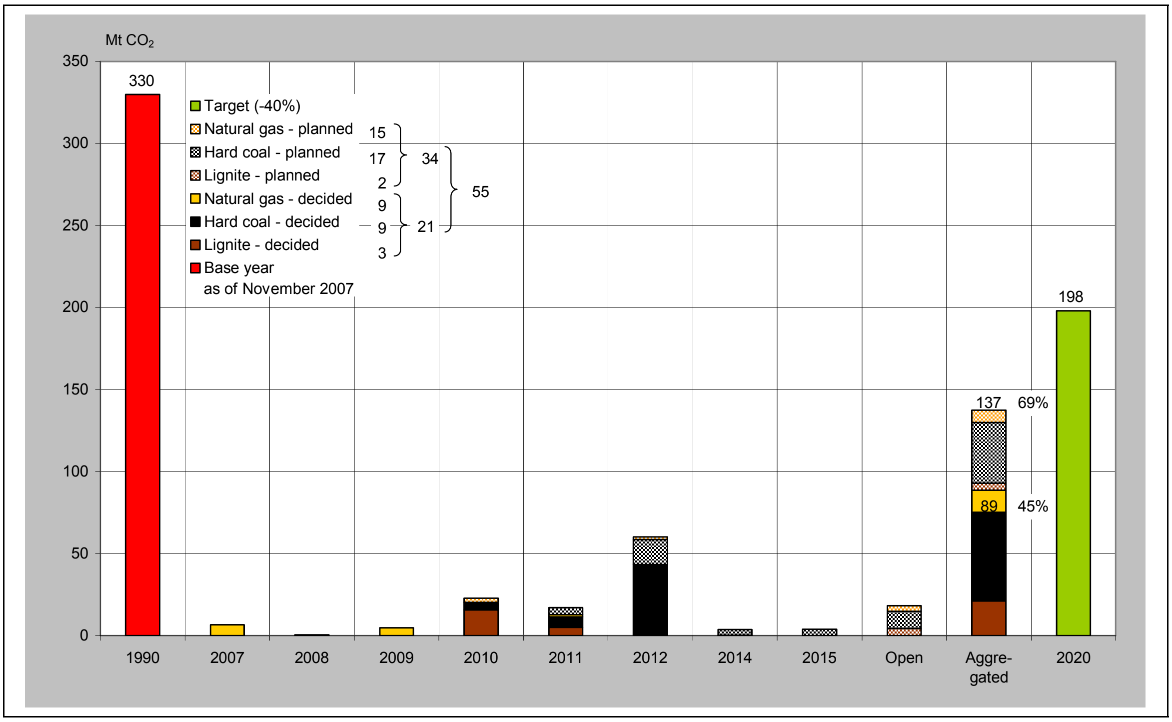
5.3 Impact on investment

The impact of the EU ETS on investment decisions after only three years of operation is even more difficult to determine than its impact on operation. This is mainly because the introduction of emissions trading has delayed rather than advanced investment decisions. Companies prefer to wait until first experiences with the new instrument have been gained (section 4.2.4) and until a clearer picture on the future design of the scheme is available.

At the same time, German electricity companies cannot wait too long. Their power plants portfolios are aging strongly following several years without substantial power plant investments. Except for the retrofitting of several old power plants in the former East Germany after reunification, only a few new power plants were built. After the turn of the century, power plant investments were as low as in the 1960s despite a more than threefold increase in electricity generation (Figure 4, p. 38). Further pressure to build new power plants derives from the decision to phase out electricity generation from nuclear plants by 2022 at the latest. The 14 year rule, according to which new power plants would have received free allowances for 14 years (section 4.3.4), also motivated many utilities to advance their investment plans in order to commission the new capacities before the end of the second trading period in 2012 because it was believed that this rule would not be prolonged to the third trading period.

Against this background, several electricity companies abandoned their reluctance towards power plant investments and disclosed in 2007 their plans to build new capacities. While 2005 and 2006 were rather quiet with regard to announcements on investment decisions, this situation had substantially changed in 2007. By the end of 2007 plans to commission up to 55 large power plants had been communicated to the public. For some of these plans final investment decisions had already been taken. In a few cases construction had already begun. Taking into account the likelihood of each plant to be implemented, all planned investments together amounted to a generation capacity of almost 27 GW. Figure 19 provides an overview of the impact on CO_2 emissions under the assumption that all known plans would be implemented by 2020.

Figure 19 *Emissions by planned generation capacities and fuel*



Sources: *bdew (2007); BUND (2007); Platts (2007); compiled by Öko-Institut*

By the end of 2007, investment decisions for 21 power plants had already been taken, all of which planned to be commissioned before the end of 2012. Moreover, 34 generation capacities were planned, some of which were also to be commissioned before 2013 and some only after that date.

By assuming usual operational hours, fuel specific emissions rates and state of the art efficiency for these plants, the impact of these investment plans on CO_2 emissions can be estimated. The CO_2 emissions of all plants with firm investment decisions would amount to 89 Mt CO_2. This amount would increase to 137 Mt CO_2 if the emissions of all capacities under consideration are added. Assuming furthermore that the electricity sector should at least contribute 40 % share of the CO_2 emissions reduction as part of Germany's GHG mitigation efforts, these emissions would account for 45 % and 69 % of the emissions budget available to the electricity sector, respectively. The emissions of all lignite and hard coal plants alone would amount to almost 60 % of the electricity sector's emission budget in 2020.

By 2050 GHG emissions in industrialized countries have to be reduced by at least 80 % compared to 1990 levels (IPCC 2007a: 776). Applying this target to Germany's electricity sector as well would result in an emissions budget of no more than 66 Mt CO_2. With lifetimes of 40 years or more, most of the planned power plants would still be generating electricity in 2050, resulting in aggregated emissions which exceed the available emission budget by more than 100 %.

These considerations illustrate that emissions trading seems to have had little impact on power plant investments in Germany to date: 31 hard coal and lignite power plants with some 19 GW of aggregated capacity are planned or are under construction compared to just 24 gas power plants with an aggregated capacity of merely 7.5 GW. Emissions trading discriminates against hard coal and particularly lignite due to their substantially higher carbon content, so that one could expect that the relation should be the reverse or that hardly any hard coal or lignite power plants would be commissioned. The counterintuitive empirical result, however, correlates with the observation made earlier (section 4.3.4) that carbon prices are only the third most important factor in investment decisions, after fuel and electricity prices: expectations of the development of future coal, gas and electricity prices were evidently such that they clearly offset the expectations of the carbon price development. Moreover, the higher allowance allocation to coal compared to gas power plants has also contributed considerably to the coal bias of power plant investments in Germany (section 3.3.2.2.2).

In January 2008, the Commission published its draft directive on the review of the EU ETS, which suggested an allowance cap of 21 % below the 2005 verified emission levels and that all allowances should be auctioned to power plants from 2013 onwards (COM(2008) 16). The amendment of the EU ETS Directive was eventually adopted in December 2008. It will terminate preferential allocation to new hard coal and lignite power plants in Germany by 2012 because neither exiting nor new plants would receive any free allocation of allowances. As a result, some utilities have withdrawn their investment plans or postponed final decisions for several years.

In summary, the analysis so far indicates that emissions trading has had little impact on the choice of fuel for new power plants in Germany. Investment plans for coal power capacities exceeded planned gas power capacities by a factor of 2.5. New information on a more stringent design of the EU ETS in the future resulted, however, in a revision of at least some of these investment plans or a postponement of final decisions. Clearly the EU ETS has had a certain degree of impact on the investment decisions of utilities. Nevertheless, the still prevailing bias for coal-fired power plants raises questions as to whether emissions trading alone can provide a sufficiently strong long-term price signal which drives investments towards low carbon technologies.

5.4 Conclusions

This chapter aims at identifying whether the introduction of emissions trading has, after three years of experiences have been gathered with the new instrument, already had a specific impact on the German electricity industry or not. For this purpose, the ways in which emissions trading may have influenced the merit order and the operation of power plants are analyzed and the impacts on investment decisions are identified.

The results of this analysis are somewhat mixed. Definite evidence is not yet available, neither for the impact on operation nor for the impact on investment decisions. Variations in the structure of fuel consumption for electricity generation are not substantially different to the annual changes observed before the EU ETS began. Fuel and electricity price developments have clearly offset the incentives of emissions trading towards the use of less carbon intensive fuels.

However, results of model simulations support the notion that emissions trading has avoided an increase of CO_2 emissions which would have occurred if the EU ETS had not been established. According to these simulations a small share of the electricity generation has shifted due to emissions trading from coal towards natural gas and biomass and a somewhat larger share from lignite towards hard coal. Moreover, emissions trading has induced a shift to more efficient power plants with the result that the overall fuel consumption and total CO_2 emissions have declined.

One important reason for the fact that definite evidence for the impact of emissions trading is not yet available can be found in the mixed incentives provided by the development of the carbon price. After a strong increase to values above € 30/EUA, carbon prices dropped considerably after it became clear that too many allowances had been allocated for the first trading period. The mixed incentives towards a more sustainable electricity system are therefore to be attributed to the poor implementation of the scheme during the first trading period rather than to the instrument as such.

With regard to the incentives for long-term power plant investments, the picture is somewhat similar. The electricity companies were at first rather reluctant to decide on investments in new power plants and postponed their decisions until first experiences with the new instrument had been gained. However, in 2007, when many utilities disclosed their investment plans, it became evident that substantially more coal power capacities were planned than gas power capacities which are substantially less carbon intensive. Expectations regarding the future developments of coal and gas prices had apparently outperformed the expectations on the future carbon price. However, in January 2008 some of these investment plans were reversed after the European Commission has published its draft directive on the review of the EU ETS. This illustrates that power plant investment decisions indeed depend – at least to some extent – on the companies’ expectations with regard to the future development of the EU ETS. Nevertheless, the dominance of coal-fired power plants over less carbon intensive natural gas power plants still prevails in Germany even after the revisions of some of the investment plans.

All the same, there are at least some indications supporting the assumption that emissions trading has had an impact on both the operation of power plants and investment decisions for new power plants despite a rather generous allowance allocation. However, the performance of the new instrument in this regard might develop its full potential if the companies are confronted with real scarcity and a correspondingly higher allowance price.

6 Summary and conclusions

One major objective of the introduction of emissions trading in the European Union was to promote innovation towards mitigating climate change. Focusing on the German electricity industry – which alone accounts for one third of Germany's CO_2 emissions – this thesis has analyzed the extent to which this objective has been achieved up to now and how the design of the trading scheme could be improved towards achieving the this objective.

These questions have been tackled from two perspectives: first from a theoretical perspective and second from an empirical perspective. The theoretical analysis was largely based on neoclassical environmental economics by using an algebraic model which enabled comparison of the profits of the covered companies under various configurations of the analyzed design options and the derivation of their innovation incentives from a comparison of the results. The empirical analysis was based on two surveys of the German electricity industry – the first one being conducted prior to the start of the EU ETS, and the second following two and a half years of experience with the instrument – which allowed for the identification of concrete changes in the companies' perceptions and attitudes towards innovation due to the introduction of emissions trading.

A basis for these two methodological approaches to the core research questions was created through a thorough analysis of the particularities and characteristics of innovation in the German electricity industry in order establish the foundation for a scientifically sound analysis of potential innovation incentives and innovation effects. The analysis was rounded off with empirical scrutiny of available indicators which enable evaluation of whether emissions trading has already induced innovations to date. Four key results can be concluded from this approach.

(1) The responsibility for innovation in the electricity sector is divided between the electricity industry and the technology manufacturers

This conclusion is based on Schumpeter's (1942; 1939) three stages of innovation, starting with the invention as the first phase followed by development of marketable products and the diffusion of those innovative products to the market as the second and third phases respectively. The electricity industry is concerned with the diffusion of innovative technologies to the market. Their main task in the innovation process is to increase the market share of promising new technologies by dint of selecting those innovations which best fit their requirements and expectations. The manufacturers of generation and transmission technologies are predominantly concerned with the second phase in which inventions are further developed to marketable products. To a certain extent they also participate in the invention phase of the overall innovation process. However, this task is usually carried out together with universities and research institutes.

This separation of responsibilities in the overall innovation process distinguishes the electricity sector from other innovation intensive sectors such as car manufacturing or the chemical sector where the responsibilities of all three phases of the overall innovation process are usually integrated within one company. This vertical integration was also prevalent in the early years of the electricity sector in the late 19th century. At its beginning, the electricity sector was as vertically integrated as the car manufacturing or the chemical sector are today because the integration was useful as long as the product was still under development. However, alternate current at 220 V was introduced before the turn of the 19th century in Germany. The basic characteristics of the electricity industry's product have effectively not changed since then, making vertical integration no longer important.

The innovation interface between technology manufacturers and the electricity industry are investment decisions. Electricity companies contribute to the innovation process by selecting between alternative innovative technologies. Investments are to some extent a prerequisite of innovation in the electricity industry. Therefore, investment decisions are an important indicator for the innovation process in the electricity sector. The development of investment in absolute or relative terms can be considered an indicator for innovation cycles. Moreover, the structure of historical or projected investments provides important insights which technologies are considered most innovative by the electricity industry. The theoretical analysis therefore focused on the impacts of the configurations of the analyzed design options on investment incentives.

Alongside investment data, emission rates are another important indicator for analyzing innovation incentives in the electricity industry, particularly with regard to analysis of environmental innovations. This applies to the development of the emission rates of individual generation technologies or fuels and also to the emission rate of the electricity system as a whole. Likewise, emissions rates might also enable comparison of the environmental performance of competing electricity companies, although such data is usually difficult to obtain or calculate.

Investment was used as an important indicator both in the theoretical and empirical analysis while emissions rates were basically more relevant to examination of the innovation effects of the EU ETS that were already noticeable. However, due to time lags in the compilation of aggregated emission rates such data is not yet available.

Nevertheless, an important result of the comprehensive analysis of the history and the nature of innovation processes in the electricity industry is that the electricity industry usually contributes to the diffusion of innovative technologies rather than to the inventions themselves or to their development to marketable products.

(2) Innovation incentives considerably depend on the specific design of an emissions trading scheme

Design options which substantially determine the innovation incentives of an emissions trading scheme are the general policy framework in which such a scheme is embedded, the overall cap of the scheme which creates sufficient scarcity and several allocation provisions.

Investments in the electricity industry usually have an economic lifetime of 40 years and more. Predictability and long-term stability are therefore important characteristics which influence the propensity of companies to invest in new technologies. Political uncertainties which derive from short commitments and trading periods and the lack of a long-term mitigation perspective contribute to a delay of investments and innovation because they increase the option value of waiting for additional information to become available so that more informed decisions can be taken. This is particularly relevant when deciding whether to invest in gas or coal technologies since the option values of both alternatives react inversely to changes in the expectations of the carbon prices.

Thus, an agreement on a long-term mitigation path under the framework of the UNFCCC would also considerably improve the investment perspectives within the EU ETS. Such an agreement should preferably include a clear long-term target for the different groups of countries and binding commitments for the short and medium term. Since an extension of the commitment periods would reduce the transparency of the scheme because the compliance status would be checked less frequently, it would be more appropriate to decide on several periods in advance so that investors have a clear picture of the absolute targets for the next 15 to 20 years.

However, the long-term predictability of the EU ETS not only depends on an agreement under the UNFCCC framework but can also be promoted by internal decisions. The decision of the EU Council on long-term commitments in March 2007 and the perspectives provided in the Directive on the review of the EU ETS according to Art. 30 are important contributions to creating investment stability within the EU.

To establish an investment friendly environment it is essential that clear long-term targets and absolute short and medium commitments are agreed upon. In terms of the degree of innovation incentives, however, the level of the absolute commitments is crucial. A more stringent commitment will generally induce more innovation than a weaker commitment simply because a stringent commitment would establish higher carbon prices which, in turn, would allow for more advanced technologies to enter the market although they are still more expensive.

Besides these framework issues, time plan issues and the overall cap, several allocation provisions are relevant in terms of innovation incentives of emissions trading. Whether allowances are allocated for free or auctioned to incumbents does not directly influence innovation incentives. However, the type of allocation to incumbents can influence innovation incentives if new entrants are treated as incumbents after a certain period of time. Investors would anticipate future allocations with the effect that innovation incentives would be the stronger the more allowances allocated free of charge can be expected in the future. Evidently this effect will be the smaller the longer new installations are considered as new entrants.

The treatment of new entrants and closures has, in contrast, significant direct impact on innovation incentives of emissions trading. New entrants can consider the expected carbon price in their investment decisions in contrast to incumbents who did not have this opportunity when they decided on their investment because the EU ETS was not yet established then. From an efficiency perspective it would be appropriate if new entrants buy all allowances on the market. Free allocation of allowances to new entrants can thus be considered an investment subsidy which basically also fosters innovation.

A closure provision urges operators of old installations to return their allowances received via free allocation to the authorities. It is often considered unfair if operators can retain these freely received allowances although they do not need them anymore. In contrast to the alleged name, a closure provision does not promote the closure of old installations but rather contributes to the extension of their lifetime because operators include the value of the potentially forfeited allowances into their calculations on continuing operation. A closure provision basically delays innovation since it promotes keeping old inefficient installations in the market which initially would have been crowded out through the introduction of emissions trading.

Both the new entrants and the closure provisions distort the market from an environmental economics perspective and increase the available generation capacity. Specifically the distorting effects of the closure provisions can partly be alleviated through transfer and malus rules. However, the analysis has shown that the alleviating effects are relatively small and that they do not at all offset the distortions created by the closure provision. The overall effect on CO_2 emissions will be positive unless the allocation to new entrants is not differentiated by fuel because new installations are in general more efficient than old installations. However, the CO_2 reductions of the electricity industry would be smaller if the allocation to new entrants depends on the fuel than in the undifferentiated case because incentives to shift to less carbon intensive fuels such as natural gas would be eliminated. Fuel specific new entrant provisions would therefore delay the transition to a less carbon intensive electricity system but indirectly promote such transition in other sectors due to the overall cap.

The theoretical analysis clearly confirms the hypotheses presented in the introduction to this thesis: the design of an emissions trading scheme effectively influences the level and structure of innovation and technological change in the electricity industry. Innovation incentives of emissions trading depend on the configuration of all mentioned design options, namely the general climate policy framework and its time plan, allocation rules particularly those for new entrants and closures, regulations on the transferability of allowances between commitment periods and last but not least the overall emission cap which determines above all the scarcity within the scheme.

From an innovation perspective, several conclusions can be drawn for the optimal design of an emissions trading scheme:

- A trading scheme needs to be embedded in a comprehensive climate policy with meaningful long-term targets and clear short-term commitments both at the global and at the EU level.
- Trading periods should not be extended beyond five years because this would considerably reduce the transparency of a trading scheme. However, to create long-

term stability for investment decisions, the emission caps should be fixed several periods in advance with the option to only strengthen them at a later stage if appropriate. Investors should have a clear picture of the targets for at least next 15 to 20 years.

- Free allocation to new entrants can only be justified as long as incumbents receive free allocation. And all new installations should receive the same per unit allocation independently of the fuel they use in order to not disturb the CO_2 scarcity signal.
- Closure provisions should be abolished so that allowances can be retained for several years after the closure of an installation. This would make a specific transfer rule obsolete and reduce the importance of a malus rule.

However, particularly the last two conclusions apply only as long as allowances are not fully auctioned off to all participants of a trading scheme. A transition from free allocation to auctioning would abolish the need for the innovation incentive disturbing specific treatment of closures and new entrants. The gradual introduction of full auctioning would thus not only make a trading scheme more simple and transparent but also contribute to the manifestation of the intrinsic innovation incentives of an emissions trading scheme.

(3) Emissions trading has already contributed to innovation in the electricity sector since and even prior to the introduction of the EU ETS

The two surveys have revealed additional insights with regard to innovation incentives of emissions trading in general and with regard to individual design options in particular. The results of the surveys basically also confirm the hypothesis that the level of innovation incentives and their structure are determined by the specific configurations of several design options.

Even before the start of emissions trading several “soft” institutional innovations such as the establishment of monitoring routines, the development of tools for comparing current emissions with available allowances, the integration of CO_2 into existing trading floors or the adaptation of their risk hedging strategies had been initiated in most of the companies. However, “hard” technological innovations which required decisions about substantial investments tended to be delayed at the beginning of emissions trading until more experiences with the new instrument had been gained.

Nevertheless, after two and a half years of experience with the new instrument the debate on power plant investments gained more momentum. Several companies revealed their investment plans and confirmed that the expected carbon price is – after fuel and electricity prices expectations – already the third most important factor in their investment decisions. Expected carbon prices are considered in the companies’ investment decisions and play an important role when it comes to the question of which technology or fuel should be applied.

For internationally operating electricity companies emissions trading may also influence the decisions of where to locate which type of technology or fuel respectively. Some companies consider Germany in this respect basically as “coal friendly” due to its generous allocation provisions for new coal-fired power plants and prefer, therefore, to place their planned coal-fired power plants in Germany while gas fired installations will be located elsewhere in Europe.

Some of the specific provisions of the German NAP have also influenced the innovation incentives of emissions trading, particularly the so-called 14 year rule and the malus rule. According to the first drafts of the NAP for the period 2008 to 2012, new installations would have received free allocation for 14 years from their year of commission onwards. Since most companies expected that this provision might not be extended to the third NAP, they advanced their investment plans in order to be able to commission particularly new coal-fired power plants before the end of the second commitment period in 2012. In its review of the German NAP the Commission, however, rejected this provision and accepted the plan only on the condition that the 14 year rule was abolished. To some extent the Commission’s decision alleviated the spike in the investment cycle initiated through time pressure of the first draft. The malus rule, according to which less efficient installations generally receive fewer allowances than more efficient installations, has induced efficiency improvements in old installations to a certain degree, thereby contributing to innovation.

Emissions trading has also spurred the development of certain technologies, particularly clean coal and renewable energies. Biomass has directly profited from emissions trading since companies with bivalent power plants tried to increase the share of carbon free biomass and substitute fuels at the expense of coal. However, many companies also confirmed that emissions trading has also intensified their interest in other renewable technologies despite the fact that renewables are principally promoted by the German Renewable Energy Sources Act. The introduction of a carbon price has clearly enforced the perception that renewables will play an important role in the future electricity supply.

Clean coal and particularly CCS are certainly the technologies which benefited most from emissions trading. In 2004, before the start of the trading scheme, these technologies received little attention. In 2007, this had substantially changed. First demonstration plants for CCS and IGCC power plants were either already under construction or in preparation. The large majority of the companies – not just the larger ones – believed that those technologies would not receive the attention they receive today without the introduction of a price for CO_2.

A final finding which supports the influence of emissions trading on innovation in the electricity industry is the increased attention which is paid to CDM and JI. In 2004, the flexible Kyoto mechanisms were almost not an issue. In 2007, this had considerably changed. All of the larger companies had established specific departments for the acquisition of credits from CDM and JI and have also allocated significant financial and personal resources to these departments.

(4) During the pilot phase, the EU ETS has not developed its full potential in terms of incentivizing innovations in the electricity industry

Definitive empirical evidence for emissions trading's impact on innovation is not yet available. That is because innovation is a long-term phenomenon which can – with some degree of certainty – only be detected after several years. Taking into account that some indicators such as differentiated and aggregated CO_2 emissions are only available after a considerable time lag of almost two years, it is even more difficult to identify the impacts of emissions trading. The few indications that are currently available provide somewhat mixed results.

A change in the operation of power plants, in particular a fuel shift to less carbon intensive fuels, should be reflected in the aggregated fuel use structure for electricity generation. Yet the annual variations in fuel structure do not show any specific differences based on the introduction of emissions trading but are instead rather similar to previous years. However, fuel price developments might have offset the incentives of emissions trading with the result that the induced changes could not be detected in the fuel structure. Model simulations support the view that emissions trading has induced some fuel shift from coal to gas and biomass and that it has contributed to a reduction of CO_2 emissions by a few percentage points.

With regard to power plant investments the picture is somewhat similar. After the utilities had abandoned their reluctance to invest in new power plants because they wanted to gain more experiences with the new instruments before taking long-term investment decisions, it became clear that most companies preferred coal to gas power plants despite their higher carbon costs. Fuel price expectations had evidently outperformed carbon price projections. However, in early 2008 the Commission published their proposal to abandon free allocation to the electricity industry and to auction all allowances from 2013 onward. Since this would also remove any preferential treatment for new coal-fired power plants, some companies abolished or at least delayed their plans to invest in coal technologies.

This supports again the notion that the design of the trading scheme has an impact on the level and structure of induced innovation. However, the mixed incentives provided during the first trading period are one important reason why reliable evidence of the impacts of emissions trading on innovation incentives is yet not available. Carbon prices rose strongly to levels of 30 €/EUA but collapsed immediately after it became clear in April 2006 that too many allowances had been allocated for the first trading period. Innovation incentives would certainly have been stronger and easier to detect with a more stringent allocation of allowances during the first period. In this sense the weakness of evidence concerning the innovation impacts of emissions trading should be attributed to poor implementation of the scheme in the first trading period rather than to the instrument itself.

Overall conclusion

The analysis of the EU ETS has revealed some indications that the instrument has basically worked as originally intended although it has certainly not yet developed its full potential in terms of promoting innovation towards a more climate friendly electricity system. The pilot phase was helpful for identifying flaws and weaknesses of the current implementation of the instrument. The experiences of the pilot phase should be used as a basis for the development of an improved design. From an environmental innovation perspective, the following improvements are essential:

- Closure provisions should be abolished as soon as possible because they basically extend the lifetime of old installations, thereby delaying innovation. The distorting effect can be alleviated through specific provisions such as a transfer or a malus rule. However, these additional provisions only attenuate the distortion to some extent. Removing closure provisions would make such specific rules obsolete and both reduce the complexity and improve the transparency of the trading scheme.
- Fuel specific allocation to new entrants should also be abandoned since it eliminates – at least partly – the incentive to shift investments towards technologies which use more carbon friendly fuels such as natural gas or biomass. If certain promising innovative technologies need additional support to enhance their market penetration, this should be arranged using flanking instruments outside of the carbon market.
- Introducing full auctioning for the electricity industry would remedy both of the before mentioned weaknesses. Free allocation to new entrants can only be justified as long as incumbents receive free allowances as well. In addition, closure provisions are obsolete if no free allocation of allowances takes place. Auctioning would enable the removal of the provisions which distort the innovation incentives of emissions trading and at the same time eliminate the windfall profits generated by the free allocation of allowances. In this way, auctioning would not only make the trading scheme less complex but would also improve its fairness.
- Innovation incentives could also be enhanced by improving the investment stability of the trading scheme. For this purpose it is important that the trading scheme is embedded in an overall climate change policy with meaningful long-term targets and stringent short and medium term commitments. Commitment periods should not be extended because this would reduce the transparency of the scheme. However, the investment stability would be improved if the commitments are agreed for several periods in advance so that investors always have a clear perspective of at least 15 to 20 years ahead.

The Directive for amending the EU ETS which was adopted in December 2008 has already taken on board some of these suggestions, most notably the transition from free allocation to auctioning which should be the rule for the entire electricity industry in Germany from 2013 onwards. It can be expected that the innovation incentives of the EU ETS will be considerably boosted due to these changes.

Whether these expectations will indeed be fulfilled or not can only be verified in the future. Innovation is a continuous process and should therefore be observed over a longer period of time. The time horizon covered in this thesis is relatively small compared to the time requirements of transition processes within a large infrastructure system like the electricity industry. Therefore, resuming this research on the innovation incentives of emissions trading in the German electricity industry at a later stage might well be worthwhile; then the analysis could be based on data spanning a longer timeframe. The panel analysis could also, for example, be carried out again some time after a post 2012 regime has been agreed upon under the UNFCCC, possibly in late 2010 or early 2011. It could also be repeated a few years after the changes suggested in the Commission's draft directive for the review of the EU ETS have become effective, for example in mid-2014.

Moreover, at these points in time, longer time series will also be available for important indicators such as the structure of fuel consumption for electricity generation, the development of power plant investments by fuel and technology or the trend of the respective CO_2 emissions factors. This would undoubtedly facilitate an even clearer determination of changes in innovation process induced by emissions trading.

7 References

2002/358/CE (Commission of the European Communities): Council Decision concerning the approval, on behalf of the European Community, of the Kyoto Protocol to the United Nations Framework Convention on Climate Change and the joint fulfilment of commitments thereunder. In: Official Journal of the European Union. L 130. pp 1-20. Brussels. http://eur-lex.europa.eu/LexUriServ/site/en/oj/2002/l_130/l_13020020515en00010020.pdf

2003/87/EC (European Parliament and Council of the European Union): Directive establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC. In: Official Journal of the European Union. L 275. pp 32-46. Strasbourg, Brussels. http://eur-lex.europa.eu/LexUriServ/site/en/oj/2003/l_275/l_27520031025en00320046.pdf

2004/101/EC (European Parliament and Council of the European Union): Directive amending Directive 2003/87/EC establishing a scheme for greenhouse gas emission allowance trading within the Community, in respect of the Kyoto Protocol's project mechanisms. In: Official Journal of the European Union. L 338. pp 18-23. Strasbourg, Brussels. http://europa.eu.int/eur-lex/lex/LexUriServ/site/en/oj/2004/l_338/l_33820041113en00180023.pdf

2004/156/EC (Commission of the European Communities): Commission Decision establishing guidelines for the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council. In: Official Journal of the European Union. L 59. pp 1-74. Brussels. http://eur-lex.europa.eu/LexUriServ/site/en/oj/2004/l_059/l_05920040226en00010074.pdf

AGEB (Arbeitsgemeinschaft Energiebilanzen) (ed.) 2007a: Bruttostromerzeugung in Deutschland von 1990 bis 2006 nach Energieträgern. http://www.ag-energiebilanzen.de/cms/verwaltung/files.php?path=../../daten/1187962763_91.0.77.229.pdf&name=BRD_Stromerzeugung1990-2006_22Aug2007.pdf&mime=application/pdf

AGEB (Arbeitsgemeinschaft Energiebilanzen) (ed.) 2007b: Einsatz von Energieträgern zur Stromerzeugung in Deutschland. http://www.ag-energiebilanzen.de/cms/verwaltung/files.php?path=../../daten/1187100877_91.0.92.54.xls&name=BE-STR.XLS&mime=application/vnd.ms-excel

Ahmad, S. 1966: On the Theory of Induced Innovation. In: Economic Journal. Vol. 76. pp 344-357

Ahman, M.; Burtraw, D.; Kruger, J.; Zetterberg, L. 2007: A Ten-Year Rule to guide the allocation of EU emission allowances. In: Energy Policy. Vol. 35. pp 1718-1730

arrhenius Institut (arrhenius Institut für Energie- und Klimapolitik) (ed.) 2007: Effekt Emissionshandel - Auswertung der Modellläufe für das Jahr 2006. unpublished personal communication as of 29 November 2007

Azar, C.; Dowlatabadi, H. 1999: A Review of Technical Change in Assessment of Climate Policy. In: Annual Review of Energy and the Environment. Vol. 24. pp 513-544

Bader, P. 2000: Europäische Treibhauspolitik mit handelbaren Emissionsrechten Empfehlungen für die Umsetzung der Kyoto-Verpflichtung vor dem Hintergrund US -amerikanischer Lizenzierungserfahrungen. Berlin

BASIC 2006: The Sao Paulo Proposal for an Agreement on Future International Climate Policy. Discussion Paper for COP-12 & COP-MOP-2. Nairobi. http://www.basic-project.net/data/SP_prop_rev_nairobi.pdf

bdew (Bundesverband der Energie- und Wasserwirtschaft) (ed.) 2007: Im Bau oder in Planung befindliche Kraftwerke - differenziert nach Jahr der voraussichtlichen Inbetriebnahme (Stand: 24. Oktober 2007). Berlin

Binswanger, H.P. 1974: A Microeconomic Approach to Innovation. In: Economic Journal. Vol. 84. pp 940-958

Bloom, N.; Bond, S.; van Reenen, J. 2007: Uncertainty and Investment Dynamics. In: Review of Economic Studies. Vol. 74. pp 391-415. http://cep.lse.ac.uk/textonly/people/vanreenen/papers/roes_7923.pdf

Blyth, W.; Yang, M. 2006: Impact of Climate Change Policy Uncertainty in Power Investment. IEA (International Energy Agency), IEA Working Papers LTO/2006/02. Paris

BMU (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit) 2003: Mehr als 2600 Anlagen vom Emissionshandel erfasst. http://www.bmu.de/pressearchiv/15_legislaturperiode/pm/5104.php

BMU (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit) 2006: Nationaler Allokationsplan 2008-2012 für die Bundesrepublik Deutschland. Berlin. http://www.bmu.de/files/emissionshandel/downloads/application/pdf/nap_2008_2012.pdf

BMU (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit) 2007a: Hintergrundpapier - Emissionshandel in der zweiten Handelsperiode 2008 - 2012 - Einfacher - wirksamer - effizienter. Berlin. http://www.bmu.de/files/pdfs/allgemein/application/pdf/hg_emissionshandel2008_2012.pdf

BMU (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit) 2007b: KfW Bankengruppe übernimmt Verkauf von CO2-Emissionszertifikaten. BMU-Pressedienst. Berlin. http://www.bmu.de/pressemitteilungen/aktuelle_pressemitteilungen/pm/pdf/40644.pdf

BMWA (Bundesministerium für Wirtschaft und Arbeit) 2003: Forschungs- und Entwicklungskonzept für emissionsarme fossil befeuerte Kraftwerke. Dokumentation. Berlin. http://www.fz-juelich.de/ptj/projekte/datapool/page/1329/doku527.pdf

BMWA (Bundesministerium für Wirtschaft und Arbeit) 2005: Innovation und neue Energietechnologien - Das 5. Energieforschungsprogramm der Bundesregierung. Berlin. http://www.bmwi.de/Dateien/BMWi/PDF/foerderdatenbank/energieforschungsprogramm,property=pdf,bereich=bmwi,sprache=de,rwb=true.pdf

BMWi (Bundesministerium für Wirtschaft und Technologie) 2007a: E-Energy - Informations- und kommunikationstechnologiebasiertes Energiesystem der Zukunft. Ein Förderwettbewerb des Bundesministeriums für Wirtschaft und Technologie. Berlin. http://www.bmwi.de/Dateien/BMWi/PDF/foerderdatenbank/e-energy-richtlinien,property=pdf,bereich=bmwi,sprache=de,rwb=true.pdf

BMWi (Bundesministerium für Wirtschaft und Technologie) (ed.) 2007b: Energiedaten - Zahlen und Fakten - Nationale und Internationale Entwicklung. Berlin. http://www.bmwi.de/BMWi/Redaktion/Binaer/energie-daten-gesamt,property=blob,bereich=bmwi,sprache=de,rwb=true.xls

BMWi (Bundesministerium für Wirtschaft und Technologie) (ed.) 2008: Energiedaten - Zahlen und Fakten - Nationale und Internationale Entwicklung. Berlin.

Bohn, T.; Marschall, H.-P. 1992: Die technische Entwicklung der Stromversorgung. In: Fischer, W. (ed.), Die Geschichte der Stromversorgung. Frankfurt/Main. pp 39-120

Böhringer, C.; Hoffmann, T.; Lange, A.; Löschel, A.; Moslener, U. 2004: Assessing Emission Allocation in Europe. An Interactive Simulation Approach. ZEW (Zentrum für Europäische Wirtschaftsforschung), Discussion Paper 04-40. Mannheim. ftp://ftp.zew.de/pub/zew-docs/dp/dp0440.pdf

Bonus, H. 1990: Preis- und Mengenlösungen in der Umweltpolitik. In: Jahrbuch für Sozialwissenschaften. Vol. 41. pp 343-358

Botterud, A.; Korpås, M. 2004: Modelling of power generation investment incentives under uncertainty in liberalised electricity markets. Dept.of Electrical Power Engineering, Norwegian University of Science and Technology Trondheim. http://www.saee.ch/saee2004/botterud.pdf

Brennan, M.J.; Schwartz, E.S. 1985: Evaluating Natural Resource Investments. In: The Journal of Business. Vol. 58 (2). pp 135-157

Buchner, B. 2007: Policy Uncertainty, Investment and Commitment Periods. IEA (International Energy Agency) COM/ENV/EPOC/IEA/SLT(2007)8. Paris. http://www.iea.org/textbase/papers/2007/Uncertainty_Investment&Commitment.pdf

Buchner, B.; Bosetti, V.; Carraro, C. 2004: Climate Policy and the Kyoto Protocol - Banking Provision. Does it Really Matter? FEEM (Fondazione ENI Enrico Mattei) Milan. http://www.esri.go.jp/jp/prj-2004_2005/kankyou/kankyou16/03-1-R.pdf

Buchner, B.; Carraro, C.; Ellerman, A.D. 2006: The Allocation of European Union Allowances: Lessons, Unifying Themes and General Principles. MITJPSPGC (MIT Joint Program on the Science and Policy of Global Change), Report 140. Cambridge, MA. http://web.mit.edu/globalchange/www/MITJPSPGC_Rpt140.pdf

BUND (Bund für Umwelt und Naturschutz) (ed.) 2007: BUND-Übersicht - 26 neue Kohlekraftwerke in Deutschland. Berlin. http://vorort.bund.net/klimaschutz/publikationen/publikationen_80/files/2573_uebersicht kohleseptember07.pdf

Burtraw, D.; Farrell, A.E.; Goulder, L.H.; Peterman, C. 2006: Chapter 5: Lessons for a cap-and-trade program. In: Hanemann, W.M.; Farrell, A.E. (ed.), The California Climate Change Center at UC Berkeley. Berkeley, CA. pp 195-241. http://calclimate.berkeley.edu/5_Cap_and_Trade.pdf

Burtraw, D.; Palmer, K.; Bharvirkar, R.; Paul, A. 2002: The Effect on Asset Values of the Allocation of Carbon Dioxide Emission Allowances. RFF (Resources for the Future), Discussion Paper 02–15. Washington, D.C. http://www.rff.org/Documents/RFF-DP-02-15.pdf

Bush, V. 1945: Science - The Endless Frontier. (Office of Scientific Research and Development) Washington DC. http://www.nsf.gov/about/history/vbush1945.htm

Butzen, P.; Fuss, C.; Vermeulen, P. 2002: The Impact of Uncertainty on Investment Plans. NBB (National Bank of Belgium), Working Papers - Research Series NBB Working Paper No. 24. Brussels. http://www.nbb.be/doc/oc/repec/reswpp/WP24.pdf

Cames, M.; Stronzik, M. 2002: Directive on the Implementation of EU-wide Emissions Trading COM(2001) 581. ZEW, Öko-Institut (Zentrum für Europäische Wirtschaftsforschung, Öko-Institut) Mannheim, Berlin. ftp://ftp.zew.de/pub/zew-docs/div/opinion.pdf

Capros, P.; Mantzos, L. 2000: The Economic Effects of EU-Wide Industry-Level Emission Trading to Reduce Greenhouse Gases. Results from the PRIMS Energy System Model. NTUA (National Technical University of Athens) Athens

Cass, L. 2005: Norm Entrapment and Preference Change: The Evolution of the European Union Position on International Emissions Trading. In: Global Environmental Politics. Vol. 5 (2). pp 38-60

CCAP (Center for Clean Air Policy) 1999: Design of a Practical Approach to Greenhouse Gas Emissions Trading Combined with Policies and Measures in the EC. Washington DC. http://europa.eu.int/comm/environment/docum/pdf/0087_ccap.pdf

Christiansen, A.C.; Wettestad, J. 2003: The EU as a frontrunner on greenhouse gas emissions trading: how did it happen and will the EU succeed? In: Climate Policy. Vol. 3. pp 3-18

Coase, R.H. 1960: The Problem of Social Cost. In: Journal of Law and Economics. Vol. 3 (October). pp 1-44

COM(1999) 230 (Commission of the European Communities): Preparing for Implementation of the Kyoto Protocol. Brussels. http://ec.europa.eu/environment/docum/pdf/99230_en.pdf

COM(2000) 87 (Commission of the European Communities): Green Paper on Greenhouse Gas Emissions Trading Within the European Union. Brussels. http://eur-lex.europa.eu/LexUriServ/site/en/com/2000/com2000_0087en01.pdf

COM(2001) 581 (Commission of the European Communities): Proposal for a Directive of the European Parliament and of the Council Establishing a Framework for Greenhouse Gas Emissions Trading within the European Community and Amending Council Directive 96/61/EC (Presented by the Commission). Brussels. http://eur-lex.europa.eu/LexUriServ/site/en/com/2001/com2001_0581en01.pdf

COM(2001) 708 final (Commission of the European Communities): Report from the Commission to the European Parliament and the Council under Council Decision 93/389/EEC as amended by Decision 99/296/EC for a monitoring mechanism of Community greenhouse gas emissions. Brussels. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2001:0708:FIN:EN:PDF

COM(2003) 830 (Commission of the European Communities): Communication from the Commission on guidance to assist Member States in the implementation of the criteria listed in Annex III to Directive 2003/87/EC establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC, and on the circumstances under which force majeure is demonstrated. http://eur-lex.europa.eu/LexUriServ/site/en/com/2003/com2003_0830en01.pdf

COM(2005) 703 (Commission of the European Communities): Communication from the Commission "Further guidance on allocation plans for the 2008 to 2012 trading period of the EU Emission Trading Scheme". Brussels. http://eur-lex.europa.eu/LexUriServ/site/en/com/2005/com2005_0703en01.pdf

COM(2006) 818 (Commission of the European Communities): Proposal for a Directive of the European Parliament and of the Council amending Directive 2003/87/EC so as to include aviation activities in the scheme for greenhouse gas emission allowance trading within the Community. http://ec.europa.eu/environment/climat/pdf/aviation_ets_com_2006_818-21273_en.pdf

COM(2007) 2 (Commission of the European Communities): Limiting Global Climate Change to 2 degrees Celsius - The way ahead for 2020 and beyond. Brussels. http://eur-lex.europa.eu/LexUriServ/site/en/com/2007/com2007_0002en01.pdf

COM(2008) 16 (Commission of the European Communities): Proposal for a Directive of the European Parliament and of the Council amending Directive 2003/87/EC so as to improve and extend the greenhouse gas emission allowance trading system of the Community. Brussels. http://ec.europa.eu/environment/climat/emission/pdf/com_2008_16_en.pdf

COM(2008) 16 provisional (Commission of the European Communities): Proposal for a Directive of the European Parliament and of the Council amending Directive 2003/87/EC so as to improve and extend the greenhouse gas emission allowance trading system of the Community. Brussels. http://ec.europa.eu/environment/climat/emission/pdf/ets_revision_proposal.pdf

COM(2008) 16 provisional (Commission of the European Communities): Proposal for a Directive of the European Parliament and of the Council amending Directive 2003/87/EC so as to improve and extend the greenhouse gas emission allowance trading system of the Community. Brussels. http://ec.europa.eu/environment/climat/emission/pdf/ets_revision_proposal.pdf

Cramton, P.; Kerr, S. 2002: Tradeable Carbon Permit Auctions - How and why to auction not grandfather. In: Energy Policy. Vol. 30. pp 333-345. http://www.cramton.umd.edu/papers2000-2004/02ep-tradeable-carbon-permit-auctions.pdf

Cronshaw, M.B.; Kruse, J.B. 1996: Regulated Firms in Pollution Permit Markets With Banking. In: Journal of Regulatory Economics. Vol. 9. pp 179-189

Dales, J.H. 1968: Land, Water, and Ownership. In: The Canadian Journal of Economics. Vol. 1 (4). pp 791-804

Damro, C.; Luaces Méndez, P. 2003: Emissions Trading at Kyoto: From EU Resistance to Union Innovation. In: Environmental Politics. Vol. 12 (2). pp 71-94

DB 2001: Der Informationsgehalt von Umfragedaten zur erwarteten Preisentwicklung für die Geldpolitik. In: Deutsche Bundesbank Monatsberichte. pp 35-50. http://www.bundesbank.de/download/volkswirtschaft/mba/2001/200101mba_umfragepreise.pdf

DeCanio, S.J.; Howarth, R.B.; Sanstad, A.H.; Schneider, S.H.; Thompson, S.L. 2000: New Directions in the Economics and Integrated Assessment of Global Climate Change. Pew Center on Global Climate Change Arlington. http://www.pewclimate.org/docUploads/directions.pdf

DEFRA (Department for Environment, Food and Rural Affairs) 2003: Commentary on preliminary 1st year results and 2002 transaction log. Press Release. London defra (Department for Environment Food and Rural Affairs) 2007: Taking Forward the UK Climate Change Bill: The Government Response to Pre-Legislative Scrutiny and Public Consultation. London. http://www.official-documents.gov.uk/document/cm72/7225/7225.pdf

DEHSt (Deutsche Emissionshandelsstelle) (ed.) 2004: Emissionsfaktoren und Kohlenstoffgehalte. Berlin. http://www.dehst.de/cln_006/nn_476194/SharedDocs/Downloads/__Archiv/Antragstellung__dl/Emissionsfaktoren__und__C-Gehalte,templateId=raw,property=publicationFile.pdf/Emissionsfaktoren_und_C-Gehalte.pdf

DEHSt (Deutsche Emissionshandelsstelle im Umweltbundesamt) 2005: Implementation of emissions trading in the EU - national allocation plans of all EU States - Brief fact sheets of EU member state allocation plans. Berlin. http://www.dehst.de/cln_007/nn_593634/SharedDocs/Downloads/EN/ETS/EU__NAP__Vergleich,templateId=raw,property=publicationFile.pdf/EU_NAP_Vergleich

Destatis (Statistisches Bundesamt Deutschland) (ed.) 2005: STATIS-Archiv-CD - Statistische Zeitreihen von 1950 - 2003 (3 CDs). Wiesbaden. https://www-ec.destatis.de/csp/shop/sfg/vollanzeige.csp?ID=1015868&CSPCHD=000000010003NjYJh5xeJ02245138463

Destatis (Statistisches Bundesamt Deutschland) (ed.) 2007a: Beschäftigung, Umsatz, Investitionen und Kostenstruktur der Unternehmen in der Energie- und Wasserversorgung. Vol. Fachserie 4 Reihe 6.1. Wiesbaden

Destatis (Statistisches Bundesamt Deutschland) (ed.) 2007b: Index der Erzeugerpreise gewerblicher Produkte. 61241BJ007. Wiesbaden

Destatis (Statistisches Bundesamt Deutschland) (ed.) 2007c: Investitionserhebung im Verarb. Gewerbe, Bergbau 1995 - 2005. 42231BJ002, 42231BJ102. Wiesbaden

Deutscher Bundestag 1990: 3. Bericht der Enquete-Kommission Vorsorge zum Schutz der Erdeatmosphäre zum Thema Schutz der Erde. Bundestagsdrucksache 11/8030. http://dip.bundestag.de/btd/11/080/1108030.pdf

Deutscher Bundestag 2002: Endbericht der Enquete-Kommission "Nachhaltige Energieversorgung unter den Bedingungen der Globalisierung und der Liberalisierung". Bundestagsdrucksache 14/9400. http://dip.bundestag.de/btd/14/094/1409400.pdf

DG ENV (Commission of the European Communities, Directorate-General Environment) 2001: Final Report: ECCP Working Group 1 "Flexible Mechanisms". Brussels. http://ec.europa.eu/environment/climat/pdf/final_report.pdf

DG ENV (Commission of the European Communities, Directorate-General Environment) 2004: EU Emissions Trading. An Open Scheme Promoting Global Innovation to Combat Climate Change. Brussels. http://ec.europa.eu/environment/climat/pdf/emission_trading3_en.pdf

DG ENV (Commission of the European Communities, Directorate-General Environment) 2007: Final Report of the 3rd meeting of the ECCP working group on emissions trading on the review of the EU ETS on Further Harmonisation and Increased Predictability, 21 - 22 May 2007. Brussels. http://ec.europa.eu/environment/climat/emission/pdf/070521_22_final_report_m3_tc.pdf

DG TREN (Commission of the European Communities,Directorate-General Energy and Transport) 2007: EU Energy in Figures Pocket Book 2007. Brussels. http://ec.europa.eu/dgs/energy_transport/figures/pocketbook/doc/2007/2007_energy_en.xls

Dixit, A.K.; Pindyck, R.S. 1994: Investment under Uncertainty. Princeton

Dushnitsky, G.; Lenox, M.J. 2005: When do incumbents learn from entrepreneurial ventures? Corporate venture capital and investing firm innovation rates. In: Research Policy. Vol. 34. pp 615-639. http://rael.berkeley.edu/files/2007/NemeKamm_EP07.pdf

Ecofys 2007: Future International Action on Climate Change Network. http://www.fiacc.net/home_page.htm

ECX (European Climate Exchange) 2008: Historical data - ECX CFI Futures Contract. http://www.europeanclimateexchange.com/content.asp?id=4&sid=Futures%20PriceV

EEA (European Environment Agency) 2007a: Annual European Community greenhouse gas inventory 1990-2005 and inventory report 2007. Copenhagen. http://reports.eea.europa.eu/technical_report_2007_7/en

EEA (European Environment Agency) 2007b: EPER - The European Pollutant Emission Register. http://www.eper.ec.europa.eu/eper/, accessed on 2007/09/15b

EEX (European Electricity Exchange) (ed.) 2007: Marktdaten. http://www.eex.com/de/Downloads/Marktdaten

EEX (European Energy Exchange) 2008: Ergebnisse Strom. http://www.eex.com/de/Downloads/Marktdaten, accessed on 2008/05/22

Ellerman, A.D. 2006: New Entrant and Closure Provisions: How do they distort? MIT CEEPR (Massachusetts Institute of Technology - Center for Energy and Environmental Policy Research), Working Papers WP-2006-013. Cambridge, MA. http://web.mit.edu/ceepr/www/2006-013.pdf

Ellerman, A.D.; Joskow, P.L.; Schmalensee, R.; Montero, J.-P.; Bailey, E.M. 2000: Markets for Clean Air. The U.S. Acid Rain Program. Cambridge, MA

Endres, A. 2007: Umweltökonomie - Lehrbuch. Stuttgart, 3. ed.

Engel, D.; Keilbach, M. 2002: Firm Level Implications of Early Stage Venture Capital Investment - An Empirical Investigation. ZEW (Zentrum für Europäische Wirtschaftsforschung), Discussion Paper 02-82. Mannheim. ftp://ftp.zew.de/pub/zew-docs/dp/dp0282.pdf

Erdmann, G. 1993: Elemente einer evolutorischen Innovationstheorie. Berlin

Ernst & Young 2006: Energiemix 2020 - Szenarien für den deutschen Stromerzeugungsmarkt bis zum Jahr 2020. Düsseldorf, Hamburg. http://www.ey.com/global/download.nsf/Germany/Studie_Energiemix2020_2006/$file/Studie_Energiemix2020_2006.pdf

EU COM (Commission of the European Communities) 2007a: Allocation plans and decision for 2005 to 2007. http://ec.europa.eu/environment/climat/first_phase_ep.htm

EU COM (Commission of the European Communities) 2007b: Commission adopts amendment decision on the Slovak National Allocation Plan for 2008 to 2012. Press Release. Brussels. http://ec.europa.eu/environment/climat/pdf/press_release_sk.pdf

EU COM (Commission of the European Communities) 2007c: Community transaction log. http://ec.europa.eu/environment/ets/

EU COM (Commission of the European Communities) 2007d: Emissions trading - Commission announces linkage EU ETS with Norway, Iceland and Liechtenstein. Brussels. http://europa.eu/rapid/pressReleasesAction.do?reference=IP/07/1617&format=PDF&aged=0&language=EN&guiLanguage=de

EU Council (Council of the European Union) 2007: Presidency Conclusions European Council 8/9 March 2007. Brussels. http://www.consilium.europa.eu/ueDocs/cms_Data/docs/pressdata/en/ec/93135.pdf

EWI; Prognos (Energiewirtschaftliches Institut an der Universität zu Köln, Prognos AG) 2007: Energieszenarien für den Energiegipfel 2007. Basel, Köln. http://www.bundesregierung.de/Content/DE/Artikel/2007/07/Anlage/2007-07-03-energieszenarien,property=publicationFile.pdf

Fees, E. 1997: Mikroökonomie - Eine spieltheoretisch- und anwendungsorientierte Einführung. Marburg

Feldenkirchen, W. 1995: Siemens 1918 - 1945. Munich

Felderer, B.; Homburg, S. 1987: Makroökonomik und neue Makroökonomik. Berlin et al., 3rd. ed.

Fischer, C. 2005: Technical innovation and design choices for emissions trading and other climate policies. In: Hansjürgens, B. (ed.), Emissions Trading for Climate Policy - US and European Perspectives. Cambridge, MA. pp 37-52

Flauger, J. 2007: Kraftwerks-Projekten droht das Aus. In: Handelsblatt, issue of 05.09.2007. http://www.handelsblatt.com/news/_pv/_p/200038/_t/ft/_b/1318607/default.aspx/index.html

Freeman, C. 1994: The economics of technical change. In: Cambridge Journal of Economics. Vol. 18. pp 463-514

Freeman, C.; Soete, L. 1997: The economics of industrial innovation. Cambridge, MA, 3. ed.

Frémont, R. 2006: Coal becomes less attractive. In: Tendances Carbone. Vol. 1 (2). p.1. http://www.caissedesdepots.fr/IMG/pdf/tendances_carbone_n2_eng.pdf

Fritsch, M.; Wein, T.; Ewers, H.-J. 2003: Marktversagen und Wirtschaftspolitik. Munich, 4. ed.

Gagelmann, F. 2006: Innovation effects of tradable emission allowance schemes: The treatment of new entrants and shutdowns. UFZ (Zentrum für Umweltforschung), Discussion Papers 4/2006. Leipzig. http://www.ufz.de/data/dp2006044484.pdf

Gagelmann, F.; Frondel, M. 2005: The impact of emission trading on innovation - science fiction or reality? In: European Environment. Vol. 15 (4). pp 203-211

Godby, R.W.; Mestelman, S.; Muller, R.A.; Weiland, J.D. 1997: Emissions Trading with Shares and Coupons when Control over Discharges Is Uncertain. In: Journal of Environmental Economics and Management. Vol. 32. pp 359-381

Goulder, L.H.; Schneider, S.H. 1999: Induced technological change and the attractiveness of CO2 abatement policies. In: Resource and Energy Economics. Vol. 21 (3-4). pp 211-253

Graichen, P.; Requate, T. 2003: Der steinige Weg von der Theorie in die Praxis des Emissionshandels - Die EU-Richtlinie zum CO2-Emissionshandel und ihre nationale Umsetzung. CAU (Christian-Albrechts-Universität Kiel), Economics Working Paper No 2003-08. Kiel. http://opus.zbw-kiel.de/volltexte/2003/852/pdf/EWP-2003-08.pdf

Griliches, Z. 1957: Hybrid Corn: An exploration in the economics of technical change. In: Econometrica. Vol. 48. pp 501-522

Griliches, Z. 1992: The Search for R&D Spillovers. In: Scandinavian Journal of Economics. Vol. 94 (0). pp 29-47

Grubb, M.; Koehler, J. 2000: Induced technical change: Evidence and implications for energy-environmental modelling and policy. Cambridge University, Department of Applied Economics, Working Paper Cambridge. http://www.econ.cam.ac.uk/dae/repec/cam/pdf/wp0031.pdf

Grubb, M.; Neuhoff, K. 2006: Allocation and competitiveness in the EU emissions trading scheme: policy overview. In: Climate Policy. Vol. 6. pp 7-30. http://www.climate-strategies.org/uploads/6_grubb.pdf

Gruber, E.; Schleich, J. 2003: Barriers to energy efficiency - an econometric analysis of determinants. In: ECEEE (European Council for an Energy Efficient Economy) (ed.), 2003 Summer Study – Proceedings. Stockholm. pp 1033-1039. http://test.eceee.org/library_links/proceedings/2003/abstract/5166gruber.lasso

Gugele, B.; Ritter, M. 2001: European Community and Member States greenhouse gas emission trends 1990-99. ETC/ACC (European Topic Centre on Air and Climate Change), European Environment Agency Topic report 10/2001. Copenhagen. http://reports.eea.europa.eu/topic_report_2001_10/en/topic_10_web.pdf

Hahn, R.W.; Stavins, R. 1991: Incentive-Based Environmental Regulation: A New Era from an Old Idea?
13. In: Ecology Law Quarterly. Vol. 18 (1). pp 1-42

Hansjürgens, B. 2005: Introduction. In: Hansjürgens, B. (ed.), Emissions Trading for Climate Policy. Cambridge, MA et al. pp 1-14

Harrison, D.Jr. 1999: Turning theory into practice for emissions trading in the Los Angeles air basin. In: Sorrell, S.; Skea, J. (ed.), Pollution for Sale. Emissions Trading and Joint Implementation. Cheltenham, Northampton: Edward Elgar. pp 63-82

Hauschildt, J. 2004: Innovationsmanagement. Munich, 3. ed.

Hicks, J. 1932: The theory of wages. London

Hillebrand, B.; Löbbe, K.; Clausen, H.; Dehio, J.; Halstrick-Schwenk, M.; von Loeffelholz, H.D.; Moos, W.; Storchmann, K.-H. 2000: Nachhaltige Entwicklung in Deutschland - Ausgewählte Problemfelder und Lösungsansätze. Essen. Hillebrand et al. (2000) Nachhaltige Entwicklung in Deutschland - Ausgewählte Problemfelder und Lösungsansätze, Essen [Untersuchungen des RWI, Heft 36].pdf

Hoibye, G. 1999: Designing a scheme for SO2 trading in Norway. In: Sorrell, S.; Skea, J. (ed.), Pollution for sale. Emissions Trading and Joint Implementation. Cheltenham. pp 101-108

Hughes, T.P. 1983: Networks of Power: Electrification 1880-1930. Baltimore, MD

IEA (International Energy Agency) 2007: Tackling Investment Challenges in Power Generation in IEA Countries. Paris

IEPA (Illinois Environmental Protection Agency) 2007: Emissions Reduction Market System - A Brief Overview. http://www.epa.state.il.us/air/erms/overview.html, accessed on 2008/07/18

IPCC (Intergovernmental Panel on Climate Change) 2007a: Climate Change 2007 - Mitigation - Contribution of Working Group III to the Fourth Assessment Report. Cambridge, UK. http://www.ipcc.ch/ipccreports/ar4-wg3.htm

IPCC (Intergovernmental Panel on Climate Change) 2007b: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report. Cambridge, UK. http://www.gtp89.dial.pipex.com/chpt.htm

IPCC (Intergovernmental Panel on Climate Change) 2007c: Fourth Assessment Report - Climate Change 2007: Synthesis Report. Geneva. http://www.ipcc.ch/ipccreports/ar4-syr.htm

Ishii, J.; Yan, J. 2004: Investment under Regulatory Uncertainty: U.S. Electricity Generation Investment Since 1996. CSEM (Center for the Study of Energy Markets), Working Paper CSEM WP 127. Berkeley, CA. http://www.ucei.berkeley.edu/PDF/csemwp127.pdf

ITPS (Institute for Technological Prospective Studies) 2000: Preliminary Analysis of the Implementation of an EU-Wide Permit Trading Scheme on CO2 Emissions Abatement Costs, Results from the POLES model. Seville. http://ec.europa.eu/environment/enveco/climate_change/pdf/poles.pdf

Jaffe, A.B. 1998: The Importance of 'Spillovers' in the Policy Mission of the Advanced Technology Program. In: Journal of Technology Transfer. Vol. 23 (2). pp 11-19. http://www.atp.nist.gov/eao/jtt/jaffe.htm

Jaffe, A.B.; Newell, R.G.; Stavins, R.N. 2001: Technological Change and the Environment. RFF (Resources for the Future), Discussion Paper 00-47REV. Washington, D.C. http://www.rff.org/documents/RFF-DP-00-47.pdf

Jaffe, A.B.; Newell, R.G.; Stavins, R.N. 2002: Environmental Policy and Technological Change. In: Environmental and Resource Economics. Vol. 22. pp 41-69

Jung, C.; Krutilla, K.; Boyd, R. 1996: Incentives for Advanced Pollution Abatement Technology at the Industry Level: An Evaluation of Policy Alternatives. In: Journal of Environmental Economics and Management. Vol. 30. pp 95-111

Kalckreuth, U.v. 2000: Exploring the Role of Uncertainty for Corporate Investment Decisions in Germany. Economic Research Group of the Deutsche Bundesbank, Discussion paper 5/00. Frankfurt/Main. http://opus.zbw-kiel.de/volltexte/2006/4141/pdf/200005dkp.pdf

Kamien, M.I.; Schwartz, N.L. 1968: Optimal "Induced" Technical Change. In: Econometrica. Vol. 36 (1). pp 1-17

Kantzenbach, E. 1967: Die Funktionsfähigkeit des Wettbewerbs. Göttingen

Kemfert, C.; Kohlhaas, M.; Truong, T.; Protsenko, A. 2006: The environmental and economic effects of European emissions trading. In: Climate Policy. Vol. 6. pp 441-455. http://www.earthscanjournals.com/cp/006/0441/0060441.pdf http://www.climate-strategies.org/uploads/CP_6_4_08_Kemfert_edited.pdf

Klepper, G.; Peterson, S. 2004: The EU emissions trading scheme allowance prices, trade flows and competitiveness effects. In: European Environment. Vol. 14 (4). pp 201-218. http://www3.interscience.wiley.com/cgi-bin/fulltext/109584419/PDFSTART

Kletzan, D.; Köppl, A.; Kratena, K.; Bliem, M. 2002: Design und ökonomische Evaluierung eines Österreichischen CO_2-Pilot-Trading-Systems. WiFo (Österreichisches Instituts für Wirtschaftsforschung) Vienna. http://www.wifo.ac.at/wwa/servlet/wwa.upload.DownloadServlet/bdoc/S_EMISSION_TRADING.PDF

Kling, C.; Rubin, J. 1997: Bankable permits for the control of environmental pollution. In: Journal of Public Economics. Vol. 64. pp 101-115

Kneese, A.V.; Schultze, C.L. 1975: Pollution, Prices, and Public Policy. Washington DC. http://www.questia.com/PM.qst?a=o&d=13761017

Kolk, J.v.d.; Harmsen, H. 2002: Trading for a better environment - Feasibility of CO_2 emission trading in the Netherlands. KPMG Milieu De Meern. http://www.ieta.org/ieta/www/pages/getfile.php?docID=152

Laurikka, H.; Koljonen, T. 2006: Emissions trading and investment decisions in the power sector-a case study in Finland. In: Energy Policy. Vol. 34. pp 1063-1074

Leiby, P.; Rubin, J. 2001: Intertemporal Permit Trading for the Control of Greenhouse Gas Emissions. In: Environmental and Resource Economics. Vol. 19. pp 229-256

Lijesen, M.G. 2007: The real-time price elasticity of electricity. In: Energy Economics. Vol. 29 (2). pp 249-258

Löschel, A. 2001: Technological Change in Economic Models of Environmental Policy: A Survey. ZEW (Zentrum für Europäische Wirtschaftsforschung), Discussion Paper 01-62. Mannheim. ftp://ftp.zew.de/pub/zew-docs/dp/dp0162.pdf

Lucas, R.E. 1988: On the Mechanics of Economic Development. In: Journal of Monetary Economics. Vol. 22. pp 3-42. http://www.uac.pt/~amenezes/macroeconomiaII/macroeconomiaII_20062007/papers/lucas1988.pdf

MacCrimmon, K.R.; Wehrung, D.A. 1984: The Risk In-Basket. In: Journal of Business. Vol. 57. pp 367-387

Mackenzie, I.A.; Hanley, N.; Kornienko, T. 2007: The optimal initial allocation of pollution permits: a relative performance approach. In: Environmental and Resource Economics. Vol. DOI: 10.1007/s10640-007-9125-4. http://www.springerlink.com/content/b33537t6024001v7

Manne, A.; Richels, R. 1992: Buying Greenhouse Insurance: The Economic Costs of CO2 Emission Limits. Cambridge, MA

Mansfield, E. 1968: Industrial Research and Technological Innovation: An Econometric Analysis. New York

Matschoss, C.; Schulz, E.; Gross, A.T. 1934: 50 Jahre Berliner Elektrizitäts Werke, 1884-1934. Berlin

Matthes, F.C.; Neuhoff, K. 2006: Auctioning in the European Union Emissions Trading Scheme. (Öko-Institut, University of Cambridge). http://climatestrategies.org/uploads/Auctioning_in_the_EU_ETS_-_Report.pdf?PHPSESSID=a5a93e99ba2c9f8b856bbd8ff47234ea

Mayring, P. 2003: Qualitative Inhaltsanalyse - Grundlagen und Techniken. Weinheim, 8th. ed.

McDonald, R.; Siegel, D. 1985: The Value of Waiting to Invest. In: Quarterly Journal of Economics. Vol. 101. pp 707-728

Milliman, S.R.; Prince, R. 1989: Firm incentives to promote technological change in pollution control. In: Journal of Environmental Economics and Management. Vol. 17. pp 247-265

MoE (Ministry of the Environment) 2007: The Midnight Sun Dialogue on Climate Change. Discussion and Background Papers. Riksgränsen. http://www.sweden.gov.se/content/1/c6/08/40/82/add2137b.pdf

Müller, E. 1996: Stand und Perspektiven der deutschen CO_2-Minderungspolitik. Presented at the conference "Fachtagung "Klimaschutz als Strategie - Innovative Ansätze zur Verminderung energiebedingter CO_2 Emissionen"" Berlin

Nelson, R.R.; Winter, S.G. 1982: An Evolutionary Theory of Economic Change. Cambridge, MA

NETT (National Emissions Trading Taskforce) 2006: Possible Design for a National Greenhouse Gas Emissions Trading Scheme. Discussion Paper. http://www.emissionstrading.nsw.gov.au/__data/assets/pdf_file/0010/2017/Discussion_Paper_-_Full_document.pdf

Neveling, S.; Bumke, S.; Dietrich, J.-H. 2002: Ansätze wirtschaftswissenschaftlicher und soziologischer Innovationsforschung. In: Eifert, M.; Hoffmann-Riem, W. (ed.), Innovation und rechtliche Regulierung: Schlüsselbegriffe und Anwendungsbeispiele rechtswissenschaftlicher Innovationsforschung. Baden-Baden. p 364. http://www2.jura.uni-hamburg.de/ceri/download04.pdf

Nordhaus, W.D. 1994: Managing the Global Commons: The Economics of Climate Change. Cambridge, MA

Nordhaus, W.D. 2002: Modeling Induced Innovation in Climate-Change Policy. In: Grübler, A.; Nakicenovic, N.; Nordhaus, W.D. (ed.), Technological Change and the Environment. Washington DC. pp 182-209. http://nordhaus.econ.yale.edu/induced_innovation_preprint.pdf

Nussbaum, H. 1968: Versuche zur reichsgesetzlichen Regelung der deutschen Elektrizitatswirtschaft und zu ihrer Überfuhrung in Reichseigentum, 1909 bis 1914Jahrbuch für Wirtschaftsgeschichte. Berlin

Oanda 2008: FXHistory - historical currency exchange rates. http://www.oanda.com/convert/fxhistory?lang=de, accessed on 2008/05/22

Oberndorfer, U.; Rennings, K.; Sahin, B. 2006: The Impacts of the European Emissions Trading Scheme on Competitiveness and Employment in Europe, a Literature Review. ZEW (Center for European Economic Research) Mannheim. http://assets.panda.org/downloads/zew_eu_ets_impacts_full_report.pdf

Oberthür, S.; Ott, H. 1999: The Kyoto Protocol: International Climate Policy for the 21st Century. Berlin

OECD; Eurostat (Organisation for Economic Co-operation and Development; Eurostat) 1996: Oslo Manual - The Measurement of Scientific and Technological Activities - Proposed Guidelines for Collecting and Interpreting Technological Innovation Data. Paris. http://www.oecd.org/dataoecd/35/61/2367580.pdf

Pearce, D.W.; Turner, R.K. 1990: Economics of natural resources and the environment. London

Pedersen, S.L. 2000: The Danish CO2 Emissions Trading System. In: RECIEL. Vol. 9 (3). pp 223-237

Phaneuf, D.J.; Requate, T. 2002: Incentives for Investment in Advanced Pollution Abatement Technology in Emission Permit Markets with Banking. In: Environmental and Resource Economics. Vol. 22. pp 369-390

Philibert, C.; Reinaud, J. 2004: Emissions Trading: Taking Stock and Looking Forward. IEA (International Energy Agency) Paris. http://www.oecd.org/dataoecd/58/59/32140134.pdf

Pigou, A.C. 1932: The Economics of Welfare. London, 4. ed. http://oll.libertyfund.org/EBooks/Pigou_0316.pdf

Platts (ed.) 2007: World Electric Power Plants Data Base (WEPP). Washington, DC. http://www.platts.com/Analytic%20Solutions/UDI%20Data%20&%20Directories/World%20Electric%20Power%20Plants%20Database/

PointCarbon 2008: Historic prices. http://www.pointcarbon.com/news/historicprices/, accessed on 2008/05/22

Porter, M.E.; van der Linde, C. 1995: Toward a New Conception of the Environment-Competitiveness Relationship. In: Journal of Economic Perspectives. Vol. 9. pp 97-118

Prittwitz, V.v. 1990: Das Katastrophenparadox. Elemente einer Theorie der Umweltpolitik. Opladen

Reichwald, R.; Piller, F. 2006: Interaktive Wertschöpfung - Open Innovation, Individualisierung und neue Formen der Arbeitsteilung. Wiesbaden

Reilly, J.M.; Paltsev, S. 2005: An Analysis of the European Emission Trading Scheme. MIT Joint Program (Massachusetts Institute of Technology - Joint Program on the Science and Policy of Global Change), Report No. 127. Cambridge, MA. http://web.mit.edu/globalchange/www/MITJPSPGC_Rpt127.pdf

Reinaud, J. 2005: Industrial Competitiveness under the European Emissions Trading Scheme. IEA (International Energy Agency) Paris. http://www.iea.org/textbase/papers/2005/Industrial_Competitiveness.pdf

Requate, T. 2002: Does the Environment Benefit from Banking Programs for Tradable Permits? Kiel University, Department of Economics. Manuscript

Requate, T.; Unold, W. 2003: Environmental policy incentives to adopt advanced abatement technology: Will the true ranking please stand up? In: European Economic Review. Vol. 47. pp 125-146

Romer, P.M. 1986: Increasing Returns and Long-Run Growth. In: The Journal of Political Economy. Vol. 94 (5). pp 1002-1037

Romer, P.M. 1990: Endogenous Technological Change. In: The Journal of Political Economy. Vol. 98 (5). pp 71-102

Rosenberg, N. 1982: Inside the black box - Technology and economics. Cambridge, MA

Rudolph, S. 2005: Handelbare Emissionslizenzen. Die politische Ökonomie eines umweltökonomischen Instruments in Theorie und Praxis. Marburg

Scherer, F.M. 1965: Firm Size, Market Structure, Opportunity, and the Output of Patented Inventions. In: American Economic Review. Vol. 55. pp 1097-1125

Schleich, J.; Betz, R. 2005: Incentives for energy efficiency and Innovation in the European Emissions Trading System. In: ECEEE (ed.), ECEEE 2005 Summer Study - What Works & Who Delivers. Stockholm. pp 1495-1506

Schleich, J.; Betz, R.; Rogge, K. 2007: EU Emission Trading – better job second time around? Presented at the conference "Saving Energy - just do it!", organised by European Council for an Energy Efficient Economy (eceee) La Colle sur Loup. http://www.eceee.org/conference_proceedings/eceee/2007/Panel_7/7.109/

Schleich, J.; Cremer, C. 2007: Using benchmarking for the primary allocation of EU allowances - An application to the German power sector. ISI (Fraunhofer Institute Systems and Innovation Research), Working Paper Sustainability and Innovation S 6/2007. Karlsruhe. http://www.isi.fhg.de/e/working%20papers/WP_Benchmarking.pdf

Schleich, J.; Ehrhart, K.-M.; Hoppe, C.; Seifert, S. 2006: Banning banking in EU emissions trading? In: Energy Policy. Vol. 34. pp 112-120

Schmookler, J. 1966: Invention and Economic Growth. Cambridge, MA

Schneider, L. 2007: Is the CDM fulfilling its environmental and sustainable development objectives? An evaluation of the CDM and options for improvement. WWF and Öko-Institut (World Wide Fund for Nature, Öko-Institut) Berlin. http://www.wwf.de/fileadmin/fm-wwf/pdf_neu/CDM_Evaluation_Report.pdf

Schumpeter, J.A. 1942: Capitalism, Socialism and Democracy. New York

Schumpeter, J.A. 1939: Business Cycles. A Theoretical, Historical and Statistical Analysis of the Capitalist Process. New York, Toronto, London. http://classiques.uqac.ca/classiques/Schumpeter_joseph/business_cycles/schumpeter_business_cycles.pdf

Schwarze, R. 2001: Dynamische Anreizwirkung von Umweltzertifikaten. In: Zeitschrift für Umweltpolitik & Umweltrecht. Vol. 24 (4). pp 501-536

SDT (Spectron Deloitte & Touche) 2008: Zeebrugge Day Ahead Index. http://www.energate.de/markt/preise/index.php?action=show_preisreihe&id=59226&data[mode]=tcd, accessed on 2008/05/22

Sharpe, W.F.; Alexander, G.J. 1990: Investments. Englewood Cliffs, New York, 4th. ed.

Sijm, J.; Neuhoff, K.; Chen, Y. 2006: CO_2 cost pass-through and windfall profits in the power sector. In: Climate Policy. Vol. 6. pp 49-72. http://www.climate-strategies.org/uploads/sijm.pdf

Simon, H.A. 1947: Administrative Behavior - A Study of Decision-making Processes in Administrative Organization. New York

Smith, A. 2004: Policy transfer and the development of UK climate policy. In: Policy & Politics. Vol. 32 (1). pp 79-93

Solow, R.M. 1957: Technical Change and the Aggregate Production Function. In: The Review of Economics and Statistics. Vol. 39 (3). pp 312-320

Sorrell, S. 1999: Why sulphur trading failed in the UK. In: Sorrell, S.; Skea, J. (ed.), Pollution for sale. Emissions Trading and Joint Implementation. Cheltenham. pp 170-209

Spectron 2008: Coal Index. http://www.energate.de/markt/preise/index.php?action=show_preisreihe&id=76242&data[mode]=tcd, accessed on 2008/05/22

Spence, M. 1984: Cost Reduction, Competition and Industry Performance. In: Econometrica. Vol. 52 (1). pp 101-122

Stavins, R.N. 2002: Lessons from the American Experiment with Market-Based Environmental Policies. FEEM (Fondazione Eni Enrico Mattei), Nota di Lavoro 30. Milano

Stavins, R.N. 1996: Correlated Uncertainty and Policy Instrument Choice. In: Journal of Environmental Economics and Management. Vol. 30. pp 218-232. http://enviro.colorado.edu/class/8535/CorrUncertainty.pdf

Stephan, G.; Müller-Fürstenberger, G. 1999: Banking and Trade of Carbon Emission Rights - A CGE Analysis. (Institute of Applied Micro-Economics, University of Bern) Bern. http://www.soc.uoc.gr/calendar/2000EAERE/papers/PDF/C5-Muller-Furstenberger.pdf

Stern, N. (ed.) 2006: Stern Review: The Economics of Climate Change. Cambridge, UK. http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/stern_review_report.cfm

Sterner, T.; Hammar, H. 2005: Designing instruments for climate policy. In: Hansjürgens, B. (ed.), Emissions Trading for Climate Policy - US and European Perspectives. Cambridge, MA. pp 17-36

Stifterverband (ed.) 2007: FuE-Gesamtaufwendungen des Wirtschaftssektors, FuE-Personal im Wirtschaftssektor. http://www.stifterverband.de

Stoneman, P. 1987: The Economic Analysis of Technology Policy. Oxford, U.K.

Stratmann, K. 2007: Auktion von Zertifikaten beginnt 2008. In: Handelsblatt, issue of 14.05.2007. http://www.handelsblatt.com/news/Politik/Deutschland/_pv/_p/200050/_t/ft/_b/1267823/default.aspx/auktion-von-zertifikaten-beginnt-2008.html

Sullivan, R.; Blyth, W. 2006: Climate Change Policy Uncertainty and the Electricity Industry: Implications and Unintended Consequences. Chatham House and Insight Investment, Briefing Paper EEDP BP 06/02. London. http://se2.isn.ch/serviceengine/FileContent?serviceID=EINIRAS&fileid=FB7E6852-06E6-97D0-7107-84CC06EB34D5&lng=en

TEHG (Deutscher Bundestag): Gesetz zur Umsetzung der Richtlinie 2003/87/EG über ein System für den Handel mit Treibhausgasemissionszertifikaten in der Gemeinschaft. In: Bundesgesetzblatt. Teil I Nr. 35. pp 1587-1590. Berlin. http://www.bgblportal.de/BGBL/bgbl1f/bgbl104s1578.pdf

The White House 2001: President Bush Discusses Global Climate Change. http://www.whitehouse.gov/news/releases/2001/06/print/20010611-2.html, accessed on 2001/06/11

Tietenberg, T.H. 1984: Environmental and Natural Resource Economics. RFF (Resources for the Futures) Washington D.C.

Tietenberg, T.H. 1985: Emissions Trading. An exercise in reforming pollution policy. Washington, DC

Trigeorgis, L. 1995: Real options: an overview. In: Trigeorgis, L. (ed.), Real Options in Capital Investment: Models, Strategies, and Applications. Westport, CT. pp 1-30

UBA (Umweltbundesamt) (ed.) 2007: Zentrales System Emissionen (ZSE). Dessau

UNFCCC (United Nation Framework Convention on Climate Change) 2007: Bali Action Plan. Decision -/13.CP. http://unfccc.int/files/meetings/cop_13/application/pdf/cp_bali_act_p.pdf

US EPA (United States Environmental Protection Agency) 2007: Overview of the Ozone Transport Commission (OTC) NOx Budget Program. http://www.epa.gov/airmarkt/progsregs/nox/otc-overview.html, accessed on 2008/07/18

VDEW (Vereinigung Deutscher Elektrizitätswerke) (ed.) 1993: Zahlen zur Entwicklung der öffentlichen Elektrizitätsversorgung von 1950 bis 1991. Frankfurt/Main

VDEW (Vereinigung Deutscher Elektrizitätswerke) (ed.) 2007: Investitionen der Stromversorger. Berlin

VGB (VGB PowerTech) 2004: Referenzkraftwerk Nordrhein-Westfalen. Konzeptstudie. Essen

VGB (VGB PowerTech) 2007: COMTES700. http://www.comtes700.org, accessed on 2007/10/03

VIK (Verband der Industriellen Energie- und Kraftwirtschaft) (ed.) 1991: Statistik der Energiewirtschaft 1991. Essen

VIK (Verband der Industriellen Energie- und Kraftwirtschaft) 2005: VIK-Berechnungen zu den Windfall Profits der Strombranche durch den CO2-Emissionshandel. Essen. http://www.vik.de/fileadmin/vik/Pressemitteilungen/JPK2005/VIK_Berechnungen_Windfall_Profits.pdf

Voß, J.-P. 2007: Innovation processes in governance: the development of 'emissions trading' as a new policy instrument. In: Science and Public Policy. Vol. 34 (4). pp 329-343

Voß, J.-P.; Fischer, C.; Schumacher, K.; Cames, M.; Pehnt, M.; Praetorius, B.; Schneider, L. 2003: Innovation. An integrated concept for the study of transformation in electricity systems. TIPS (Transformation and Innovation in Power Systems Project), Working Paper Berlin/Heidelberg. http://www.tips-project.de/download/TIPS_innovation_paper_031217.pdf

Weimann, J. 1991: Umweltökonomik. Berlin et al., 2. ed.

Weitzman, M.L. 1974: Prices vs. Quantities. In: Review of Economic Studies. Vol. 41 (4). pp 477-491

Wettestad, J. 2005: The Making of the 2003 EU Emissions Trading Directive: An Ultra-Quick Process due to Entrepreneurial Efficiency? In: Global Environmental Politics. Vol. 5 (1). pp 1-23

Winter, S.G.; Kaniovski, Y.M.; Dosi, G. 2000: Modeling Industrial Dynamics with Innovative Entrants. In: Structural Change and Economic Dynamics. Vol. 11. pp 255-293

Woerdman, E. 2002: Implementing Kyoto Mechanisms: Political Barriers and Path Dependence. Thesis, University of Groningen. Groningen

Zängl, W. 1989: Deutschlands Strom - Die Politik der Elektrifizierung von 1866 bis heute. Frankfurt/Main; New York

Zapfel, P. 31.1.2007: Interview on "Entstehungsgeschichte des Europäischen Emissionshandelssystems", Zapfel, P., Berlin

Zapfel, P.; Vainio, M. 2002: Pathways to European Greenhouse Gas Emissions Trading History and Misconceptions. FEEM (Fondazione Eni Enrico Mattei), Nota Di Lavoro 85.2002. http://www.feem.it/web/activ/_activ.html

ZuG 2007 (Deutscher Bundestag): Gesetz über den nationalen Zuteilungsplan für Treibhausgas-Emissionsberechtigungen in der Zuteilungsperiode 2005 bis 2007 (Zuteilungsgesetz 2007). In: Bundesgesetzblatt. Teil I Nr. 45. pp 2211-2222. Berlin. http://www.bgblportal.de/BGBL/bgbl1f/bgbl104s2211.pdf

ZuG 2012 (Deutscher Bundestag): Gesetz über den nationalen Zuteilungsplan für Treibhausgas-Emissionsberechtigungen in der Zuteilungsperiode 2008 bis 2012 (Zuteilungsgesetz 2012). In: Bundesgesetzblatt. Teil I Nr. 38. pp 1788-1808. Berlin. http://www.bgblportal.de/BGBL/bgbl1f/bgbl107s1788.pdf

8 Annex

8.1 Structured questionnaire of the first survey

Öko-Institut

Bereich Energie & Klimaschutz
Martin Cames, Marianne Walther von Loebenstein
13. Juli 2004

Umfrage – Interviewleitfaden

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1 AnsprechpartnerIn

1. Sind sie damit einverstanden, dass wir das Gespräch aufzeichnen?
2. Unternehmen:
3. Name:
4. Tel:
5. e-mail:
6. Funktion, Stellenbezeichnung:
7. Zuständigkeiten im Rahmen des Emissionshandels:

2 Veränderungen in Organisation und Management

2.1 Welche institutionellen Vorbereitungen aufgrund der Einführung des Emissionshandels haben sie bereits in ihrem Unternehmen getroffen bzw. sind geplant?

1. Haben sie neue Abteilungen oder Bereiche eingeführt? Wenn ja, welche?
2. Haben sie eine Taks Force zum Emissionshandel eingerichtet?
3. Haben sie bereits Emissionsinventare erstellt oder sind diese in Vorbereitung? Gibt es Schnittstellen zwischen den Emissionsinventaren und dem Emissionsmonitoring im Rahmen des Emissionshandels?
4. Wurde oder wird die EDV-Infrastruktur für kontinuierliche Emissionsdatenerfassung im Datenübertragung angepasst?
5. Haben sie ein Instrument zum regelmäßigen Abgleich der aktuellen Emissionen mit ihren Emissionsberechtigungen geplant oder bereits etabliert?
6. Haben sie eine interne CO_2-Vermeidungskostenkurve erstellt (spezifische Kosten & Potenzial) und diese mit externen Potenzialen verglichen oder sind solche Vergleiche in Vorbereitung?
7. Haben sie einen Trading Floor für CO_2-Emissionsrechte etabliert, wurde diese Aufgabe in bestehende Trading Floors integriert oder sind derartige Schritte geplant? Wenn ja, könnte es dabei zu Kooperationsmöglichkeiten mit anderen Unternehmen kommen (z.B. mit anderen Stadtwerken)?
8. Ist der Aufbau einer Risikoabsicherungsstrategie für die Preise von Emissionsrechten z.B. durch Handel am CO_2-Spotmarkt oder durch Handel mit CO_2-Forwards (Headging) geplant oder wurden entsprechende Schritte bereits eingeleitet?
9. Werden sie anderen Unternehmen Dienstleistungen im Zusammenhang mit dem Emissionshandel anbieten? Wenn ja, welche?

10. Welche sonstigen institutionellen oder organisatorischen Veränderungen haben sie geplant oder bereits durchgeführt?

2.2 Welche Abteilungen in ihrem Unternehmen werden durch den Emissionshandel besonders betroffen sein? Bitte nennen sie die 3 wichtigsten!

1. Risk-Management
2. Produktion
3. Umweltschutz
4. Einsatzplanung
5. Rechnungswesen
6. Marketing
7. Trading
8. Controlling
9. Energieträger-Einkauf/Beschaffung
10. Rechtsabteilung
11. Sonstige (bitte spezifizieren)

2.3 Von welchen Unternehmen erwarten sie Unterstützung bei der Vorbereitung oder Durchführung des Emissionshandels?

1. Energiedienstleister, Contractoren
2. Zertifizierer
3. Broker
4. Software-Provider (z. B. SAP)
5. Consultants
6. Technologie-Provider
7. Sonstige (bitte spezifizieren)

3 Veränderungen im Betrieb bestehender Anlagen

3.1 Planen sie eine Veränderungen in der Kraftwerkseinsatzplanung (Merit Order)?

3.2 Sind Veränderungen im Brennstoffeinsatz (insbesondere bei bivalenten Kraftwerken) geplant?

1. Einsatz emissionsärmerer, fossiler Brennstoffe (Steinkohle aus Lateinamerika oder Australien ist z. B. emissionsärmer als Kohle aus Südafrika)
2. Erhöhung der Zufeuerung oder vollständige Umstellung auf Ersatzbrennstoffe (z. B. Biomasse)

3.3 Welche sonstigen Veränderungen im Betrieb bestehender Anlagen sind geplant?

3.4 Welche der bisher genannten Maßnahmen werden aufgrund der Einführung des Emissionshandels durchgeführt oder sind aufgrund des Emissionshandels in ihrer Bedeutung gestiegen?

4 Veränderungen in der Investitionsstrategie

4.1 Welche Veränderungen im Kraftwerkpark planen sie in ihrem Unternehmen?

1. Ersatz alter fossiler Kraftwerke durch neue, effizientere fossile Kraftwerke
2. Ersatz alter fossiler Kraftwerke durch neue, effizientere fossile Kraftwerke in Verbindung mit einem Brennstoffwechsel hin zu weniger CO_2-intensiven Brennstoffen
3. Ersatz alter fossiler Kraftwerke durch neue Anlagen mit regenerativen Energieträgern
4. Ersatz alter fossiler, ungekoppelter Kraftwerke durch neue, effizientere KWK-Anlagen
5. Stilllegung alter Anlagen bei gleichzeitiger höherer Auslastung in bestehenden effizienteren Anlagen
6. Kraftwerksneubau

Bitte spezifizieren sie die jeweils geplante Technologie (BoA, GuD etc.) sowie den geplanten Brennstoff bzw. Energieträger (Steinkohle, Braunkohle, Erdgas, Biomasse, Wind etc.).

Bitte spezifizieren sie auch, ob die Maßnahmen eher kurz-, mittel- oder langfristig geplant sind.

4.2 Welche Effizienzverbesserung planen sie an bestehenden Anlagen?

1. Art (neue Beschaufelung, zusätzliche Zwischenüberhitzung etc.)
2. Betroffene Anlagen (Technologie, Brennstoff)
3. Zeithorizont der Maßnahmen (kurz-, mittel-, langfristig)
4. Umfang (z.B. Wirkungsgradverbesserung um x %)

4.3 Welche sonstigen Investitionsmaßnahmen planen sie?

1. Investition in Strom- und Gasnetze (Ausbau, Verstärkung, Reduktion von Verlusten)
2. Investitionen in das Know-how der MitarbeiterInnen
3. Investitionen in Anlagen <20 MW zur Vermeidung der Teilnahme am Emissionshandel
4. Sonstige

4.4 Haben sie Investitionen in JI- oder CDM-Projekte geprüft oder bereits durchgeführt? Wenn ja, was steht dabei im Vordergrund: die Akquisition von günstigen Minderungskrediten oder Sekundäreffekte wie z.B. Erschließung neuer Märkte oder Geschäftsfelder?

4.5 In welchem Umfang (MW) besteht in ihrem Unternehmen in den nächsten 10 Jahren Erneuerungsbedarf für Erzeugungskapazitäten? Fallen die Ersatzinvestitionen mit Ersatzinvestitionen der Wettbewerber zusammen, so dass man von einem Investitionszyklus sprechen kann?

4.6 Welche Technologien und Brennstoffe werden durch den Emissionshandel wettbewerbsfähiger? Oder verändert der Emissionshandel die Wettbewerbsposition der einzelnen Technologien und Brennstoffe nur marginal?

4.7 Welche der bisher genannten Maßnahmen werden aufgrund der Einführung des Emissionshandels durchgeführt oder sind aufgrund des Emissionshandels in ihrer Bedeutung gestiegen?

4.8 Haben sie Emissionsszenarien für die Entwicklung ihres Kraftwerksparks erstellt? Wenn ja, welche Rolle spielt die Einführung des Emissionshandels dabei?

5 Innovationsstrategie ihres Unternehmens

5.1 Gibt es derzeit eine explizite Entwicklungs- oder Innovationsstrategie in ihrem Unternehmen? Wenn ja, wie sieht sie aus?

5.2 In welcher Weise etablieren sie Innovationen oder innovative Technologien in ihrem Unternehmen?

1. Etablierung von Such- und Entwicklungsstrategien für neue Produkte, Prozesse oder Geschäftsformen; wenn ja, wie sehen sie aus?
2. Beteiligung an F&E-Aktivitäten zusammen mit anderen Energieversorgungsunternehmen (z.B. Referenzkraftwerk NRW)
3. Venture Capital: Aufkauf kleiner, innovativer Unternehmen mit dem Ziel deren Know how zu akquirieren
4. On site development: Kooperation mit Anlagenherstellern bei der Optimierung bereits im Betrieb befindlicher Anlagen
5. Sonstige

5.3 Wie groß ist der Anteil der MitarbeiterInnen, sich damit befassen bezogen auf die Gesamtzahl der MitarbeiterInnen in %?

5.4 Beteiligen sie sich an der Entwicklung oder Förderung von Innovationen? (Projekte, Kooperationen etc.)

5.5 Wie hoch waren die jährlichen Aufwendungen für F&E in den letzten Jahren (absolut und/oder als Anteil am Umsatz)?

5.6 Welcher Anteil hiervon entfiel auf F&E-Aktivitäten für umwelt- bzw. klimafreundliche Innovationen?

5.7 In welchen Technologien sehen sie große Innovationspotenziale und wo werden sie ihre F&E-Aktivitäten intensivieren (z.B. durch Beteiligungen, Studien und Projekte)?

1. Clean coal (Referenzkraftwerk, Braunkohlevergasung, Sequestrierung etc.)
2. Werkstoffe, Prozesse
3. Kraft-Wärme-Kopplung
4. Virtuelles Kraftwerk, Dezentralisierung von Netzstrukturen
5. Wasserstoffwirtschaft (Brennstoffzelle)
6. Regenerative Energiequellen, wenn ja, welche?
7. Verteilungs- und Transportanlagen (z.B. Supraleitung)
8. Sonstige

5.8 Welche der oben genannten Aspekte zur Innovationsstrategie werden durch den Emissionshandel besonders beeinflusst?

5.9 Hat der Emissionshandel Auswirkungen auf die Innovationsaktivitäten ihres Unternehmens? Wenn ja, welche und in welchem Zeitraum?

5.10 Erwarten sie, dass durch die Einführung des Emissionshandels in ihrem Unternehmen kostengünstige oder sogar kostenlose Treibhausgasminderungspotenziale entdeckt werden, die bisher noch nicht erschlossen wurden?

(ggf. Hinweis auf ökonometrisch nachweisbaren Zusammenhang zwischen dem weichen Instrument Öko-Audit und Energieeffizienz)

5.11 Welche Veränderungen in der Innovationsstrategie erwarten sie in der Stromwirtschaft insgesamt?

6 Ausgestaltung des Emissionshandels

6.1 Welche Ausgestaltungsoptionen des europäischen Emissionshandelssystems sind für ihr Unternehmen besonders relevant? Nennen sie die drei wichtigsten!

1. Nationales Minderungsziel (Cap)
2. Art und ggf. Verteilung der Primärallokation
   (Grandfathering, Benchmarking, Auctioning)
3. Anlagenstillegung
4. Neuanlagen
5. Übertragung von Emissionsrechten von stillgelegten Anlagen auf Neuanlagen

6. Basisjahr und Anerkennung von Early action
7. Sonderregelungen für KWK, prozessbedingte Emissionen etc.
8. Banking/Crediting
9. Sonstige

6.2 Welche der Ausgestaltungsoptionen lösen ihrer Ansicht nach Innovationsanreize in ihrem Unternehmen aus?

6.3 Verlassen sie bitte die Perspektive ihres Unternehmens und nehmen stattdessen unternehmensübergreifende Perspektive ein. Welche der genannten Ausgestaltungsoptionen sind aus dieser Perspektive besonders relevant für die Innovationswirkung des Emissionshandels? Nennen sie die drei wichtigsten!

6.4 Wie müssten die für die Innovationswirkungen des Emissionshandels besonders relevanten Ausgestaltungsoptionen aus ihrer Sicht zukünftig ausgestaltet sein, damit der Emissionshandel innovationsfördernd wirkt?

1. Ambitioniertes oder zumindest strengeres nationales Minderungsziel
2. Veränderung der Übertragungsregelung (z.B. jeweils bis zum Ende der Verpflichtungsperiode, statt 4 Jahre)
3. Strenge Regelung für Anlagenstilllegung und Ausstattung von Neuanlagen (z.B. Emissionsrechte müssen bei Stilllegung sofort zurückgegeben werden; Neuanlagen werden unabhängig von Vorgängeranlagen nach BAT-Benchmark ausgestattet)
4. Reduzierung der Sonderreglungen für KWK, prozessbedingte Emissionen etc.
5. Auctioning oder (brennstoffunabhängiges) Benchmarking statt Grandfathering mit Updating
6. Sonstige

8.2 Structured questionnaire of the second survey

Öko-Institut

Bereich Energie & Klimaschutz
Martin Cames
24. April 2007

Umfrage – Interviewleitfaden

Insgesamt 62 Fragen

1 AnsprechpartnerIn

(Folgende Informationen soweit wie möglich vor dem Gespräch erfassen und recherchieren; im Gespräch dann nur noch nachfragen stellen!)

1. Sind sie damit einverstanden, dass wir das Gespräch aufzeichnen?
2. Unternehmen:
3. Name:
4. Tel:
5. e-mail:
6. Funktion, Stellenbezeichnung:
7. Zuständigkeiten im Rahmen des Emissionshandels:
8. Hintergrundinformationen zum Unternehmen
   (KW-Park, Umsatzentwicklung, Anzahl der MitarbeiterInnen, Beteiligungen, etc.)

2 Innovationsstrategie ihres Unternehmens

2.1 Gibt es derzeit eine explizite Entwicklungs- oder Innovationsstrategie in ihrem Unternehmen? Wenn ja, wie sieht sie aus?

2.2 In welcher Weise etablieren sie Innovationen oder innovative Technologien in ihrem Unternehmen?

1. Onsite development: Kooperation mit Anlagenherstellern bei der Optimierung bereits im Betrieb befindlicher Anlagen
2. Venture Capital: Aufkauf kleiner, innovativer Unternehmen mit dem Ziel deren Know-how zu akquirieren
3. Beteiligung an F&E-Aktivitäten zusammen mit anderen Energieversorgungsunternehmen (z.B. Referenzkraftwerk NRW)
4. Etablierung von Such- und Entwicklungsstrategien für neue Produkte, Prozesse oder Geschäftsformen; wenn ja, wie sehen sie aus?
5. Sonstige

2.3 In welchen Technologien sehen sie große Innovationspotenziale und wo werden sie ihre F&E-Aktivitäten intensivieren (z.B. durch Beteiligungen, Studien und Projekte)?

1. Clean coal (Referenzkraftwerk, Kohlevergasung, CCS, etc.)
2. Werkstoffe, Prozesse
3. Kraft-Wärme-Kopplung
4. Virtuelles Kraftwerk, Dezentralisierung von Netzstrukturen
5. Wasserstoffwirtschaft (Brennstoffzelle)
6. Regenerative Energiequellen, wenn ja, welche?
7. Verteilungs- und Transportanlagen (z.B. Supraleitung)
8. Speichertechnologien (Druckluft, Pumpspeicher, etc.)
9. Sonstige

2.4 Hatte der Emissionshandel Auswirkungen auf die Innovationsaktivitäten ihres Unternehmens?

2.5 Wenn ja, welche der oben genannten Innovationsaspekte wurden durch den Emissionshandel besonders beeinflusst?

2.6 Erwarten sie Auswirkungen auf ihre Innovationsaktivitäten in der Zukunft?

2.7 Wenn ja, welche der oben genannten Aspekte zur Innovationsstrategie werden zukünftig durch den Emissionshandel besonders beeinflusst?

2.8 Wurden durch die Einführung des Emissionshandels in ihrem Unternehmen kostengünstige oder sogar kostenlose Treibhausgasminderungspotenziale entdeckt, die bisher noch nicht erschlossen wurden oder erwarten sie dass das zukünftig noch der Fall sein wird?
(ggf. Hinweis auf ökonometrisch nachweisbaren Zusammenhang zwischen dem weichen Instrument Energie-Audit und Energieeffizienz)

2.9 Welche Veränderungen in der Innovationsstrategie erwarten sie in der Stromwirtschaft insgesamt?

3 Veränderungen in Organisation und Management

Welche institutionellen Veränderungen aufgrund der Einführung des Emissionshandels haben sie bereits in ihrem Unternehmen umgesetzt bzw. sind geplant?

3.1 Haben sie neue Abteilungen oder Bereiche eingeführt? Wenn ja, welche?

3.2 Haben sie eine Task Force zum Emissionshandel eingerichtet bzw. besteht diese Task Force weiterhin?

3.3 Haben sie Emissionsszenarien für die Entwicklung ihres Kraftwerksparks erstellt?

3.4 Haben sie eine interne CO_2-Vermeidungskostenkurve erstellt (spezifische Kosten & Potenzial) und diese mit externen Potenzialen verglichen oder sind solche Vergleiche in Vorbereitung?

3.5 In welchen Abständen werden Emissionsdaten erfasst (kontinuierlich, stündlich, täglich, wöchentlich, monatlich, jährlich)?

3.6 Gibt es eine kontinuierliche elektronische Emissionsdatenerfassung?

3.7 Gibt es eine Stelle in ihre Unternehmen, an dem sämtliche Emissionsdaten regelmäßig zusammenlaufen?

3.8 Haben sie ein Instrument zum regelmäßigen Abgleich der aktuellen Emissionen mit ihren Emissionsberechtigungen geplant oder bereits etabliert?

3.9 Wenn ja, in welchem Abstand erfolgt der Abgleich (Echtzeit, stündlich, täglich, wöchentlich, monatlich)?

3.10 Wurde Unternehmenssoftware für den Emissionshandel entwickelt, angepasst oder angeschafft?

3.11 Wenn ja, welche Funktion hatte diese Software bzw. was musste angepasst werden?

3.12 Haben sie einen Trading Floor für CO_2-Emissionsrechte etabliert oder wurde diese Aufgabe in bestehende Trading Floors integriert oder sind derartige Schritte geplant?

3.13 Wenn ja, gab es dabei Kooperationen mit anderen Unternehmen (z.B. mit anderen Stadtwerken) oder könnte es zu solchen Kooperationsmöglichkeiten kommen?

3.14 Ist der Aufbau einer Risikoabsicherungsstrategie für die Preise von Emissionsrechten z.B. durch Handel am CO_2-Spotmarkt oder durch Handel mit CO_2-Forwards (Hedging) geplant oder wurden entsprechende Schritte bereits eingeleitet?

3.15 Werden sie anderen Unternehmen Dienstleistungen im Zusammenhang mit dem Emissionshandel anbieten? Wenn ja, welche?

3.16 Welche sonstigen institutionellen oder organisatorischen Veränderungen haben sie geplant oder bereits durchgeführt?

4 Veränderungen im Betrieb bestehender Anlagen

4.1 Wenn sie zurückblicken, hat sich der Kraftwerkseinsatz (Merit Order) aufgrund des Emissionshandels verändert?

4.2 Wenn ja, in welcher Weise (Verschiebungen zwischen Brennstoffen bzw. zwischen Lastbereichen)?

4.3 Erwarten sie in Zukunft (weitere) Veränderungen im Kraftwerkseinsatz (Merit Order)?

4.4 Erwarten sie Veränderungen beim Brennstoffeinsatz (insbesondere bei bivalenten Kraftwerken)?

1. Einsatz emissionsärmerer, fossiler Brennstoffe (Steinkohle aus Lateinamerika oder Australien ist z.B. emissionsärmer als Kohle aus Südafrika)
2. Erhöhung der Zufeuerung oder vollständige Umstellung auf Ersatzbrennstoffe (z.B. Biomasse)

4.5 Welche sonstigen Veränderungen im Betrieb bestehender Anlagen sind geplant?

4.6 Welche der bisher genannten Maßnahmen werden aufgrund der Einführung des Emissionshandels durchgeführt oder sind aufgrund des Emissionshandels in ihrer Bedeutung gestiegen?

4.7 Welchen durchschnittlichen Zertifikatspreis hatte sie vor Beginn des Emissionshandels erwartet?

1. Für die Periode 2005 bis 2007
2. Für die Periode 2008 bis 2012

4.8 Welchen durchschnittlichen Zertifikatspreis erwarten sie zukünftig?

1. Im Jahr 2010
2. Im Jahr 2020
3. Im Jahr 2050

5 Veränderungen in der Investitionsstrategie

5.1 Welche der folgenden Faktoren haben den größten Einfluss auf ihre Investitionsentscheidungen? Bitte benennen sie die fünf wichtigsten in der Reihenfolge ihrer Wichtigkeit!

1. Brennstoffdiversifizierung
2. Erwartete Investitionskosten
3. Erwartete Nachfrageentwicklung
4. Erwarteter Brennstoffpreis
5. Erwarteter CO_2-Preis
6. Erwarteter Strompreis
7. Internationales Klimaregime
8. Nationale Gesetzgebung
9. Technologiediversifizierung
10. Versorgungssicherheit
11. Sonstige: bitte benennen

5.2 In welchem Umfang (MW) besteht bis zum Jahr 2020 in ihrem Unternehmen Erneuerungs- oder Erweitungsbedarf für Erzeugungskapazitäten?

5.3 Wenn ja, welche Rolle spielt die Einführung des Emissionshandels dabei?

5.4 Fallen die Ersatz- oder Erweiterungsinvestitionen mit Investitionen der Wettbewerber zusammen, so dass man von einem Investitionszyklus sprechen kann?

5.5 Welche konkreten Veränderungen im Kraftwerkpark haben sie seit 2004 durchgeführt oder planen sie bis zum Jahr 2020?

Unternehmensspezifische Liste mit bekannten Planungen vorlegen (Standort, Leistung, Brennstoff, Technologie, Jahresnutzungsgrad, geplante Inbetriebnahmen) und fragen ob die Liste so bestätigt wird oder ob es noch darüber hinausgehende Planungen gibt.

5.6 Welche der oben genannten Projekte sind durch den Emissionshandel induziert oder in der Planung tangiert?

5.7 Welche Effizienzverbesserung haben sie an bestehenden Anlagen durchgeführt oder planen sie bis zum Jahr 2020?

Z. B. Kürzere Revisionszyklen (Reinigung von Schaufeln), neue Beschaufelung, Einbau einer zusätzlichen Zwischenüberhitzung, Vorschalten von Gasturbinen, Mitteldruckverbund erstellen, Reduktion des Eigenbedarf durch geregelte Pumpen, Wirkungsgradsteigerung durch neue Rieseleinrichtung im Kühlturm, Minimierung der Leitungsverlust im Fernwärmenetz, etc.

5.8 Welche der oben genannten Effizienzverbesserungen sind durch den Emissionshandel induziert oder in der Planung tangiert?

5.9 Welche sonstigen Investitionsmaßnahmen haben sie durchgeführt oder planen sie?

5.10 Welche der zuvor genannten Maßnahmen werden aufgrund der Einführung des Emissionshandels durchgeführt oder sind aufgrund des Emissionshandels in ihrer Bedeutung gestiegen?

5.11 Welche Technologien und/oder Brennstoffe werden ihrer Einschätzung nach durch den Emissionshandel zukünftig wettbewerbsfähiger?

5.12 Haben sie Investitionen in JI- oder CDM-Projekte geplant oder bereits durchgeführt?

5.13 Wenn ja, was steht dabei im Vordergrund: die Akquisition von günstigen Minderungskrediten oder Sekundäreffekte wie z. B. Erschließung neuer Märkte oder Geschäftsfelder?

6 Ausgestaltung des Emissionshandels

6.1 Welche Ausgestaltungsoptionen des europäischen Emissionshandelssystems sind für ihr Unternehmen besonders relevant? Nennen sie die fünf wichtigsten in der Reihenfolge ihrer Wichtigkeit!

1. Minderungsziel (Cap)
2. Primärallokation (Grandfathering, Benchmarking, Auctioning)
3. Anlagenstillegung
4. Neuanlagenregelung
5. Übertragung von Emissionsrechten von stillgelegten Anlagen auf Neuanlagen
6. Basisjahr und Anerkennung von Early action
7. Sonderregelungen für KWK, prozessbedingte Emissionen etc.
8. Banking/Crediting
9. Ex-post-Korrektur
10. Dauer der Verpflichtungsperioden
11. Zukünftiges internationales Klimaregime
12. Sonstige

6.2 Welche der oben genannten Ausgestaltungsoptionen lösen ihrer Ansicht nach Innovationsanreize in ihrem Unternehmen aus?

6.3 Verlassen sie bitte die Perspektive ihres Unternehmens und nehmen stattdessen unternehmensübergreifende Perspektive ein. Wie müssten die folgenden Optionen jeweils ausgestaltet sein damit der Emissionshandel besonders innovationsfördernd wirkt?

1. Cap (Minderung gegenüber 2000-2002): -10 %, -20 %, -30 %
2. Anteil der Auktionierung: 10 %, 20 %, 40 %, 100 %
3. Allokation für Bestandsanlagen: Grandfathering, brennstoffspezifischer Benchmark, Durchschnittsbenchmark
4. Allokation für Neuanlagen: brennstoffspezifischer Benchmark, Durchschnittsbenchmark, keine Zuteilung
5. Anlagenstilllegung: Sofortige Rückgabe der Emissionsrechte, Rückgabe am Ende der Periode
6. Übertragungsregelung: 10 Jahre, 5 Jahre, bis zum Ende der Periode, keine
7. Dauer der Periode: 5 Jahre, 10 Jahre, 15 Jahre
8. Sonderregelungen: Early Action, KWK, Atom, keine
9. Klimaregime: bis 2012, bis 2020, bis 2030, bis 2050

6.4 Welche der oben genannten Ausgestaltungsoptionen sind aus dieser Perspektive besonders relevant für die Innovationswirkung des Emissionshandels? Nennen sie die fünf wichtigsten in der Reihenfolge ihrer Wichtigkeit!