Ralf Antes
Bernd Hansjürgens
Peter Letmathe
Editors

Emissions Trading

Institutional Design, Decision Making and Corporate Strategies

Springer

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Preface and acknowledgements

This book follows the book "Emissions Trading and Business" published in 2006. It continues our work on the project Corporate Sustainability, which is funded by the Dresdner Bank Stiftungsfonds im Stifterverband für die Deutsche Wissenschaft. The German Society for Operations Research (GOR) co-funded the print of the book. We would like to express our gratitude for the financial and administrative support, particularly to Dr. Armin Sandhövel (Allianz AG, former vormals Dresdner Bank AG), Dr. Gabriele Jachmich (Stiftungsfonds Dresdner Bank) and Heike Heuberger (Dresdner Bank AG), Dr. Heinz-Rudi Spiegel and Sigrid Westermann (Stifterverband für die Deutsche Wissenschaft) and Professor Dr. Thomas Spengler (GOR).

Whereas interdisciplinarity appears to have become an institution in sustainability research, intradisciplinary cooperation between economists and management scholars is lacking. To enable and to foster such intradisciplinary research, therefore, is an explicit aim of the whole project. Accordingly, and similar to the first book, this volume again is based on cooperation between the German Society for Operations Research and the Faculty of Law and Economics of the University Halle-Wittenberg, in particular the Department of Environmental Economics and the Department of Corporate Environmental Management.

We are pleased to have brought together young and established scholars from both different disciplines and different countries to discuss with us the topic of emissions trading. We had 34 submissions from research institutions of fifteen countries (which indicates the global relevance of the subject). After a review process we accepted the papers of 14 young scholars from Finland, Germany, Lithunia, the United Kingdom, Sweden and the United States of America. Additionally, Joseph Kruger (National Commission on Energy Policy, former Environmental Protection Agency/Resources for the Future; USA) and Joseph Sarkis (Clark University, Worcester, USA) publish papers in the volume.

The book is inspired by the contributions presented at the workshop "Business and Emissions Trading" in November 2004 at the Leucorea, the former University of Wittenberg/Germany, which today serves as a venue of the University Halle-Wittenberg. For the book the contributions were revised and updated.

We would like to thank all those individuals who contributed to this book for sharing their work and ideas with us, as we learned a great deal from them. We would like to thank Professor Dr. Hans-Ulrich Zabel for his constant support. We would like to thank Paul Ronning, who did a great job in improving the English texts for the non-native speakers, and Barbara Fess and Katharina Wetzel-Vandai from Springer Publishers for their great patience and helpfulness at all times. And

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Ralf Antes, Bernd Hansjürgens and Peter Letmathe

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Introduction

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1 Introduction

This introductory chapter is divided into two sections: Section 1.1 gives an overview of existing and recently planned emissions trading schemes all over the world. It will elaborate on the institutionalization of emissions trading, mainly in the field of greenhouse gas emissions reductions. Section 1.2 gives a brief overview of this book.

1.1 The institutionalization of greenhouse gas emissions trading

The innovations of greenhouse gas emissions trading (GHG ET) and real running schemes are expanding world-wide. As illustrated in Figure 1, there are currently five schemes in force: the EU GHG Emissions Trading Scheme (which is the largest), the New South Wales GHG Reduction Scheme (which is the oldest), the Chicago Climate Exchange (which was the first to encompass all greenhouse gases), the Norwegian mandatory domestic emissions trading scheme, and the Japanese Voluntary Emissions Trading Scheme. A number of additional schemes are presently in the pipeline being designed, or they have already been implemented.

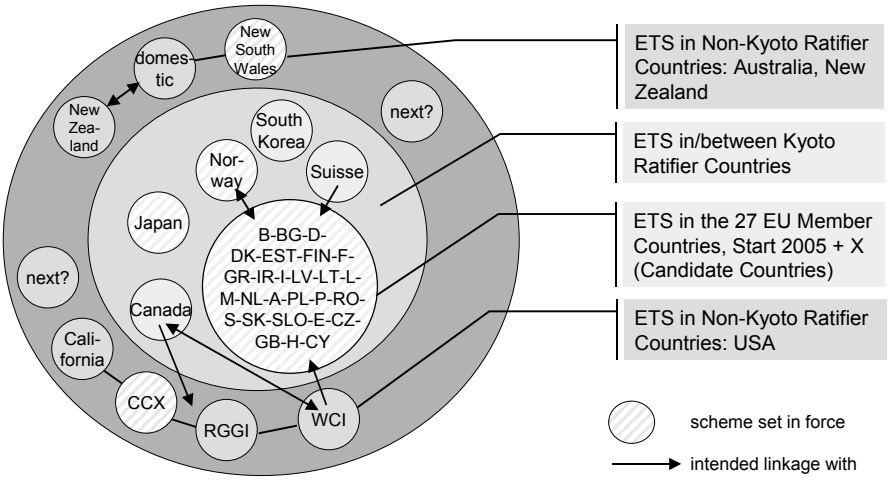

Fig. 1. The greenhouse gas emissions trading universe in 2007

The institutionalisation of emissions trading is pre-determined by the Kyoto Protocol: Once an Annex B-country has ratified the protocol, it has to implement the flexible Kyoto mechanisms, where emissions trading is one of them. However, this is only part of the story. Neither non-ratifier nor developing country needs to launch a GHG emissions trading scheme according to the Kyoto-Protocol. Nevertheless, this is exactly what has happened or is currently happening in the US, in

Australia and in South Korea. Even for China an emissions trading scheme is discussed.[1]

The formal institutional changes which can be observed, (e. g., the Kyoto Protocol, and the EU emissions trading directive) are part of a much broader societal process of institutionalisation of climate change mitigation. An important force within this process is the growing awareness that climate change is really occurring and that it is caused predominantly by anthropogenic activities. But there is a second informal institutional force that economic institutionalists call "prevalent habits of thought" (Veblen 1994, 1899, p. 190) and that sociological institutionalists call "rationalized myths": "… rationalized and impersonal prescriptions that identify various social purposes as technical ones and specify in a rule-like way *the appropriate means* [italics by eds.] to pursue these technical purposes rationally." (Meyer and Rowan 1991, 1977, p. 44) Of course, and notwithstanding criticisms as "letters of indulgence", emissions trading has become a powerful idea in economics, environmental politics, and business. It is increasingly accepted that it is a superior means to achieve emissions reductions of greenhouse gases. This becomes particularly clear through the emergence of regional emissions trading initiatives (e.g. in countries like the U.S or Australia, where such schemes have come into force (e.g. in California, RGGI, WCI, CCX, New South Wales). This happened against the will of the federal governments, which did not ratify the Kyoto Protocol. Moreover, in Australia and Canada, governments which have recently denied any necessity of climate change mitigation now are under increasing pressure to force the implementation of domestic emissions trading schemes.

Figure 1 above provides a rough overview of the worldwide state of greenhouse gas emissions trading schemes. More details on the various emissions trading schemes are given in the following:

Australia

- *New South Wales Greenhouse Gas Reduction Scheme (GGAS):* The GGAS started on 1 January 2003 and aims to reduce GHG emissions caused by the production and use of electricity.[2] In 2006 the Government extended the scheme until 2021, or until a national emissions trading scheme can be established (GGAS 2007).
- *Domestic GHG ET scheme:* In May 2007 the Prime Ministerial Task Group on Emissions Trading delivered its report and recommended: "It is in Australia's interest to develop a domestic emissions trading scheme that might, over time, be linked to complementary schemes in other countries." (Prime Minis-

[1] Since 2002 China has gained experience with regional and local SO_2 emissions trading in the power sector; see Zhu 2007. According to a statement of the Vice-Minister of Finance, Zhang Hongli, from August 2007, "the government will invest more than 1.33 billion yuan ($176 million) to help cut pollutant emissions". The fund should mainly be used for improving emission monitoring and "also … to promote emissions trading"; see Xin 2007.

[2] http://www.greenhousegas.nsw.gov.au/; 06.09.2007

terial Task Group 2007, p. 9) On 3 June 2007, the Prime Minister announced that the Australian Government would introduce a 'cap and trade' emissions trading scheme. On 17 July 2007, the Prime Minister launched the government's climate change policy statement, which endorses the key features of the emissions trading system outlined in the report. "Trading under the scheme will commence no later than 2012."[3]

Canada

On April 26, 2007, the Government of Canada released an *Action Plan* to Reduce Greenhouse Gases and Air Pollution. "Domestic emissions trading will be an important component of the Government's market-driven approach".[4] The scheme will encompass a domestic inter-firm trading system, a domestic offset system and access to CDM. Greenhouse gases emissions trading systems for sulphur oxides (SO_X) and nitrogen oxides (NO_X) should be introduced, too.[5] Linkages with other international ET schemes (USA, "possibly Mexico") will be explored. Two provinces (British Columbia, Manitoba) do already cooperate with five US states in the Western Climate Initiative to establish a regional ET scheme (see below).

Japan

In April 2005 Japan started a domestic *Voluntary Emissions Trading Scheme* focusing on carbon dioxide. The scheme was designed according to the voluntary United Kingdom Emissions Trading System (UK ETS), which existed from 2002 to 2006. The first phase (ending in August 2007) started with 31 participants, the second round started one year later with 58 participants. The costs for GHG reduction activities were partly subsidized (US$ 10 t/CO_2).

New Zealand

The initiative to install a domestic emissions trading scheme in New Zealand traces back to first governmental proposals in 1996 and 1998. In March 2007 the New Zealand Institute for Economic Research (NZIER) published a *proposal for a domestic emissions trading scheme*, which includes all "internationally recognised" greenhouse gases and which combines upstream and downstream approaches (NZIER 2007). The government expects a start "probably … after 2012"[6] It is intended to work closely together with Australia to develop a framework for similar schemes throughout the region (Ansley 2007).

[3] http://www.dpmc.gov.au/climate_change/emissionstrading/index.cfm; 06.09.2007
[4] http://www.ecoaction.gc.ca/news-nouvelles/20070426-10-eng.cfm; 07.09.2007
[5] http://www.ecoaction.gc.ca/news-nouvelles/20070426-13-eng.cfm; 07.09.2007
[6] http://www.environmental-finance.com/onlinews/23febade.htm; 07.09.2007

Norway

Similar to the EU ETS and based on the Greenhouse Gas Emissions Trading Act, Norway implemented a mandatory domestic GHG ETS for the period January 2005 - December 2007. The scheme included CO_2 sources that were not covered by CO_2 taxation (51 installations); this made up 10-15% of the total greenhouse gas emissions (Rosland 2005). For the period 2008-2012 the program scope will be widened to adapt it closer to the EU scheme. As a consequence the number of installations will be doubled, and up to 40% of the Norwegian GHG will be covered. There will be the possibility to transfer allowances between companies in Norway and the EU member countries.

South Korea

South Korea signed and ratified the Kyoto Protocol but was classified as a developing country. Therefore, it is not targeted to reduce greenhouse gas emissions between 2008 and 2012. Nevertheless, there are various activities from industry, research institutes and particularly from the government to foster the establishing of emissions trading schemes not only for greenhouse gases but also for local air pollutants (SO_X, NO_X, TSP) in the Seoul Metropolitan area. (Kim and Haites 2005, p. 68-74). Two ministries, the Ministry of Environment and the Ministry of Commerce, Industry and Energy have independently developed frameworks for a pilot phase CO_2 trading scheme. Both proposals are quite similar to the emissions trading scheme running in the UK 2002-2006. Core design elements are voluntary participation and incentive auction as initial allocation. (Kim and Haites 2005, p. 66-68). Up to the present a pilot phase emissions trading scheme has not been launched, "its implementation might not be possible in the near future" (Kim and Haites 2005, p. 68). However, currently, the government approved 50 projects designed to reduce greenhouse gas emissions and will start issuing carbon credits to project owners to establish *a domestic carbon credit market* by the end of 2007. The credits could be sold as CER overseas if they meet the standards or they could be sold to the government for a fixed price (KRW 5,000 = US$5,30 metric ton).[7]

Switzerland

Switzerland plans a *CO_2 emissions trading scheme* for the 2008-2012 period and aims at linking this system with the EU emissions trading scheme. The sectors included will be similar to those of the EU ETS. "The Swiss emissions trading scheme primarily concerns companies that assume a legally binding commitment to reduce their energy-related CO_2 emissions and thus accept a target for 2008-2012." (FOEN 2006, p. 2) In return, these companies will be exempted from the CO_2 tax on heating fuels, which will be introduced on 1 January 2008.

[7] http://www.nasdaq.com/aspxcontent/NewsStory.aspx?cpath=20070822%5cACQDJON20070708220214DOWJONESDJONLINE000324.htm&; 07.09.2007

United States of America

- *Chicago Climate Exchange (CCX):* The CCX was launched in 2003 as a voluntary but legally binding compliance regime. It is the first ET scheme to encompass all six greenhouse gases. Starting with 13 members in 2003 the CCX currently has "nearly 300 members from all sectors and Offset Projects worldwide"[8] In 2005 the CCX launched the European Climate Exchange (ECX), which currently has 65 businesses as members.[9]
- *Regional Greenhouse Gas Initiative (RGGI):* RGGI is a cooperation of currently nine Northeast and Mid-Atlantic states (Connecticut, Delaware, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont) to develop a regional, mandatory market-based cap-and-trade program for the electric power sector (Burtraw et al., 2005; Burtraw and Palmer 2006). Emissions trading should start in 2009. In the beginning it will focus on carbon dioxide; later it may be extended to other greenhouse gases.[10]
- *California's Global Warming Solutions Act (AB 32):* The Act requires the State of California to reduce greenhouse gas emissions to 1990 levels by 2020. In a report delivered to the California's State Air Resources Board (CARB) in June 2007 the Market Advisory Committee makes recommendations for the design of a greenhouse gas cap-and-trade system. Core elements are: to "eventually include all major greenhouse gas-emitting sectors", and "to encourage linkages with other mandatory GHG cap-and-trade systems". If an emissions trading scheme will be adopted it will start on January 2012 at the latest to achieve the 2020 targets (Market Advisory Committee 2007).
- *Western Climate Initiative (WCI):* In the WCI five US states (Arizona, California, New Mexico, Oregon, Utah, Washington) and two Canadian provinces (British Columbia, Manitoba) cooperate to establish a regional market based mechanism to reduce GHG. In the memorandum of understanding signed in February 2007 the members agreed to jointly set a regional emissions target (15% below 2005 levels by 2020; WCI 2007). "By August 2008 they will also complete the design of a market-based mechanism"[11]

A consequence of these emerging ET schemes is that more and more companies around the world are affected by greenhouse gas emissions trading: This implies new challenges for them: As polluters they have to cope with the new institutional arrangement; they have to integrate ET into their organizational structures, They have to analyze their mitigation potential; and they have to decide about make-or-buy strategies. Other companies, which are not directly involved in ET, are also affected: the suppliers of environmental technologies may face increasing demand, the consumers may face higher energy prices like in the chemical industry, and the financial services industry seeks new market opportunities for innovative products.

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[8] http://www.chicagoclimatex.com/content.jsf?id=1, 06.09.2007
[9] http://www.chicagoclimatex.com/content.jsf?id=1042; 06.09.2007
[10] http://www.rggi.org/index.htm, 06.09.2007
[11] http://www.westernclimateinitiative.org/Index.cfm; 06.09.2007

1.2 Overview of the book

The book "Emissions Trading: Institutional Design, Decision Making and Corporate Strategies" has the objectives (1) to analyze design features of the market-based instrument "emissions trading", (2) to shed light on the effects of emissions trading on business investments and corporate decisions, and (3) to develop business strategies to cope with the new challenge of emissions trading. Focusing on these topics, the book is at the borderline between environmental economics and environmental business. In the following, a brief overview of the 16 contributions will be given which are divided into three parts.

Part A "Institutional Design" deals with design features of emissions trading. The five contributions analyze which impacts will occur with the choice of various design options and which design options should be proposed. In a first chapter, *Joe Kruger* – in a more general consideration – sheds light on the relationship between environmental regulators and the regulated industry. Elaborating on the changing roles and interactions between these two groups he concludes that emissions trading as a market-based instrument has brought a new paradigm compared to traditional command-and-control environmental policy. *Heinrich Tschochohei* and *Jan Zöckler*, in the second chapter, come to a quite different conclusion: Analysing the German National Allocation Plan within the first phase of the European Emission Trading System (2005-2007), they argue on the basis of a public choice approach that the new ETS – at least in Germany – has not brought such a change of paradigm. Instead, the interests of the regulated industry were prevailing in the design of German National Allocation Plan in 2005.

Within the various design options of emissions trading schemes, one important element is the initial allocation of allowances. Here grandfathering and auctioning are the basic alternatives. Three chapters in Part A deal with this topic: First, *Anja Pauksztat* analyses the options and product-based benchmarks (as a special form of grandfathering) in the energy sector and develops concrete calculation schemes. Second, *Bodo Sturm* analyzes – on the basis of experimental research – whether market power exists in a multiple unit double auction. And finally, *Frank Gagelmann* analyses market performance of alternative allocation schemes, in particular market liquidity and volatility.

In **Part B, "Investment and Corporate Decisions",** market effects of emissions trading and their consequences for corporate decision making are analyzed. Especially in the electricity market, investment decisions have a planning horizon of several decades. This means that not only the present situation is relevant for decision-making, but future prospects even more so, e.g. expected prices of emissions allowances, changes in the legal framework, and the accompanying uncertainty. To deal with this situation, business managers need both, sound market information including forecasts about future developments, and methods for decision-making which allow one to include this information and to cope with uncertainty. The different contributions of Part B provide a solid basis for integrating these aspects into decision making. In the first contribution, *Fichtner* gives an overview of the impacts of emissions trading on the European electricity market. He presents a linear optimization model which allows the includion of all major electricity generating installments in Europe. Subsequently, he uses the model to

simulate the current and future situations of the electricity market and shows that from the year 2000 to 2020 electricity production will change significantly. In Germany, the importance of nuclear power and lignite will go down, while other energy sources, in particular renewables, will gain greater market share. In the second chapter, *Weidlich, Sensfuß, Genoese* and *Veit* consider the impact of emissions trading on electricity markets by modelling and simulating the emissions trading market with a multi-agent-system. They concentrate on the German market with a special focus on representing the allowance trading process and the implications for power plant investment decisions. The proposed model enables the analysis of various market designs as well as various emissions allowances and electricity trading strategies. As mentioned, uncertainty is an important ingredient in emissions trading, exerting significant impact on corporate decision making. In the third contribution, *Sarkis* and *Tamarkin* investigate opportunities to include uncertainty with real-option-based models. Applying a quadranominal lattice approach, the authors come to the conclusion that photovoltaic technologies will be an attractive alternative to traditional power generating technologies, if significant cost reductions can be achieved. Besides costs, public policy will also influence the attractiveness of photovoltaic technologies. In a fourth chapter, *Klingelhöfer* presents a linear model to evaluate investments with specific regard to tradable emissions permits and uncertainty. Uncertainty is again embedded in the consideration by using an option pricing model, from which the results can be used to apply sensitivity analysis in the linear model. Through duality theory, Klingelhöfer identifies the main determinants of investments related to greenhouse gas emissions. He also shows that emissions trading does not always encourage environmentally beneficial investments. In the fifth and last contribution of Part B, *Laurikka* explores quantitative implications of emissions trading on investment decisions in a deregulated electricity market. Within a case study in Finland he compares a gas-fired condensing power plant, a hydro power plant with a reservoir and an off-shore wind power farm. By simulating different possible market outcomes with a single-firm exogenous and stochastic price model he comes to the result that emissions trading increases the expected profitability of all three types of power plants. In the case of the gas-fired power plant the expected higher profitability is related to a higher overall risk.

In **Part C** "**Corporate Strategies"** the corporate strategic dimension of emissions trading is considered. The Part starts with a theoretical analysis of *Charlotte Hesselbarth.* She provides a framework of the strategic options of a sustainability-oriented management and investigates how these options are impacted by ET. Potentials for intersection management (success factors, triple-win-situations) are pointed out as well as prospects for structural policy and, due to the limits of market-based instruments and monetary regulation, norm-setting activities (overtaking of sustainability responsibility). Likewise a broad view on corporate strategies, this time an empirical one, is undertaken by *Jonatan M. Pinkse.* Based on questionnaire data of 218 companies from various countries and industries, he investigates what activities large companies have undertaken to utilize emissions trading and/or offset projects as part of a strategy for climate change. His findings show that many companies have the intention to participate in the emissions market, but

are waiting with implementation until government policy becomes more concrete. Quite similar results are derived by *Rūta Bubnienė* for Lithunian companies covered by the EU ETS. Her empirical findings indicate that, although there is potential for Lithuanian companies to take an active role in the carbon market, uncertainty regarding the outcomes of the scheme prevents them from taking a proactive position at the beginning of the first phase of the scheme. *Marcus Wagner* shows that combining ET with other management tools could be very helpful in building capacity in the sense of an intersection management. He analyzes interactions of corporate energy management strategies in Europe with the EU ETS and environmental management systems. He finds out that using both instruments, ETS and EMS, has a very positive effect. In particular the EMS plays a critical role, because it is its implementation that enables the correct identification of marginal costs for the activities, based on learning processes and better information quality. Another empirical study by *Michael Nye,* which is based on semi-structured interviews with key corporate participants in the UK ETS, underpins the importance of capacity building. The analysis of the interview data reveals that the development of an emissions trading market can be linked to the ability of firms to make an informed participation decision that takes into account the interdependent dimensions of emissions trading. To a more skeptical view on the intersection potential of ET comes the investigation of climate strategies of Swedish companies by *Fredrik von Malmborg.* Employing a transaction cost theory approach in combination with perspectives of institutional theory in organisational analysis, he finds that participation in the Kyoto project mechanisms is less attractive than other options. His primary reasons are high transaction costs and a low potential for sourcing legitimacy needed to obtain other resources.

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Part A

Institutional design

Companies and regulators in emissions trading programs

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Abstract

Much has been written about the economic and environmental performance of US emissions trading programs for "acid rain" (sulfur dioxide) and nitrogen oxides. Less explored have been the unique roles and interactions of environmental regulators and the companies they regulate. I first examine how these roles change the way that regulators and companies operate within their own organizations and with each other. Next, I use examples from US trading programs to illustrate the design and administrative features that allow program administrators and industry to best fulfill their respective roles and maximize economic benefits. Finally, I determine whether these features are present in the EU Emissions Trading System and examine the implications for its effectiveness.

Keywords: Emissions trading, climate change, environmental management, information technology

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1 Introduction

One of the most striking aspects of an emissions trading program is the unique roles and interactions of environmental regulators and the companies they regulate. Emissions trading programs are starkly different from traditional regulatory programs that mandate specific technologies or facility-specific standards. In an emissions trading program, regulators defer decisions on technology and compliance strategy to the companies, which best understand their business operations. Regulators focus instead on monitoring and verification of emissions, tracking the transfer of emissions allowances, ensuring that companies hold enough allowances to match their emissions, and assessing any necessary penalties.

Similarly, companies have a very different role in emissions trading programs. Under the traditional command-and-control approach, a company might simply have its environmental compliance department interpret and implement a technology mandate. In contrast, an emissions trading program requires a more integrated approach. Because there is complete flexibility in compliance in an emissions trading program, the compliance strategy becomes integrated into the company's overall business strategy. Most companies explore numerous compliance scenarios before selecting a strategy based on their analysis of fuel markets, tax and accounting consequences, finance implications, and even public relations.[1]

In this chapter, I examine how those new roles change the way that both regulators and companies operate within their own organizations, interact with each other, and contribute to the overall effectiveness of the program. I also explore whether the same factors that shaped the US programs are affecting the European Union Emissions Trading System (EU ETS).

In brief, I find that companies participating in the US sulfur dioxide (SO_2) and nitrogen oxides (NO_x) trading programs have developed internal structures to handle the significant complexities of flexible compliance planning and to manage both price and regulatory uncertainties. Regulators at the Environmental Protection Agency (EPA) have developed their internal structures to ensure consistency and environmental integrity, but also to improve administrative certainty for companies. Although regulatory uncertainties are often beyond the control of both program administrators and companies, the focus of both parties on a routine and predictable administrative program has been mutually beneficial and has led to a reasonably harmonious relationship between industry and agency.[2] Although it is

[1] Lober and Bailey found that there was a correlation between nonparticipation in the SO_2 allowance auctions and concerns by companies about negative public views of allowance trading (Lober and Bailey 1997). Some of this concern was spurred by negative press reports about the first few SO_2 allowance trades. For example, following the first publicly reported allowance trade in 1992, an opinion piece in *USA Today* argued that as a result of allowance trading "people will die" (Kruger and Dean 1997).

[2] Regulatory uncertainties such as restructuring of the electric power sector may have both economic and market implications. However, for purposes of this paper, the term regulatory uncertainties refers to potential changes in environmental requirements that might affect utility decision making about compliance strategies or investment choices.

far too early to make any definitive conclusions about the EU ETS, I find that many of these same features are present. However, companies in the European Union face significantly greater uncertainty about future environmental requirements than did their US counterparts. Moreover, it will be worth watching whether the flexible system of emissions reporting and verification for the EU ETS will provide the administrative certainty required for the efficient and effective operation of the program.

2 Industry's role: strategic planner and entrepreneur

Compliance planning in an emissions trading program is both simpler and more complex than under command-and-control regulations. It is simpler in that the compliance determination itself is objective and straightforward – a company simply holds enough allowances to match its emissions. The flexibility of emissions trading programs allows a company to tailor a cost-effective strategy to its own circumstances. A company is not forced to meet a technology mandate that may not make sense for its plant configuration or business plan. There are no complex reviews of whether the firm meets technical or process specifications, or whether its pollution abatement equipment is operating as it should. Finally, there is no uncertainty about whether regulators will react favorably to a compliance plan.[3]

On the other hand, the flexibility and freedom inherent in a performance-based emissions trading program put added pressure on a company to develop an effective strategy. A poor strategy could lower shareholder value and erode the competitiveness of a company vis-à-vis other firms in the industry. Thus, a variety of factors must be considered, including future changes in fuel markets, technological options, financing issues, tax considerations, and possible regulatory changes. Reconciling all of these factors may be considerably more challenging than implementing a technology mandate.

The wide range of possible strategies and options increases the complexity of the analysis that must take place as a company develops its compliance strategy. Compliance choices may require large capital outlays or have long lead times for completion. For example, some of the initial compliance decisions for the SO_2 program had to be made three years in advance to allow time to install pollution control equipment (Reinhardt 1993). Building a new power plant may require an even longer lead time for design, permitting, and construction (EMA 1999). Thus,

[3] In contrast, traditional regulatory programs often use a detailed permitting process that requires government review of technology or process measures used to reduce emissions. In these programs, sources submit detailed permit applications describing plan configurations, the proposed technology and its specifications, expected emissions and levels of operation, proposed expenditures, and other information. Government officials review this information for each facility and issue a detailed, legally enforceable permit. In some countries, significant changes at a facility require additional extensive submissions by industry and review by government officials (UK Environment Agency 2000; US EPA 2000).

knowledge of how requirements of a trading program may evolve over time and how these changing requirements will alter the cost of complying with an emissions trading program is critical to making the right investment decisions. For example, a company might make entirely different decisions if it knows that an emissions cap will remain unchanged over many years, or if it expects an overall change in a cap within a few years.

Experience in the United States has shown that companies address complexities and uncertainties in several ways. First, companies in the US SO_2 and NO_X trading programs have adopted an interdepartmental approach to compliance planning and operations. Second, to handle the complexity of planning under a variety of scenarios, companies have used sophisticated analytical tools. Third, some companies have taken advantage of risk management strategies made possible by a liquid emissions allowance market. Finally, to an unprecedented degree, companies have adopted information technologies for data management and regulatory reporting. These aspects of organization and corporate behavior in an emissions trading program are discussed below.

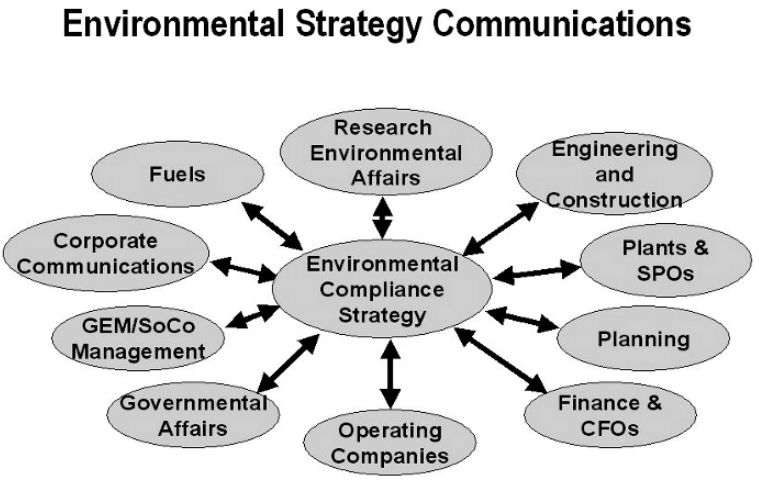

Fig. 1. Departments participating in Southern Company compliance planning. *CFO* chief financial officer, *SoCo* Southern Company, *SPO* senior production officer in charge of all the plants for a specific operating company, *GEM* Generation and Energy Marketing (an internal organization that crosses operating company boundaries and pulls together management of power plants, fuel, planning, and marketing under one umbrella)
Source: Southern Company

2.1 An interdepartmental approach

The diversity of corporate issues that arise in compliance planning in an emissions trading program are surprisingly broad. Previously, compliance planning was often assigned to an environmental affairs department. With the advent of the SO_2 trading program, environmental strategy became more central to overall business strategy. It therefore required input from a number of departments and required extensive coordination across the company (Gloski et al. 1995; Price and Crockett 1995). In the early years of the program, companies often formed teams to ensure that they had structures in place to meet compliance requirements. For example, South Carolina Electric & Gas formed an interdepartmental team to assess the capabilities required for software needed for compliance (Mosier 1995).

Interdepartmental coordination continues to be critical for compliance planning. For example, Southern Company, the United States' largest electric power company in terms of electricity sales, incorporates input from 10 departments in the development of its compliance strategies. The process includes input from senior officials, including all the chief financial officers within the holding company's six operating companies. Figure 1 shows the various departments that have input into Southern Company's compliance strategy.

There is some evidence that the way companies organize to implement trading programs may depend on the overall corporate view of emissions trading within a company. In a survey conducted for the Electric Power Research Institute during the early years of the SO_2 trading program, Price and Crockett (1995) found that companies that placed a priority on matching allowances to their own emissions often gave the lead to environmental or power production departments. In contrast, companies that viewed allowances as a marketable commodity tended to give the lead to the fuel or bulk power departments. Over time, there has also been a trend in some companies to shift allowance trading activities to new departments that focus on all energy-related commodities, including electricity and natural gas (Swift 2001).

Companies that take an active approach to managing their allowance assets may give considerable autonomy to trading departments. For example, at American Electric Power, day-to-day decisions on allowance trading are made by the company's trading department, which also handles general energy trading strategies. Meanwhile, broader decisions on capital investments for pollution controls, such as scrubbers for SO_2 or selective catalytic reduction technologies for NO_x, are made in the departments that address overall corporate strategy or major investments in generation (Braine 2004).

In some cases, effective integration of environmental planning departments with trading departments requires significant changes. For example, initially at PG&E National Energy Group, the environmental affairs department made decisions on individual allowance trades, and the energy trading department executed the trades and was responsible for overall risk management and oversight. Starting in 2000, the company decided to give day-to-day emissions allowance portfolio management duties to the trading department, with the stipulation that allowances be returned to environmental affairs by a set date for compliance. Ultimately, this

change required the environmental affairs department to have confidence that the allowance market had enough liquidity, and that an active trading program would not jeopardize environmental compliance, although it might put the cost of compliance at risk (LaCount 2000).

2.2 Sophisticated analytical tools

Although much attention is placed on the trading of allowances, it is important to note that trading is only one component of a strategy in a cap-and-trade program. The flexible, performance-based nature of these programs and the ability to conduct compliance planning on a companywide basis also allows considerable cost savings. This is true even if there is no trading (Burtraw 1996).[4] This flexibility has led companies to develop and consider multiple scenarios for compliance (Reinhardt 1993). Companies have developed sophisticated tools to help them evaluate these scenarios. For example, PEPCO, a company that operates in Maryland and the District of Columbia, developed a computer model that forecasts emissions and simulates compliance options while optimizing net profits. We Energies (formerly WEPCO) developed a simulation model that was capable of looking ahead 20 years or more while developing least-cost compliance scenarios (EMA 1999).

Some companies use these models because they believe that superior analytic capabilities provide them with a strategic edge. For example, a recent assessment of American Electric Power's environmental strategy noted that the company's development of a proprietary model to assess environmental compliance options was "one of the company's most important accomplishments." This report, written by independent members of the company's board of directors, concluded that AEP's model had provided the company with an important competitive advantage (AEP 2004).

To run these models, companies must develop a series of inputs, some of which are based on additional analyses and scenarios. For example, Southern Company holds a series of forecasting workshops for the different types of fuels used at its power plants. The company must also make periodic assumptions about future technology costs and allowance prices. Figure 2 shows some of the other considerations that go into compliance planning at Southern Company, including assumptions about how regulatory requirements may change in the future.

[4] Burtraw (1996) also found that cost savings resulted from market competition between different vendors of technologies and fuels. These vendors were forced to compete with each other for the first time under the SO_2 trading program.

2.3 Application of risk management tools and strategies

The inherent price uncertainty in emissions markets has led some US companies to use strategies to manage risk (Canterbury 2003). The same tools that are used in financial markets to hedge risk have been used in the US SO_2 program. These in-

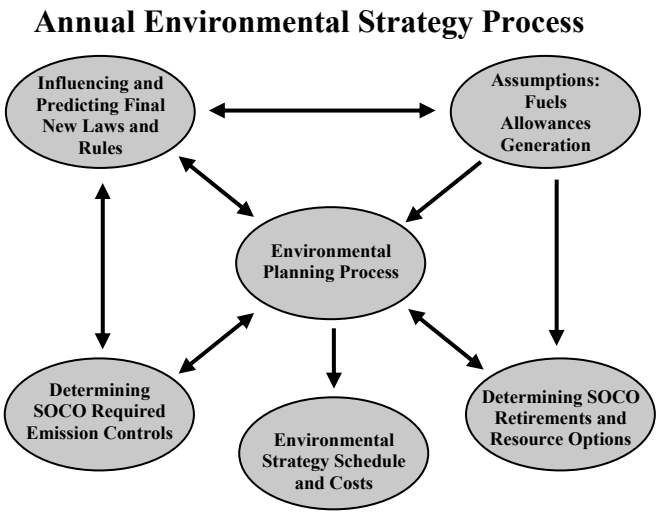

Fig. 2. Southern Company (SOCO) compliance process
Source: Southern Company

clude relatively simple strategies like dollar cost averaging, which spreads the buying or selling of allowances over a period of time so that the firm can avoid buying large amounts of allowances at the top of the market or selling large amounts at the bottom of a market cycle. They also include more complex structures, such as forward settlements, swaps of allowance vintage years, loans of allowances, options, weather-contingent contracts, and other mechanisms (EMA 1999; Hart 2000; Zaborowsky 2004).[5] Finally, there has also been bundling of coal supplies with emissions allowances in packages designed to meet the emissions specification of electric power companies and to conduct arbitrage between coal and allowance markets (Doucett and Strauss 1994; Ellerman et al. 2000).

US experience with the SO_2 trading program has shown that companies have also benefited from using banking strategies to manage price uncertainty and to facilitate compliance planning.[6] Allowance banking can create a cushion that will

[5] According to emissions trading brokers and other observers, unregulated electric power companies, merchant generators, and energy marketing firms take a more active role in the asset management of allowances than do regulated electric utilities (Zaborowsky 2002).

[6] In contrast, the lack of an adequate banking provision in the RECLAIM trading program in Southern California may have been at least partially responsible for extreme price volatility following high electricity demand in 2000. See Ellerman et al. (2003).

prevent price spikes and can hedge uncertainty in allowance prices (Jacoby and Ellerman 2004). Essentially, a banking provision allows the arbitrage between actual marginal abatement costs in one phase of a program and the expected abatement cost in a future phase of a program. Banking can also mitigate the consequences of "overinvestment" by providing extra allowances that may then be used for future compliance (Ellerman et al. 2000). Moreover, the temporal flexibility of banking is particularly useful for companies facing large capital expenditures because it provides some flexibility in the timing of those expenditures (Tietenberg 2003).

2.4 Incorporation of information technology

Companies affected by US emissions trading programs have used increasingly sophisticated software to help them manage their emissions and allowances (US EPA 1996). The huge amount of data that must be tracked by companies is, in the words of one industry official, "an accountability monster" that makes information technology a necessity (Martin 1995). In addition to the software developed by EPA for firms to submit emissions reports (discussed below), many companies use software that tracks and projects emissions throughout the year, compares emissions and allowance holdings, and manages allowance transfers and accounting issues. This same software can reconcile utility allowance databases with those of EPA and submit electronic filings to EPA. The Allowance Tracking Workstation (ATW; http://esp-net.com/pdfs/ecoAsset.pdf), a software application manufactured by Environmental Software Providers that is used to manage roughly 40% of the allowances in the SO_2 trading program (Gloski 2004), handles several types of functions:

- Generates electronic transfer file
- Generates allowance deduction form, including selection of serialized allowance blocks
- Allows electronic emissions reports to be submitted to EPA
- Tracks all allowance trades by serial numbers and allows comparison of ATW database with the EPA registry
- Tracks actual emissions versus projected emissions
- Allows tracking of multiple accounts
- Generates forms required for allowance accounting associated with interstate sales of electricity
- Calculates moving average costs of allowance for accounting and valuation purposes

Company officials have noted that integrating their emissions monitoring systems with their overall data systems allows them to share emissions information among departments (Konings 1995; Caulfield and Dene 1995). This capability also allows them to determine well ahead of compliance deadlines whether their allowance holdings are adequate. For example, Southern Company puts out

monthly emissions reports that allow its operating companies' allowance managers to determine whether they risk running short on emissions allowances. When a compliance period ends, they can tally their emissions within a few days and go out on the market to buy any additional allowances they need (Hart 2004).

3 Role of regulators

Ellerman (1999) has noted the "revolutionary" role played by the environmental regulator in an emissions trading program. He writes that this role "is no longer that of grandly deciding what is best for firms and individuals, entertaining equitable appeals, and enforcing the result" (Ellerman 1998). Instead, regulators assume the role of a banker or accountant by focusing on the accurate tracking of emissions and allowances. In the US SO_2 program, for example, approximately 75% of staff resources (75 people, including personnel in regional EPA offices and state agencies) are focused on the measurement, verification, and tracking of emissions data. They also provide policy guidance on measurement issues (discussed below), develop and operate the information systems that track emissions and allowances, certify monitoring equipment, verify reported emissions data, and audit facilities (US EPA 2003).

Although the main organizing principle of program administrators is maintaining accountability for the system, an important secondary goal is providing administrative certainty. For example, regulated companies must be certain that administrators won't second-guess their compliance or business decisions, whether technology investments or individual emissions allowance trades. Both government and industry officials have noted the importance of a "hands-off" approach by government to the market. For example, an EPA program administrator contends:

> Government should refrain from trying to participate in, control, or fine tune the market, particularly since many changes, such as restructuring, may occur outside the regulator's purview. This focus should provide the certainty, efficiency, and stability desired by all and necessary for optimal market performance. (McLean 1997)

An emissions trading manager at one of the largest power companies in the United States notes that by playing an appropriate role, regulators facilitate the market. He writes:

> The EPA has acted as a type of clearinghouse for this system and through their annual auction and their compliance verification process has assured those participating in the market that the allowances they buy, sell, or trade are valid and fungible. (Hart 2000)

In addition to not interfering in market activity, program administrators have tried to create administrative certainty by making program operations routine and not subject to discretion. The routine nature and lack of regulatory discretion of

the US trading programs manifests itself in several ways. First, the rules for emissions monitoring are extraordinarily detailed and prescriptive, leaving little discretion for either companies or regulators. Second, there is heavy reliance on information technologies to operate the program and to automate routine procedures. Finally, excess emissions penalties are nondiscretionary and automatic. These aspects of how regulators operate are described below.

3.1 Detailed rules for emissions monitoring and reporting

Monitoring rules are highly detailed in the US SO_2 and NO_x programs. The regulations for monitoring cover almost 300 pages and provide detailed standards for installation and certification of monitors, quality assurance and testing, handling of missing data, recordkeeping, and other features.[7] Most of these rules are now incorporated into software systems at both the companies and EPA so that the reporting and review of emissions reports are highly standardized.

To provide certainty and ensure consistency, EPA devotes extensive resources to answering and documenting questions that arise about monitoring requirements. EPA has an online policy manual that is largely in a question-and-answer format. It has been updated more than a dozen times over the life of the program and is now nearly 500 pages long. These detailed monitoring and reporting requirements, though complex, have provided companies with considerable certainty that if they follow the procedures, their emissions reports will be accepted in a timely manner.

3.2 Centrality of information technology

The routine nature of the decisions that regulators make and the vast amounts of emissions and allowance data that must be handled have allowed regulators to build the operation of the trading program largely around information technology (Kruger et al. 2000; Perez-Henriquez 2004). For example, companies are required to report emissions data to EPA in a standardized electronic format. Once the data are received, EPA computers run quality assurance tests and give electronic feedback to companies. Additional software is used to run electronic audits on emissions reports. Emissions data are maintained in a database that is accessible via the Internet (Husk and DeSantis 2002).

EPA's allowance registry is similar to an online banking system, with companies able to manage their allowance accounts and make transfers without submitting paper forms. Approximately 80% of all transfers of allowances are now done

[7] To a certain extent, the use of continuous emissions monitors (CEMs) in the US trading system has required this more prescriptive approach. However, although 96% of emissions in the US SO_2 program are monitored with CEMs, only 36% of units are required to use CEMs. Gas-fired units, for example, are allowed to use alternative methods. The regulations for these alternative methods are still quite detailed (e.g., there are 30 pages of regulations for a method that allows gas-fired units to use fuel meters and emissions factors).

over the Internet by the sources themselves. Similarly, EPA has implemented a new application that allows companies to log onto a secure site and perform functions that were previously done with paper forms. These include changing information about company officials who are authorized to act for an allowance account, submitting data about new or retired emissions sources, and determining whether a source is required to participate in the program (Husk and DeSantis 2002).

Electronic reporting and processing of data have been critical in meeting the tight timeframes for the annual compliance true-up period. Companies submit their final quarter's emissions data by January 31 and have until March 1 to transfer allowances and submit final compliance certification forms. EPA then completes verification of the annual emissions data and compares them electronically with allowances within the accounts of each unit. Typically, this process is completed by June.

Finally, through the development of standardized reporting formats and protocols, EPA and companies have meshed their data systems. Early in the program, EPA developed and distributed software to help companies develop their emissions reporting systems (McLean 1997). As discussed earlier, software used by companies to track allowances and emissions incorporates standardized EPA electronic reporting formats and allows companies to compare their own records of allowance holdings with those in the EPA registry.

3.3 Automatic and nondiscretionary penalties

The certainty that a penalty will be imposed is a critical element in providing the correct incentives in an emissions trading program. The automatic nature of excess emissions penalties in US trading programs contrasts with the traditional regulatory approach, in which sources in violation negotiate for a regulatory exemption (Ellerman 2003). If the negotiation costs are less than the cost of compliance, then participants in a trading program have little incentive to comply. Conversely, if participants in a trading program know that the cost of a ton of excess emissions will exceed the cost of buying an allowance on the market, they have every financial incentive to comply. Administrators of the US trading program argue that the automatic nature of penalties and the certainty of other compliance-related provisions focus corporate resources and attention on low-cost compliance strategies, rather than on lobbying or litigating to reduce costs (McLean 2004).

Compliance interactions between regulators and companies mainly involve resolving discrepancies over emissions data that arise in the quality assurance process. As discussed earlier, quarterly electronic reporting and feedback give companies adequate notice of data problems and time to correct these problems before the annual reconciliation of allowances and emissions data. Compliance is a largely routine process; allowances are electronically compared with emissions at each utility unit. With an automatic penalty that is significantly higher than the

market price for allowances, and with a liquid market for allowances, there has been nearly 100% compliance with the SO_2 trading program.[8]

4 Industry attitudes toward US program administrators

The routinization of decisions made by regulators has led to a relatively harmonious relationship between regulators and companies in the US programs. Although there has been no formal study of attitudes toward regulators in the SO_2 program, there is anecdotal evidence that industry officials are generally satisfied with the interactions. One industry representative notes that this constructive relationship between industry and regulators is due to a clear mission for regulators – that is, "to get the system up and working, to ensure compliance, and to report on progress" (Braine 2004). Swift (2001) argues that this focus on emissions results rather than compliance choices creates less friction between regulators and companies because it reduces transaction costs and avoids delays inherent in the review of industry strategies. This represents a considerable improvement over earlier emissions trading programs, in which case-by-case reviews of trades contributed to delays and uncertainties (Hahn and Hester 1989). Finally, industry officials have also lauded the lack of interference in the allowance market by program administrators (Chartier 1997), the lack of restrictions on banking (Hart 2000), and the general ease of administration (McManus 2001). All of these features have made it easier for companies to take advantage of the flexibility inherent in a market-based program.[9]

5 The European Union Emissions Trading System

5.1 Administrative certainty in the EU ETS

In general, the EU ETS incorporates many of the lessons learned from earlier emissions trading programs about the appropriate roles of regulators and companies. There are no restrictions on allowance trading, nor are there case-by-case reviews of individual allowance trades. Moreover, there is no role for regulators in determining the compliance strategies that should be followed by companies. Interestingly, it is not clear that all member state authorities fully agree with this hands-off role. In their review of member states' national allocation plans, Euro-

[8] In nine years of operation, there have been 15 penalties, ranging from $2,682 to $1,580,000. There have been a few additional civil penalties for other violations, such as failures to monitor and report emissions (Kruger 2004).

[9] Not surprisingly, Svendsen found that the flexibility of the cap and trade approach, coupled with increased competition in the electric power sector, is as one of the main reasons the US electric power industry prefers a grandfathered tradeable permits market over other regulatory approaches (Svendsen 1999).

pean Commission regulators flagged allocation provisions in some plans that would have interfered with the development of allowance markets. Specifically, the commission prohibited the use of ex post adjustment clauses in the national allocation plans of Germany, Austria, Luxembourg, Portugal, and Belgium (EC 2004a, 2004b). The commission noted that these provisions, which would allow authorities to confiscate allowances from companies if emissions were lower than predicted, "would create uncertainty for operators and be detrimental to investment decisions and the market" (EC 2004b).

The EU ETS has also emphasized standardized emissions monitoring techniques through binding guidelines that are considerably more detailed than comparable past guidance put forward for EU environmental directives (Kruger and Pizer 2004a). Nevertheless, the European Union's emissions monitoring, reporting, and verification system procedures differ from those in the United States in several ways. First, the proposed guidelines are less prescriptive and give considerably more flexibility to installations and to member states.[10] There are several reasons for this flexibility. First, it reflects the diversity in the types of sources in the EU ETS. Second, it may be a sign of a fundamental difference in the underlying monitoring and reporting approach. The EU ETS approach relies more on the professional judgment of the verifier to interpret broader monitoring guidelines. In contrast, the US system relies more heavily on detailed rules with less discretion for government verifiers.[11] Moreover, in contrast to the US trading systems, member state authorities may require companies to use third-party verifiers if the government does not have the capacity to verify hundreds of emissions reports. Also, some advocates of third-party verification have argued that it is important to have verifiers who are independent of government authorities.[12]

It is not clear whether the use of more flexible guidelines and third-party verification will increase or decrease the certainty of the acceptability of emissions reports. On one hand, a flexible monitoring process implemented by a legion of competent third-party verifiers could provide adequate certainty to companies participating in the program. On the other hand, if portions of the guidelines are

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[11] Differences in emissions monitoring and verification approaches may be analogous to differences in accounting practices in the US and Europe. The European corporate accounting system is characterized by "principles-based accounting", whereby accounting guidelines are more general and more discretion is given to interpretation. In contrast, the US accounting system is "rules-based", with more detailed decision rules for accounting and less discretion for interpretation. See Lenihan and Hume (2003) for a discussion of the advantages and disadvantages of each approach.

[12] For example, the president of the International Emissions Trading Association has written to the Polish government to encourage officials not to have a government authority conduct verification. He writes that "we believe that the role of verifier and that of competent authority should be separated and that they should have an arms-length relationship" (Marcu 2004).

viewed as ambiguous and require additional interpretation, or if third-party verifiers differ significantly in their competence or consistency, then the EU ETS monitoring process could increase administrative uncertainty. It may also be more difficult to translate the flexible approach inherent in the monitoring and verification system into a standardized electronic reporting, verification, and auditing system like that in the United States. Finally, if uncertainties lead to delays in the approval of emissions reports, the EU allowance market could be affected, since the directive restricts the transfer of allowances from installations without approved emissions reports (EC 2003).

5.2 Planning in an uncertain regulatory environment

Although there is some uncertainty about how monitoring guidelines and other provisions will work in the EU ETS, it is likely that the questions can be addressed during the pilot phase of the program. A more difficult set of questions surrounds future emissions reduction requirements. This includes ambiguity about allocations in the second phase of the program as well as uncertainty about the form and level of international commitment beyond 2012. This lack of clarity about the future will make planning difficult. It will also make it challenging for European industry to take a long-term approach to investing in climate-friendly technologies and to planning a least-cost, longer-term strategy for greenhouse gas abatement.

The absence of a banking provision between the first and second phases is a further complication for planning efforts. The lack of banking may undermine longer-term mitigation plans because firms may have little incentive to implement strategies that create extra emissions reductions beyond their allocated levels. The inability to bank these "early reductions" could be a significant disincentive if prices are low in the first period and high in the second. Moreover, although banking will be available between the second period and subsequent periods, member states and their industries facing uncertainty over the structure of a future international regime could be reluctant to make the investment decisions necessary to take advantage of a banking provision (Kruger and Pizer 2004b).

6 Conclusions

Regulators and companies have developed roles in US trading programs that allow them to organize and interact efficiently. The routine, nondiscretionary "banker-accountant" role played by regulators facilitates the complex "strategist-entrepreneur" role played by companies. Information technologies have allowed both regulators and companies to manage the huge amounts of data necessary to operate an emissions trading program and to reduce transaction and administrative costs. These technologies have also become a bridge between companies and program administrators and have allowed the two sides to operate cooperatively and efficiently. Both sides benefit from this relationship. Regulators get improved ac-

countability and improved tracking of the environmental results of the program. Companies get more administrative certainty and the freedom to focus on integrating environmental options into their overall business strategies.

What factors will determine whether effective internal structures can be developed by companies and regulators in Europe? The companies have every incentive to evolve in ways that will provide them with appropriate structures to handle the complexities of emissions trading. After all, in the long run, the fiscal impacts and strategic complexities of a carbon cap for European firms are even greater than were the impacts of the SO_2 cap on US firms.[13] A greater challenge for European companies will be planning in the absence of certainty about Phase 2 allocations and post-Kyoto targets. Without a longer time frame for planning, European companies will face challenges making the right investment decisions no matter how well they operate across departments, take advantage of sophisticated planning tools, manage the price risks of compliance, and utilize information technology.

For regulators, the crucial question is whether the more flexible monitoring and verification system in the European Union will create enough certainty for industry while still maintaining environmental integrity. If flexibility leads to inconsistencies within or between member states, regulators may seek extended reviews of company emissions reports or third-party verification. Moreover, particularly during the early years of implementation, monitoring and verification issues will arise as emissions reports are reviewed. A process to expedite policy decisions on technical issues could be critical to give companies the administrative certainty they need. With the large number and diverse nature of installations in the EU ETS, and with the possible addition of more sectors in the second phase of the program, it will be worth watching whether program administrators and third-party verifiers can handle the huge volume of information in what is largely a paper-based emissions reporting system.

Finally, although it is far too early to make any definitive determination about the roles and interactions of companies and regulators in the EU ETS, the scope and diversity of the program will likely create new models and valuable lessons. For example, will the different business sectors represented in the program develop internal structures that reflect differing corporate cultures? Similarly, will different regulatory cultures represented in EU member states affect implementation of each domestic program? If so, does this make a difference for the overall effectiveness of the EU system? These and many other questions are worthy of further research as the regulators and the regulated in Europe implement the world's largest emissions trading system.

[13] However, several surveys have found that in the short term, some firms may have faced difficulties putting the internal structures in place in time for the quick startup of the EU ETS. See Carbon Finance 2004; Ernst and Young 2004; Logica 2004; PriceWaterhouseCoopers 2004.

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Business and emissions trading from a public choice perspective – waiting for a new paradigm to emerge

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Abstract

Emissions trading is the economist's preferred instrument for handling CO_2 emissions. It is described as an efficient and effective instrument that motivates corporations to redesign their internal decision-making processes and innovation management.

Referring to the European Emissions Trading Scheme (ETS) and, in particular, to its implementation in Germany as defined by the National Allocation Plan covering the period 2005-2007 (NAP I), we derive hypotheses about the interests of the actors deciding environmental policy against the background of Public Choice Theory. This helps us to understand why the practice in environmental policy differs significantly from theory. We argue that the German NAP I reflects a structural conservatism. Although comprehensive ET comes into force for the first time, we will still have to wait for a new paradigm to emerge in environmental policy.

Keywords: German National Allocation Plan, Public Choice Theory

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1 Introduction

Emissions trading (ET) is the economist's preferred instrument for handling carbon dioxide (CO_2) emissions (e.g. Hansjürgens 2001b). It is described as an efficient and effective instrument that leads corporations to redesign their internal decision-making processes and innovation management (e.g. Perman et al. 2003). The opinion that ET can challenge corporations in an entirely new manner is widely spread among researchers as well as among laymen.

Referring to the European Emissions Trading Scheme and, in particular, to its implementation in Germany as defined by the National Allocation Plan covering the period 2005-2007 (NAP I), we argue that the practice in environmental policy differs significantly from theory. This gap can be explained using a Public Choice approach. Departing from hypotheses about the interests of the actors deciding environmental policy, we evaluate the concrete design of the German NAP I: the German NAP I reflects the concerns of important interest groups and represents a structural conservatism. Although comprehensive ET is coming into force for the first time in Europe, we will still have to wait for a new paradigm to emerge in environmental policy.

The structure of this paper is the following: in the next section, emissions trading is described as an instrument of environmental policy that – in theory – creates a market for emissions. Section 3 focuses on the political process, which – in practice – determines the concrete implementation of ET. Using Public Choice Theory, we can derive hypotheses on the influence of the interests of the actors involved in the environmental policy process. In section 4, we describe the European ETS and its implementation in Germany on the basis of these hypotheses. In section 5 we present our conclusions and give an outlook for further developments in ET.

2 Emissions trading in economic theory

Why do economists understand ET as an adequate instrument to deal with market failures, and even as a "doctor's prescription" (Hahn 1989)? What makes people believe ET would challenge prevalent business habits and influence internal decision-making?

In theory, ET is an effective and efficient instrument of environmental policy (Hahn 1983). In practice, its effectiveness has been shown in various applications (e.g. the US RECLAIM programme; Fromm and Hansjürgens 1998). Bringing ET into force requires a certain framework. First of all, the so-called cap has to be defined (a maximum total quantity of emissions which is split into permits) and a decision on the initial allocation process of the permits (auctioning vs. no charge) has to be taken. Also a market which allows for a free sale of emission permits at any price, a monitoring system as well as system sanctioning the exceeding of emissions allowed has to be set up (Perman et al. 2003).

Environmental economists evaluate instruments against the criteria of effectiveness, static efficiency and dynamic efficiency (e.g. Fritsch et al. 2003). When considering *effectiveness*, it is asked whether an instrument ensures that the emissions target is reached. As the total quantity of emissions is defined by the cap, ET caters to a concrete level of pollution avoidance. Hence, systems based on tradable permits can be considered to be effective. Of course, in order to achieve these goals, sufficient monitoring and enforcement is necessary.

Static efficiency means that a reduction in emissions is reached at the lowest costs possible. The tradability of permits allows for a market price to evolve. If a company with high abatement costs is running out of permits, it has to buy additional ones. Only companies with low abatement costs can reduce their emissions. However, this requires an adequate number of market participants in order to increase the probability of obtaining a market-clearing price. In addition, transaction costs should be kept at a minimum level (Hahn and Noll 1982; Butzengeiger and Schmidt 2007).

Dynamic efficiency is the criterion referring to incentives for investments in a lowering of abatement costs. Such incentives are likely to foster process innovations, which result in a reduction in emissions, or product innovations, such as new abatement technologies. When considering dynamic efficiency, the entire process of technological change should be analysed: innovation and diffusion of inventions, as well as the role of the regulator in a changing innovatory environment (Milliman and Prince 1989). It turns out that while the allocation mechanism has no influence on ET, the system's cost-efficiency differences in dynamic efficiency are remarkable. Milliman and Prince (1989) show that it is true that free permits as well as auctioned permits trigger innovations; but auctioned permits set a stronger incentive for promoting new technologies. According to them, this results from falling prices as a consequence of diminishing demand for emission permits due to more efficient abatement technologies.[1]

One crucial point in environmental policy is imperfect or incomplete information. When introducing ET one has to decide on total emissions only – marginal costs of abatement need not to be known but are reflected by the price of the permits. It is only rational to reduce emissions as long as abatement is cheaper than buying permits.

As a conclusion, we can say that tradable permits theoretically fulfil each of the three criteria and are therefore superior to other regulatory schemes in handling carbon dioxide emissions, in particular in comparison to the predominant approach of command and control. Making proper use of ET therefore could be regarded as a new paradigm in environmental policy.

[1] On the other hand, this feature of ET applies to all types of ET – disregarding the allocation mechanism: Whenever new technologies are introduced, fewer certificates are required, which will result in a falling market price. This fact calls for an open market policy, which again might increase transaction costs generated by running an ET system.

3 The contribution of Public Choice Theory

Being the instrument of choice in theory, ET has to be positioned politically. Hahn (1989, p. 109) states that environmental policy decisions are not shaped by academic considerations but by political processes and their actors. Public Choice Theory takes the interest of those actors into account. According to Kirchgässner and Schneider (2003, p. 369), only this approach provides convincing arguments that may explain why "despite the many papers and books written by environmental economists in favour of market based instruments, actual environmental policy still mainly uses the bureaucratic instruments of command and control." With regard to ET, Michaelowa (2004) states that the German NAP I can be explained perfectly against the background of Public Choice Theory.

In the next part, we will sketch out the basic assumptions of this approach. After describing the interests of voters, politicians, bureaucrats and interest groups, we will derive hypotheses that might explain the political implementation of ET in Germany.

With regard to the concrete design of environmental instruments, only little literature using a Public Choice approach can be found.[2] Joskow and Schmalensee (1998), for instance, explain the introduction of the U.S. Acid Rain programme while concentrating on the processes within the U.S. congress; Svendsen (2005) attributes the two main differences between the Green Paper and the Directive Proposal on ET to lobbyism. In this article, we refer to Zöckler (2004), who has developed hypotheses on the aims of major electricity companies regarding the German NAP I.

3.1 Assumptions

Public Choice Theory is based on the standard neoclassical economic assumption that the actors engaged in policy-making are myopic and selfish.[3] To explain a concrete policy, economic models have to describe the relevant actors with their preferences, their restrictions as well as overall policy (Hansjürgens 2001a, p. 65 ff.).

In general, statements against the background of Public Choice Theory and proper choice of environmental policy instruments at this stage proceed with a description of the groups typically involved in policy-making (Schneider and Weck-Hannemann 2004). Boom (2002) distinguishes between those executing environmental policy and those affected by it. The first group in turn can be subdivided into politicians and bureaucrats. The latter group is represented by interest groups. Another group is represented by those who are confronted with the results of environmental policy, that is, consumers and voters. We therefore give a short characterisation of these four groups before turning to our hypotheses in relation to ET.

[2] Usually, Public Choice Theory is used to explain the dominance of command – and control in environmental policy (e.g. Schneider and Volkert 1999; Keohane et al. 1998).

[3] For a more detailed description see Kirsch (1997) and Mueller (2003).

Voters are preoccupied with their own individual benefit. That is, they balance benefits arising from different political measures. But "especially with respect to measures which are mainly to the benefit of future generations, self-interested individuals would generally not be willing to bear high costs. This is one of the main obstacles against efficient CO_2-reduction policies" (Kirchgässner and Schneider 2003, p. 374 f.). Moreover, voters do not expend much effort on acquiring information about different policy instruments and their scientific implications. As a consequence, they are easily impressed by symbolic policies (Hansjürgens 2000).

Politicians experience recurrent elections as a restriction on their attempts at translating their ideals into practice (Frey and Kirchgässner 1994). Getting their ideologies accepted increases the politicians' utility. Due to voters' lower appreciation of environmental policy in comparison with actions that are beneficial for the economy, politicians will not pursue a strict environmental policy (Schneider and Volkert 1999).

Achieving an idealistic goal is not *bureaucracy*'s aim, either. Bureaucrats' main objective is to increase their income, prestige and recognition (Niskanen 1971). In other words, their budget and leeway for individual decisions determine bureaucrats' utility. Controlling bureaucrats' work is a challenging task due to the public good character of their output. This results in a monitoring problem (Mueller 2003).

When referring to bureaucrats one should distinguish between ministerial bureaucrats on the one hand and administrational ones on the other (Gawel 1995). The former are focused on consulting politicians and designing policies, thus aiming at transferring their ideologies into practice on the one hand and aiming at reappointment on the other hand; they are quite similar to politicians. In the following, we will focus on the latter type of bureaucrats, the type that is maximising utility by tracking a high budget and wide discretionary leeway. This is the type that Public Choice Theory refers to by the rather loose term 'bureaucrats'.

When taking *interest groups* into consideration we only refer to those kinds of groups that demonstrate assertiveness and organisational potential, i.e. industrial interest groups.[4] That means we take them as a homogeneous group, although Zöckler (2004) has shown that it was individual companies rather than (their) interest groups that were lobbying the German NAP I. Moreover, we disregard the fact that there are various principal-agent relationships within a market-oriented organisation, e.g. between owners (shareholders), managers and employees (Boom 2002). For the sake of simplicity, we are not dealing with such kinds of relationships here. In order to develop simple but sound reasons for the ET's divergence from theory, it is sufficient to keep the analysis on this level.

Corporations, on the one hand, favour the market as the mechanism coordinating supply and demand. Surprisingly, corporations exhibit bipolar behaviour when

[4] Interest groups other than industrial ones, especially environmental pressure groups, do not only lack financial backing and heterogeneous motivation, but also have to handle information asymmetries, little influence on the media and on the labour market (Kirchgässner and Schneider 2003). For fundamental ideas of collective action refer to Olson (1965).

it comes to regulation. In the context of environmental policy they prefer individual solutions to market-based instruments. Accordingly, Kolk (2000, p. 42) reports that "business perspectives on the effectiveness of the different government instruments are also more sophisticated than the widespread image of 'resisting command and control' would suggest." Indeed, she refers to several surveys documenting that managers favour direct regulation over any other type of political approach. Taken in such a simplified form, interest groups aspire towards extra privileges or monopoly positions – i.e. they are rent-seekers (Tullock 1967).

Voters as well as politicians pursue various goals (e.g. environmental protection and economic prosperity) and play only a minor role within the political process. Since the bureaucracy executing emissions trading had not been in existence when the decision regarding the actual design of ET was made, it was represented by ministerial officials only. Therefore, the industries affected by emissions trading play the main role in lobbying. The following four hypotheses reflect this finding.

3.2 Hypotheses

Based on the political economic model described above, we can derive hypotheses about the various actors' behaviour in the political process.

Hypothesis 1: Industry asks for a generous cap and an allocation free of charge. The overall goal of industry is to minimise (private) costs caused by political regulation. The higher the cap, the less emissions have to be reduced and the lower the price of a permit. With regard to the allocation process, industry refuses auctioning because it would then have to pay for each single permit – in contrast to an allocation free of charge.

Hypothesis 2: Industry refuses an ET scheme intervening in the market structure. As industry wants to avoid uncertainties, it does not want the regulator to influence the competition. Benchmarking as an allocation method implies advantages for installations with low emissions and is regarded as distorting competition –whereas grandfathering refers to historical emissions and insofar extrapolates the status quo to the future.[5] Since installations that have already reduced their emissions would be punished, their so-called early actions should be taken into consideration.

Hypothesis 3: Industry favours legislation creating barriers to enter the market (e.g. Buchanan and Tullock 1975). Existing companies can gain a competitive advantage, for example, when permits are grandfathered to them, whereas new entrants are obliged to buy their permits on the market.

Hypothesis 4: Industry as well as bureaucracy strive for complex legislation offering flexibility or freedom for negotiations between companies and bureaucrats. While bureaucracy appreciates the leeway to follow its own interests, industry seeks regulation regarding their own special interests (Cansier 1998). The latter

[5] Weck-Hannemann (1994) underlines that existing firms stick to the status quo.

may already be anchored in the law itself or could be the result of a later administrative decision owing to bilateral negotiations.

4 The ETS and its implementation in Germany

In the following, we will analyse the European ETS and, in particular, its implementation in Germany. The structure of this section follows the four hypotheses that we have derived against the background of Public Choice Theory. By doing so, we hope to be able to stress the significance of our hypotheses as well as to explain the gap observed between theory and practice.

4.1 Cap and allocation

The German NAP I fixes annual emissions for energy and industries at 503 million tons CO_2 from 2005 to 2007, and at 495 million tons CO_2 from 2008 to 2012. These Figures exceed the emissions budget that was envisaged in a voluntary agreement by German industry (Bundesregierung 2001) as well as its predicted needs standing at 496.4 Mt in 2005/07, according to a study commissioned by the BDI, the German association of industry (RWI 2003).

Vis (2004) explains that the scarcity of emission permits is the driving force behind any ET system. Due to the very generous emissions budgets all over the European Union there will be no real shortage in emissions permits. Prices have been dropping and liquidity of the permit market may be diminutive (Schüle et al. 2004). However, economic growth has to evolve in conjunction with increasing efficiency of abatement technologies in order to keep up with the existing quantity of certificates.

An allocation mostly free of charge has already been established by the EU Directive. Svendsen (2005) traces this back to the presence of powerful national industrial rent-seeking activities. The same holds true for the German NAP I: due to industrial opposition, it does not make use of the possibility to auction up to 5 percent of the permits.[6] Regarding the generous cap and the allocation free of charge, we can confirm the first hypothesis.

4.2 Grandfathering and early action

Theory states that allocation does not affect the efficiency of emissions trading (Perman et al. 2003). Being aware that "it is nearly impossible to determine an optimal allocation of allowances exogenously" (Kemfert et al. 2004, p. 120) it is of greatest interest how allocation is organised.

[6] In the European Union, only Denmark allocates a certain part of emission permits by auctioning (Bakker 2004).

In Germany, installations commissioned prior to 31 December 2002 in principle receive permits according to 97.09 percent of their historical emissions from 2000 to 2002. Thus, their compliance factor is 0.9709.[7] Installations being commissioned or modernised from 1994 onwards receive 100 percent of their historical emissions for a period of 12 years – the compliance factor of 1 rewards so-called early actions that are neither stipulated by legislation nor funded by public means. Furthermore, they did not result in a significant reduction in emissions. Due to these allocation rules, only minor differences between allocated and actual emissions are expected. As a consequence, there is little pressure to invest in pollution prevention and reduction.

A different allocation rule such as benchmarking would provide more incentives for developing cleaner production technologies. Referring to the best-available-technology (BAT) or an average value, a benchmark determines a certain standard of CO_2 that is granted for the production of one unit (industry-specific values). As a consequence, a CO_2-intensive installation would lack permits and thus be forced to modernise or be substituted. For instance, it would be feasible to allow power stations to emit 580g of CO_2 per kWh, which corresponds to the average emissions of German power plants in 2002. Obviously, only those power suppliers running installations with low emissions would be in favour of such an allocation mechanism. Fuel-specific benchmarks within the energy industry would reflect that a gas-fired station emits less than a coal-fired station. They would provide no incentives for investing in gas-fired stations but support efficient installations within the respective fuel category.

An allocation mechanism based on historical emissions instead of benchmarks extrapolates the emission structures of the past to the future and favours installations with high emissions. In correspondence to the second hypothesis, the German NAP I provides for grandfathering as a general allocation method and rewards early action. That implies the strengthening of existing market structures, in the sense that a structural change in the patterns of primary energy consumption sources is not likely to happen. That again fits with our second hypothesis.

4.3 Barriers for new entrants

New plants, like existing installations, are equipped free of charge. At a first glance, this contradicts our third hypothesis that industry would favour market barriers. Lacking historical emissions, new market participants are granted permits on the basis of benchmarks derived from BAT. For electricity, the benchmark is 750g CO_2/kWh. For installations with lower emissions, e.g. gas-fired power stations, the benchmark will not exceed their actual requirements but it will be at least 365g CO_2/kWh – which proves that the German NAP I makes use of fuel-specific benchmarks.

[7] The compliance factor of 0.9709 is mentioned in the German NAP, but it had to be reduced to 0.9538 in order to keep the cap since more installations than expected applied for an allocation based on production forecasts (DEHSt 2004).

While this rule does not favour installations with a CO_2 intensity higher than 750g CO_2/kWh (e.g. lignite), installations with lower specific emissions are not rewarded, either. There is no incentive given to build a gas-fired station emitting only 365g CO_2/kWh instead of building a hard-coal installation emitting 750g CO_2/kWh. In fact, this rule contradicts the stated goal of reducing CO_2 emissions and promotes the use of (cheaper) hard coal instead.

As a general concept, this allocation rule follows the idea that permits are related to the commissioning of a plant: as soon as, and as long as, an installation is producing, it is equipped free of charge. Graichen and Requate (2003) plead for another model where permits are not connected to production but to the installation itself: while installations would be allowed to maintain and sell their permits during the whole trading period even after their close-down, new plants would have to buy their permits on the market.

The so-called transfer clause allows a plant to transfer its permits after its close-down for another four years if a new installation is commissioned. Afterwards, the new installation is granted permits for another 14 years, with the permits equalling 100 percent of its emissions in the base period.

On the one hand, this clause gives a strong incentive for substituting an old installation with a new one; thus, it could be said that the regulation subsidises the building of the new one through a surplus in permits. On the other hand, it allows the construction of new lignite stations: as a consequence of the over-allocation for four years and the subsequent 100%-allocation, a lignite plant is not short on permits – whereas it would be short using the benchmark rule for new plants.

For the owners of plants the transfer clause provides strong incentives to substitute installations. The needs-oriented allocation subsequent to the over-allocation for four years allows investments even in new lignite stations that do not meet BAT. Due to long-term rules in effect until the year 2025, the leeway for future national allocation plans is limited (Lechtenböhmer et al. 2004). As a conclusion, it can be said that for its exogenous regulations the transfer clause reflects a command-and-control approach that aims at the closure of old installations but does not give incentives to invest in clean technology, either. That is to say, it sticks to the old paradigm. A new paradigm would comprise measures that urge companies to strategically look for new (efficient and effective) abatement technologies.

As only existing companies can make use of the transfer clause, there is discrimination against new entrants into the German NAP. This is why we cannot refuse the third hypothesis, even though new plants receive permits free of charge.

4.4 Flexibility and freedom for negotiations

In correspondence to our fourth hypothesis, the German NAP I reflects various special interests. Operators of nuclear power plants (NPP) are compensated when they close down a NPP by 2007 due to Germany's commitment to a nuclear-power phase-out. A compliance factor of 1 is applied to process-related emissions (resulting from a chemical reaction other than combustion), so there is no need to reduce emissions.

Beside these special treatments, the German NAP I provides a lot of room for flexibility. Existing companies have the option to apply for an allocation based on benchmarks (like new plants). 28 percent of all 1,849 installations have chosen this option – as a consequence, the applications would have exceeded the cap if the compliance factor had not been reduced to 0.9538 (BMU 2004). Moreover, a hardship clause allows an application for a needs-oriented allocation multiplied by the compliance factor if the regular allocation does not cover 75 percent of its needs.

Yet, we cannot decide whether ET allows freedom for negotiations between bureaucrats and companies. But it is obvious that the German NAP I itself is bureaucratic in that it reflects special interests and is flexible in favour of existing firms. These conclusions confirm our fourth hypothesis.

4.5 Review

The four hypotheses help to understand the actual design of the German NAP. In the following, we argue that practice differs significantly from theory, and that we will therefore still have to wait for a new paradigm to emerge in environmental policy.

As shown in section 3.1, the German NAP I allows the energy and manufacturing industries to emit more CO_2 than needed and more than promised – the only news is that the generous emissions budget will be legally binding. From the industries' point of view, grandfathering as a general allocation rule avoids interventions in existing market structures but it also means a conservation of historical emission structures. Although Utz Claassen, chairman of EnBW energy company, has complained about the cementation of emissions structures (EnBW 2004), it was corporate influence that prevented the use of benchmarking except for the allocation of new plants. As pointed out before, we could speak of a *structural conservatism*. Since the companies' power production is based on different energy sources (RWE produces 40% of its power in lignite and another 30% in coal stations whereas EnBW produces more than 60% in nuclear power plants), it is quite obvious who took what initiatives and why in the political process.

Actually, there is empirical evidence that the companies did not pursue common goals during the discussions prior to the introduction of ET but that they rather favoured regulations paying respect to their specific corporate interests. As a result, the NAP I represents a complex, bureaucratic implementation of ET, reflecting the interests of the biggest and most powerful companies.

The compensation for the operators of nuclear power plants is just one example of how the regulators stick to the command-and-control approach. Another example is the so-called minus clause: from 2008 coal stations older than 30 years with above-average specific emissions have to bear a reduced allocation of minus 15 percentage points. Giving an incentive for modernising or substituting an old plant, this rule symbolises a command-and-control approach. It disregards the installations' economic basis by reducing their compliance factor. Instead of trusting the forces of the permit market, which could provide incentives for operating effi-

cient installations, the above-mentioned rules underline that German NAP I contradicts the economic idea and effects of ET. To some extent, the German NAP I shows a preference for existing companies as the benefits of the transfer clause are limited to them.

Once more, it is obvious that the environmental policy is not being designed in an ivory tower, but that it is the result of a process driven by actors striving for their distinctive interests. Indeed, international perception of Germany's NAP I is such that the pressures exerted on the affected industries could have been much stronger if the German economy ministry, which was "lobbied heavily by industry", had not "won the day" (Nicholls 2004, p. 12). We have shown that the political outcome is in accordance with what Public Choice Theory predicts. What is additionally striking is that the German power market has an oligopolistic character (Monopolkommission 2004). Analogous to Sartzetakis (2004), who describes price-taker behaviour on permit markets and strategic behaviour on the product market, this would explain industries' preference for command-and-control attempts on the permit market to flank the position on the power market.

To sum up, the four hypotheses dealing with the interests of the actors designing the emissions trading scheme can explain the actual design of the German NAP – which significantly differs from its economic ideal.

All in all, the German NAP I strictly limits ET's effectiveness, justice and efficiency. Apart from opportunity costs, there is no further incentive to redesign controlling and innovation activities. To conclude, this ET scheme still reflects a command-and-control-approach and is not going to foster corporate sustainability management. Therefore, we state that the current ET system is sold as a new paradigm, but in reality it is a well-disguised old paradigm. Whereas theory clearly strives for a reduction in emissions, the practical implementation is shaped by multiple issues, such as security of supply, that may sound convincing at first, but have proven to actually stand in the way of effective and efficient action.

5 Outlook

In 2005, the "world's most comprehensive emissions trading scheme covering more than 10,000 installations in 25 member states" (Butzengeiger and Michaelowa 2004, p. 117) came into force. In this paper we have explained how the German NAP I can be seen as a kind of structural conservatism: the allocation mechanism in particular cements existing emission structures by extrapolating historical emissions. Having shown that ET today does not stand for a new paradigm in environmental policy but still reflects a command-and-control approach and perpetuates historical structures, we will have to deal with the question of future developments in ET.

There is hope that a future design for emissions trading has more in common with its label than today. More and more actors engaged in the political game will realise that the current design of emissions trading is neither effective nor efficient. Michaelowa (2004) underlines that the German NAP I promotes large

enterprises on the cost of SMEs. Wegner (2004, p. 131), a representative of a German sugar producer, for instance, explains that the German NAP I is "far from perfect" as early actions are not being honoured sufficiently. EnBW, a major German power supplier, has taken legal action against the allocation rules. E.ON Energy expects a more market-oriented design of ET in the future.

Disappointment of many companies with regard to the distribution of certificates as well as the realisation by politicians that even the actual design does not overcome corporate opposition may soon allow the patient to follow the doctor's order. What could happen regarding a redesign of the European ETS after 2012? The actors deciding on the (further) development will change the recipe of ET by trusting more in market forces: a different allocation ruling – whether it be benchmarking or even the auctioning of permits – will reduce the need for dealing with early actions, while special treatment policies will be kept to a minimum. Böhringer et al. (2004) therefore promote auctioned permits. Döring and Ewringmann (2003), however, believe that a shift to auctioning is unlikely once permits have been allocated for free.

The introduction of emissions trading in the EU is a first step towards a new environmental policy – but the bottle still contains old wine produced on command-and-control grounds. We can only hope that the contents of the bottle will correspond to its label in the future emissions trading scheme, it possibly being the most economic political approach. Schüle et al. (2004) have observed that we are witnesses of a social learning process leading from command and control towards market-based instruments.

With respect to the widespread belief that the introduction of ET would mark a new paradigm in environmental policy, we have shown that further steps need to be taken before we can talk of a shift in the pattern of thoughts. When considering that technological changes may occur without a notable advantage in cost-efficiency – e.g. due to random historical events (Arthur 1989) – current opponents of a purely market-based ET may become tomorrow's losers.

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Product-based benchmarks as a basis for the rational use of energy and corporate sustainability [1]

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Abstract

Since January 2005, the European Emission Trading Scheme is compulsory for many companies. For these companies the CO_2 emissions increase the internal energy and environmental costs. Therefore, the allocation of CO_2 emission certificates is an important economic issue for the companies covered by the scheme. This paper analyses the relevance of product-based benchmarks in the context of Emission Trading as a basis for the rational use of energy and corporate sustainability. A method for the allocation of CO_2 emission certificates based on benchmarks has been derived within a research project at RWTH Aachen University. The general procedure is described and exemplified by a production plant from the cement industry. Furthermore, the implications of these benchmarks for the industry are discussed in view of their potential to stimulate corporations and innovations in the market.

Keywords: Product-based benchmarks, energy demand, CO_2 emissions, corporate sustainability

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1 Introduction

The European Emission Trading Scheme (EU ETS[2]), which started in 2005, is compulsory for many companies. For these companies CO_2 emissions increase the internal energy and environmental costs. Therefore, the allocation of CO_2 emission certificates as decided upon in the National Allocation Plans is an important economic issue for the companies covered by the scheme.

The general advantage of an emission allowance trading scheme consists of the economically most favourable emission-reducing measures within the considered system. This implies cost minimization of environmental protection. An additional advantage is that the system implicitly guarantees the reduction of emissions to a pre-defined degree. For a company it is necessary to know the internal reduction potentials and their costs in order to realise this cost minimization of environmental protection on the company level. In this context, product-based benchmarks can help companies to identify and assess their emissions reduction potential.

This paper analyses the relevance of product-based benchmarks in the context of the EU ETS. The general possibilities for allocating CO_2 emission allowances are described including the requirements by the EU ETS. Benchmarking as an allocation method is presented and the German allocation methods within the first trading period are briefly explained. The general method of determination of product-based reference values both for energy demand and for CO_2 emissions is described. In this paper results for a production plant of the cement industry are presented. The derived benchmarks are analysed and their relevance as a basis for the rational use of energy and corporate sustainability is discussed.

2 Allocation of emission allowances

The allocation of allowances is one of the major issues of an emission trading scheme. Without going into the legal ramifications, the assumption that an allocation of free-of-charge CO_2 emission allowances should be just and reasonable seems rational, and should avoid resistance from the involved actors. This aim causes, among other things, technical problems concerning the boundaries of the trading system and the involved actors. One example for these problems is the (additional) use of alternative fuels. Momentarily, waste combustion installations are not covered by the EU ETS, but the use of the same fuel in, for example, cement production plants is covered by the EU ETS. Similar is the case with cogeneration, through which emissions from household combustion installations can be transferred into the trading scheme as a number of small emission sources is combined into one larger source.

[2] The European scheme for greenhouse gas emission allowance trading is referred to as the "EU ETS".

Another problem is the treatment of process related emissions. Contrary to energy related emissions, process related emissions depend on the production process used and can thus not be changed unless the process is altered. Energy related emissions depend on the fuel input and, through the use of regenerative fuels, can be reduced to zero.

Possible allocation methods include the auctioning of the emission allowances, grandfathering, benchmarking and combinations of these three. Grandfathering in this context means the allocation according to historic emissions of the involved actors. Both grandfathering and benchmarking can be designed to have a free-of-charge allocation.

This chapter briefly summarizes the requirements made up by the EU ETS. The concept of benchmarking as an allocation method is introduced, and the allocation methods in Germany during the first trading period are presented.

2.1 Requirements for allocation by the EU ETS[3]

The EU ETS is compulsory and started with a three-year period in January 2005. From 2008 on there are five-year trading periods. The EU ETS is restricted to carbon dioxide emissions and to emissions of those activities referred to in Annex I of the Directive. However, an extension to further activities and emission categories is planned for the future. In addition, alternative policies and measures are demanded for the sectors and installations not mentioned in Annex I of the Directive.

For each period, the member states need to develop a National Allocation Plan (NAP) where the emission targets and the allocation method are stated. The Directive sets basic criteria for NAP in Annex III. Regarding the allocation of allowances, it is stated that it should be environmentally beneficial and economically feasible, consistent with the member states emissions reduction obligation and the (technical) potential of the covered activities as well as just, thus avoiding discrimination between companies or sectors. It is also stated that the allocation of emission allowances needs to be to at least 95% free-of-charge for the first trading period from 2005 to 2007 and to at least 90% free-of-charge for the second trading period from 2008 to 2012.

2.2 Benchmarking as allocation method

Benchmarking is a broad term which needs to be specified in the context of an emission trading scheme. The concept of benchmarking as an allocation method consists of a product-based reference emission value for the considered actors, e.g. in ton CO_2 per product output. The allowances can then be determined by a basic equation such as:

[3] The following information is taken from EU Commission (2003), referred to in this document as the “Directive”.

$$A_{i,j} = f \cdot b_j \cdot a_i \quad (1)$$

with $A_{i,j}$ allocated allowances of actor i as part of sector j [t CO_2/a]
b_j product-based reference value for sector j [t CO_2/product output]
a_i activity level of actor i [product output /a]
f correction factor

The product output of an actor can be, for example, electricity in kWh or glass production in tons. The correction factor is introduced to take into account the cap on the allowances to be allocated. Thus, compliance with the environmental target can be assured. It may be different for different sectors or groups of actors.

The product-based reference values need to be determined for different sectors to have one value for comparable actors. Within the EU ETS these actors are in fact the activities and installations as listed in Annex I of the Directive. The product-based reference values can be determined one for each sector covered by the EU ETS, but an additional differentiation within a sector may be more adequate. This is one of the controversies to be discussed as a higher diversity and thus a higher number of product-based reference values can more accurately take into account the differences between installations and products. At the same time, a higher diversity results in higher transaction costs and may thus not be feasible.

Of course, different allocation formulae can be introduced. The formula discussed above is basic to an explanation of the concept of benchmarking. The introduction of an individual benchmark of the installation seems possible and compares this with the appropriate product-based reference value. Thus the emission reduction potential of the individual installation can be considered to stimulate the rational use of energy.

The general advantage of benchmarking as an allocation method is the objective approach through the consideration of the technical potential of the involved installations. The product-based reference values reflect the technical minimum of the CO_2 emission level of an installation for the fabrication of a product. In addition, a theoretical reference value for the fabrication of this product may be calculated. The product-based reference values allow thus the comparison between an existing installation with its technical optimum. The gap between these two values indicates the potential of the existing installation for improvements regarding the CO_2 emissions. This comparison can therefore be a stimulant to enhance existing plants and promote the rational use of energy.

However, the benchmarking method requires the availability of sufficiently detailed data on the different installations. Even in Germany, this level of detail is not at hand for all sectors. In addition, regular updates of the data and the resulting product-based reference values are necessary. This implies considerable effort and the cooperation with industries.

Regarding the definition of the activity level, grandfathering aspects may possibly be included into the allocation method. Thus the approach is not entirely free from the historic emissions and can be challenged as unfair.

2.3 Allocation methods in Germany[4]

The legal basis for the introduction of the EU ETS has been installed in Germany through various laws and decrees. The allocation methods are detailed in the German NAP I for the first trading period from 2005 to 2007.

In Germany grandfathering is the general allocation method for existing plants for the first allocation period. The allocation of emission allowances is free-of-charge and based on historic emissions with the possibility of accounting for early action as well as additional allowances for cogeneration installations. Benchmarking is applied to new entrants. Within the bylaw on allocation (BGB (2004c)) emission values for selected products are published. For power installations a range from 365 to 750g CO_2/kWh electricity produced is listed. For steam the range is 225 to 345g CO_2/kWh thermal energy and for hot water it is 215 to 290g CO_2/kWh. There are also emission values for some products given, such as for cement clinker with a range from 275 to 315g CO_2/kg clinker. Generally, the lowest value of a category is accepted for the allocation. For a higher value, the company needs to justify its decision.

These values are published within the official legal journal of Germany. The determination of the values is explained briefly in the corresponding explanatory statement and is partly based upon the IPPC documentations (http://eippcb.jrc.es). However, these values represent only a gross classification of the installations covered by the EU ETS and are generally rejected by industry.

3 Alternative allocation method

A method for technology-oriented allocation of CO_2 emission certificates based on benchmarks was investigated within a research project at the Chair of Technical Thermodynamics at RWTH Aachen University. The research activities were focussed on the determination of product-based reference equations both for energy demand and for CO_2 emissions of certain industrial energy and production systems. The equations allow the calculation of installation specific reference values necessary for the allocation of CO_2 emission certificates. In addition, the reference values facilitate the identification of emission intensities and related cost reduction potentials in small and medium-sized enterprises.

Within the scope of the research project five sectors that are covered by the EU ETS were analysed. These include the energy, glass, ceramics, and building materials industries as well as the pulp and paper industry.

To obtain the product-based reference equations by the developed method, selected activities and installations are analysed to define the system boundaries. The production process is analysed to define the theoretical process and to deter-

[4] The following information is taken from German laws and bylaws regarding the establishment of the EU ETS and includes BGB (2004a, 2004b, 2004c) and BMU (2004). Only the first trading period from 2005 to 2007 is considered.

mine the process related CO_2 emissions. The preliminary analysis results in the selection of categories or groups of analysed activities and installations each with a homogenous product. The documentations published by the IPPC can be used as a basis for this analysis (http://eippcb.jrc.es). The selection of categories is an important and crucial task. A higher diversity and thus a higher number of product-based reference equations can more accurately take into account the differences between categories. Thus the resulting benchmarks may be more widely accepted within the industries. At the same time a higher diversity results in higher expenses for research and the necessary updates.

For selected categories and groups the theoretical production process is investigated to determine the thermodynamic energy demand. From this value the energy related CO_2 emissions can be derived depending on the fuels employed. In addition, the process related CO_2 emissions are calculated.

To determine the reference equation, the theoretical production process is compared to existing production installations. Technical standards are being considered, thus taking into account unavoidable losses and energy demand resulting from the technical realisation of the production process. In addition, the corporate constraints need to be discussed and included. The product-based reference equations for energy demand and CO_2 emission intensity are then derived for the best available techniques.

Based on the reference equations, the allocation is determined according to Eq. 1. The results are assessed through application to existing installations. The technical potential of CO_2 emission reductions can be quantified by comparing the CO_2 emission intensity of existing installations with the corresponding product-based reference values.

4 Results for cement production

In this chapter, results of the determination of product-based reference values for energy demand and CO_2 emissions are presented for a production plant from the cement industry.

For the cement industry, as for other industrial sectors as well, the main approach is to classify the installations. Within the cement sector the proposed classification criteria are the type of kiln installed and/or the type of raw material used, thus taking into account regional differences. Then the system boundaries are defined for each established class.

The theoretical approach consists of determination of the minimal energy demand for the theoretical reaction and of the process emissions per ton clinker produced. These theoretical values depend only on the raw material composition considered.

The minimal energy demand per ton of clinker produced is derived from the theoretical values for each class by taking into account the established classification criteria. As a basis for this approach, the documentation published by the IPPC can be used (IPPC (2001)).

Two benchmarks are established: one for the energy demand per ton clinker produced and one for the CO_2 emissions per ton clinker produced, distinguishing between process and energy related emissions.

4.1 Cement production process

Cement is a hydraulic binding agent consisting of the raw materials limestone and clay or the naturally occurring mixture of both called marl. Together with sand and water cement is mixed to obtain concrete or mortar which hardens to stone and is versatile in its application. The production process for cement is sketched in Figure 1.

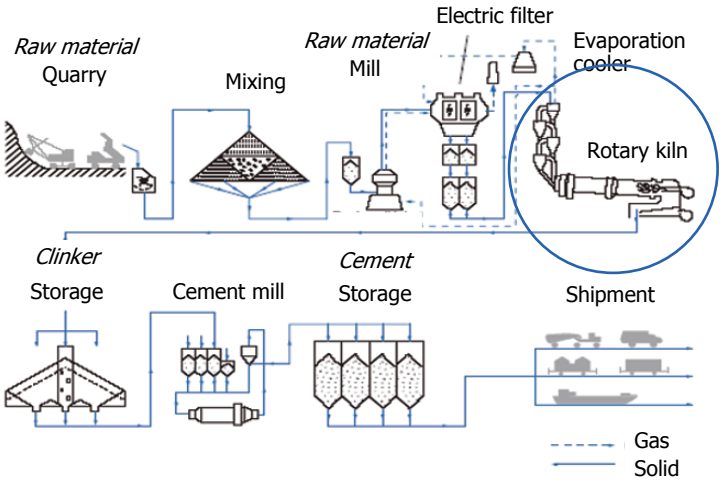

Fig. 1. Cement production process (adopted from VDZ (2000))

The raw material is taken from the quarry, then it is mixed and milled to become a defined, homogenous powder. Generally, the cement production sites are close to natural limestone reservoirs to minimize transportation costs. This, however, effects the raw material composition which may need to be adapted through the addition of other substances. The chemical reactions necessary for the cement production take place in the rotary kiln. The product of the rotary kiln is clinker which is an intermediate product. The clinker is stored. In the cement mill the clinker, together with other substances such as sulphate-containing materials and flue ash, is milled and mixed to result in the desired final product cement. The different cements are categorized into 27 standardized cement products with defined specifications depending on their clinker percentage and composition. The cement is finally shipped to the consumer.

Regarding the cement production process the most energy consuming installation is the kiln. Here the material needs to be brought to temperatures of about 1,450°C to stimulate the desired reactions. In this installation energy is provided

through various fuels while the other installations are provided with electricity only. Therefore this is also the installation where CO_2 emissions are generated.

However, if the raw material has a naturally high water content, it needs to be dried previous to the described production process. This drying process requires additional energy provided through fuel or waste heat. These semi-wet or wet processes are not considered in this paper.

The system boundaries for the analysis are thus drawn around the kiln. Figure 2 shows the system boundaries for a rotary kiln with pre-heater and calcinator.

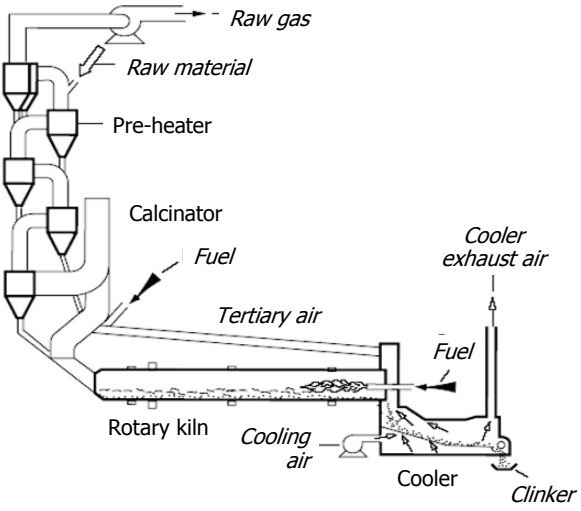

Fig. 2. System boundaries for a rotary kiln with pre-heater, calcinator and cooler (adopted from VDZ (2000))

The raw material enters the pre-heater at the top. It passes through the calcinatory and kiln. Behind the cooler the resulting clinker is extracted. The raw material is pre-heated by the flue gases from the kiln and the calcinator. Both the kiln and the calcinator are directly fuelled. The material and gases thus flow at counter current. The chemical reactions, the retention period and the temperature development within the kiln are detailed in Figure 3.

The reactions are illustrated through the change in the weight percentage of the different components. The first step consists in the drying and heating of the raw material. This happens within the pre-heater within less than one minute before the raw material reaches a temperature below 900°C. Between 600°C and 900°C the deacidification and calcination of the limestone usually takes place. This reaction releases the process related CO_2 emissions and results in a considerable loss of weight of the material. The calcination of the limestone lasts almost 30 minutes. The dissociation and generation of oxides requires a temperature between 1250-1,450°C. In this temperature range the material begins to melt and the clinker mineral “Alit” is generated. This mineral is mainly responsible for the hydraulic characteristics of the cement product. The sintering of the material takes about 10

minutes. Finally the clinker minerals crystallize while being cooled to about 1,200-1,350°C.

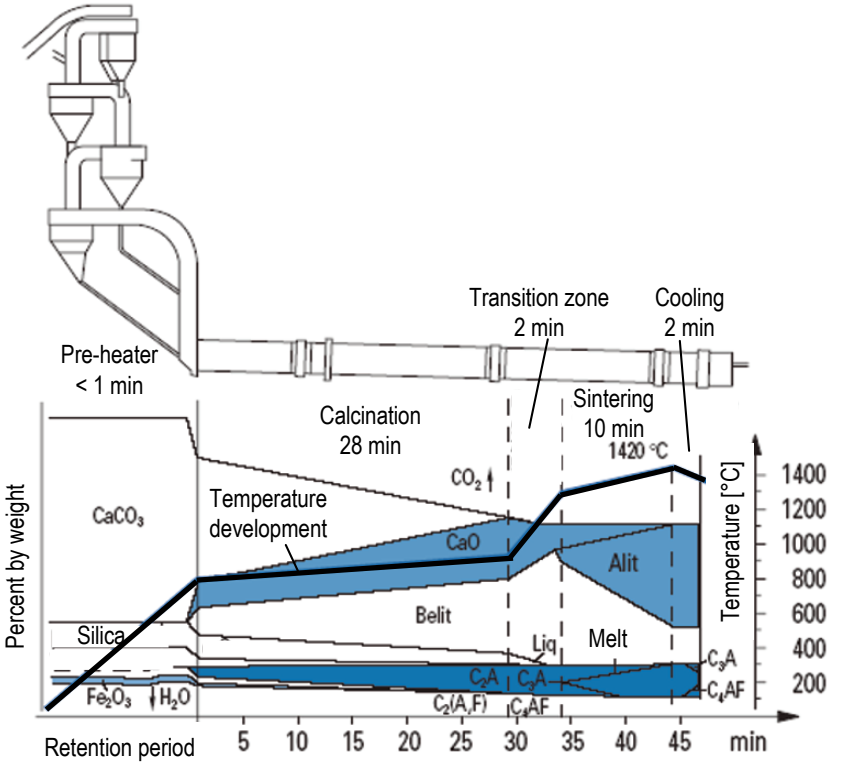

Fig. 3. Chemical reactions, retention period and temperature development in a rotary kiln (adopted from VDZ (2000))

4.2 Theoretical analysis of the rotary kiln

The process reaction within the rotary kiln consists of several individual and interacting chemical reactions. The most important and most common reactions are listed in Table 1 below. In the Table, the reaction enthalpy at 298 K for each reaction is given, as well as the energy demand calculated per ton clinker produced.

The Table shows that the reaction enthalpies can be both positive and negative. This means that some reactions require an external energy supply in order to start, while others release energy during the reaction. Taking into account the various reactions necessary for the clinker production as well as a typical raw material and clinker composition, the overall energy demand results in 1,629 MJ/t clinker.

The process-related CO_2 emissions result mainly from the dissociation of limestone ($CaCO_3$) and of magnesium carbonate or Magnesite ($MgCO_3$).

Table 1. Chemical reactions and theoretical energy demand for clinker production (VDZ (1992), LTT (2004))

Chemical reaction	Reaction enthalpy at 298 K [kJ/kg]	Energy demand [MJ/t clinker]
Illit (clay mineral)→ α-Al_2O_3 + 4 β-SiO_2 + m H_2O (liq.)	884	55
C + O_2 → CO_2	-32,786	-76
$MgCO_3$ → MgO + CO_2	1,396	1
$CaCO_3$ → CaO + CO_2	1,778	2,113
2 FeS_2 + 5 ½ O_2 → α-Fe_2O_3+ 4 SO_2	-12,914	-8
K_2O + SO_2 + ½ O_2 → α-K_2SO_4	9,690	15
4 CaO + α-Al_2O_3 + α-Fe_2O_3 → C_4AF	-67	-5
3 CaO + α-Al_2O_3 → C_3A	74	9
2 CaO + β-SiO_2 → β-C_2S	-700	-132
3 CaO + β-SiO_2 → C_3S	-495	-279
K_2O + SO_2 + ½ O_2 → α-K_2SO_4	-9,690	-65
Sum		1,629

4.3 Derived benchmarks

The analysis of the theoretical process results in the thermodynamic energy demand of 1,629 MJ/t clinker as described above. The corresponding process related CO_2 emissions can be calculated to 0.525t CO_2/t clinker produced. These values depend only on the raw material composition which varies within limited parameters for the clinker production process. However, these values describe the thermodynamic minimum. These theoretical values are in reality not achieved, but limited through technical constraints.

The technical energy demand is derived from the theoretical value by taking into account the production technology and related losses. The energy demand for pre-heating and drying of the raw material needs to be considered. This depends strongly on the water content of the raw material and the ambient temperature. Losses need to be taken into account including surface radiation, hot flue gases etc. Also, the clinker leaves the system at a temperature above the ambient temperature. These different losses depend mainly on the production process and the technology installed. The consideration of best available technology leads to a technical, minimal energy demand of 2,890 MJ/t clinker. This value is not fixed, but can be minimized as the technology advances or the production process is altered.

The energy related CO_2 emissions can be calculated from the technical energy demand by taking into account the emission factor of the fuels used. If the kiln is fired exclusively with hard coal, the energy related CO_2 emissions reach 0.279t CO_2/t clinker produced. However, if a regenerative fuel such as biomass is used,

the energy related CO_2 emissions can be considered as zero. The fuel mix therefore plays a crucial role in determining the energy related CO_2 emissions of the cement production process. The total CO_2 emissions of cement production are the sum of the energy related CO_2 emissions and the process related CO_2 emissions. These results for a production plant of the cement industry clearly illustrate the difficulties in determining product-based reference values.

General results for the buildings material industry as well as for the other sectors covered in the research project are published in the final report available online at http://referenzwerte.ltt.rwth-aachen.de as well as by Pauksztat (2006).

5 Conclusion

Product-based reference values for energy demand and CO_2 emissions of industrial energy and production systems can be an adequate instrument for supporting the rational use of energy. The benchmarks discussed above allow the identification and assessment of internal reduction potentials regarding energy demand, CO_2 emissions and corresponding costs.

Companies with similar or identical production installations can compare their own installation through the benchmarks with the analysed reference installation. Through this comparison the internal reduction potentials of the individual installation can be assessed regarding both energy demand and CO_2 emissions. Possible improvements can be derived from the technical differences between the installations. Thus the company gains insights into its own potential to reduce the energy demand and the CO_2 emissions. As energy and CO_2 emissions are cost factors with rising significance, the company can consequently identify cost reduction potentials and support its corporate sustainability.

The benchmarks offer the possibility to position the company on the market concerning its energy demand and CO_2 emissions. This self-assessment can also lead to corporations as companies recognize the need for improvement. In addition, the comparison between the theoretical energy demand of the production process with the product-based reference value can stimulate innovations as the theoretical value indicates the possible reduction potential. This can lead to an increased research effort by public bodies, universities, associations and enterprises to enhance the production processes or even to find an altered method of production.

Although the usefulness is highly dependent on the comparability of the analysed installations, the product-based reference values can be applied to existing industrial installations with similar system constellations. The derived benchmarks then allow the comparison and the self-assessment of existing installations with regard to the energy demand and the CO_2 emissions. The product-based benchmarks can be used to promote the rational use of energy and to enhance corporate sustainability. In addition, the product-based reference values for energy demand and CO_2 emissions can potentially stimulate innovations in the market.

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Double Auction experiments and their relevance for emissions trading

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Abstract

In this article, we discuss selected methodological problems from previous Double Auction (DA) experiments and analyze the two following questions experimentally. Firstly, does the framing of the decision situation influence the behavior in an emissions trading experiment? Secondly, is the Multiple Unit Double Auction (MUDA) able to suppress market power when the buying or selling side is highly concentrated? Based on a larger number of independent observations than analyzed in previous studies, the experiment generates two main results. Firstly, the framing of the decision situation does not influence the behavior of subjects. Secondly, the emissions trading market realizes a high degree of efficiency even under market power conditions. However, the MUDA is not able to restrict market power. We observe persistent price discrimination in both market power environments, i.e. the distribution of profits is strongly shifted in favor of the strong market side without greatly harming efficiency.

Keywords: Emissions trading, market power, experimental economics, Double Auction

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1 Introduction

The absence of market power, i.e. the ability to influence the market price in one's favor, is a necessary condition for the efficiency of emissions trading markets. In principle, market power may have two effects.[2] First, market power may restrict the net quantity traded and lead to an inefficient allocation of abatement. Second, market power may redistribute the gains of trade in favor of the strong market side. If the traders with market power are able to execute price discrimination, it is possible to have the second effect without the first. From the viewpoint of standard economics, only the efficiency loss due to quantity restriction raises a problem. However, if an expected unequal distribution of the gains of trade strengthens the political resistance against an emissions trading system and jeopardizes its implementation, the second effect has to be considered too.

Whether market power actually constitutes a problem has to be analyzed for each emissions trading market separately. The negative effects of market power in the new European Union greenhouse gas emissions (GHG) trading scheme seem to be negligible.[3] However, market power may constitute a serious problem for future international emissions trading within the framework of the Kyoto Protocol.[4] The former Soviet Union (FSU) will be a monopolistic supplier of GHG emission permits in this market due to its endowment with "hot air", i.e. a permit endowment above its own requirements for the commitment period, and cheap abatement measures.[5] Since the FSU countries will not (or only after an appropriate compensation) delegate their permits at the legal entity level, market power on the supply side of this market will likely emerge. In contrast, we may expect competitive behavior on the demand side, which is significantly weakened by the withdrawal of the US. Moreover, a demand cartel of the remaining OECD countries seems to be rather unlikely.[6] Therefore, emissions trading will lead to a permit price of nil and business-as-usual emissions under the assumption of price-taking behavior. Only market power, i.e. monopolistic behavior of the FSU countries, will lead to a positive price and to actual abatement (Böhringer and Löschel 2003; Böhringer and Vogt 2003). In this context, the question arises as to what extent market power in the Kyoto market will emerge and which influence the design of the trading institution will have on the exercise of market power.

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[2] We only consider market power in a single market here. See Misiolek and Elder (1989) for an analysis of market power in linked markets for emissions permits and products.

[3] The number of facilities which are affected by the EU emissions trading scheme constitutes 10,000-12,000 (Carbon Market Europe 2003). Given this number, the emergence of market power is very unlikely.

[4] Article 17 of the Kyoto Protocol allows for international emissions trading. However, it is until now unclear whether the permits are tradable only between the signatory states or also on a legal entity level.

[5] The FSU countries hold 84% of the "hot air" (Böhringer and Löschel 2003).

[6] In the event that the OECD countries would allow their legal entities to take part in trading, coordination is even more implausible (Böhringer and Vogt 2003).

The EU GHG trading scheme creates the first international emissions trading market. If this market starts successfully, the emissions trading approach will be more attractive as an environmental policy instrument for other media, such as water, and also in countries outside the US and the EU. However, the number of market participants in these regional emission markets is often small, and single companies hold a big market share. Therefore, market power may pose a grave problem for future regional emissions markets.

Several variants regarding the market design of future emissions markets are possible. In this context, the question of interest is whether a Double Auction (DA) may prevent the emergence of market power.[7] The central hypothesis (Bohm 2000; Carlén 1999) is that if emissions trading is organized according to DA rules, repeated trading leads to the competitive equilibrium even though one market participant disposes of market power. The argument that the DA is able to prevent the emergence of market power rests upon the sequential nature of this market institution and the fact that all prices are public information. If market power is on the seller side, the monopolist has, ceteris paribus, an incentive to sell additional permits as long as the permit price is above its marginal abatement costs. Therefore, closing prices should attain the competitive price. However, this price discrimination discloses information about the competitive equilibrium which will be common knowledge in later periods. Therefore, buyers will refuse to buy at prices above the competitive price in later periods. This "withholding" of demand eventually leads to the competitive equilibrium.

2 Previous results and motivation for new experiments

The DA as a market mechanism is of great importance for the allocation of homogeneous goods such as stocks and electricity. Nevertheless, no general theory of individual behavior under DA rules exists.[8] However, the DA together with other market institutions has been analyzed intensively by means of laboratory experiments. These market design experiments show that the ability to realize market power depends on the chosen market institution (Holt 1995). The DA is able to realize the competitive equilibrium under a variety of laboratory environments. However, the experimental evidence regarding the ability of the DA to suppress market power is ambiguous. Holt (1995, p. 398) noticed in a survey on industrial organization experiments:

[7] A DA is organized like most stock markets. In a DA trading period, each trader can submit offers to sell and bids to buy or accept (part of) other traders' offers or bids. The list of open bids and offers and the list of transactions is public information.

[8] There are only a few models (Easley and Ledyard 1993; Friedman 1984, 1991) which describe individual behavior in DA markets under restrictive assumptions. A survey is given by Cason and Friedman (1993). Because this paper has an empirical focus, we do not consider these models here.

"Sellers are sometimes able to exercise market power in double auctions, but the influence of seller market power is much weaker because of the incentives to offer last-minute price concessions and the more active role that buyers have in this institution".

Several experiments (Carlén 1999; Smith 1981; Williams 1980) confirm this statement. The DA is able to suppress market power and to generate the competitive equilibrium. The observed prices in later periods are near the competitive price. However, there are also deviations from the competitive equilibrium in these experiments. In particular, the quantities traded are lower than the competitive quantity, and price discrimination with high efficiency is frequently observed in earlier periods. Davis (1993) concluded that the monopolist "spoils" its own market in later periods by successful price discrimination in earlier periods. Buyers gain information about sellers' marginal costs by price discrimination and are informed that the monopolist can make profitable sales at lower prices. Holding back their demand in later periods eventually leads to a situation where only transactions in the range of the competitive price are observed, i.e. the monopolist's market power erodes due to the sequential nature of trading and the information disclosure in the DA.

In a recent experiment, Muller et al. (2002) observed that quantities are near the competitive quantity while the closing prices attain the competitive price in both market power treatments. The attained efficiency is therefore high and above the market power benchmark.[9] However, the distribution of profits is strongly shifted in favor of the strong market side. The high efficiency and the observed distribution of profits result from almost perfect price discrimination which the subjects with market power may persistently realize in this DA market. In contrast to the experiments where the efficient allocation is attained either with or without persistent price discrimination, there are also experiments (Brown-Kruse et al. 1995; Godby 1999) where the market power prediction performs better than the competitive prediction. In these experiments, prices are near the market power prediction, but there is no convergence to the competitive price.

In summary, the experimental evidence regarding market power in DA experiments is not clear. Therefore, more carefully controlled experiments are needed to get a better picture of the individual behavior in these markets.[10] Moreover, comparisons between different DA experiments are hindered by the low number of independent observations, large differences in the design of the DA institution, and the methodology used.[11] The main differences from a methodological point of view are:

Speculation: In earlier DA experiments (Smith 1981; Smith and Williams 1989), speculation is not allowed, i.e. subjects can either sell or buy permits ac-

[9] See below for the definition of "efficiency".

[10] The accumulation of stylized facts, i.e. reproducible results which are generated under different laboratory environments, is a necessary condition for drawing conclusions within the framework of the testbedding of market mechanisms. See Plott (1994) for a description of the testbedding methodology.

[11] In most studies, the low number (usually three to five) of independent observations does not allow for statistical tests and appropriate conclusions.

cording to their initial endowment. Later experiments (Carlén 1999; Muller et al. 2002) have implemented speculation as a central property of real markets.

Multiple-Unit property: Most experiments use a single-unit version of the DA, i.e. only one permit can be simultaneously bought or sold. The quantity traded in these markets is very low (in most cases 8 permits). In contrast to this, Carlén (1999) has used a multiple-unit DA in a market with a large quantity traded.

Information to subjects: There are several approaches regarding the information about the market structure subjects get before the experiment. In most cases, the marginal redemption values and the initial endowment are private information. However, in Brown-Kruse et al. (1995) and Godby (1999) the subject with market power has information about costs and endowment of the other subjects, while in Carlén (1999) the competitive equilibrium is common knowledge.

Subject pool: In some experiments (Carlén 1999; Muller et al. 2002; Smith 1981), the role of the market power subjects is assigned to "qualified" subjects such as Ph.D. students. In other experiments (Brown-Kruse et al. 1995; Godby 1999) students were used, as is the usual practice in experimental economics.

Framing: The presentation of the decision situation in most DA emissions trading experiments is "neutral", i.e. a business frame is chosen and there is no reference to the pollution background and emissions trading.[12] In contrast to this procedure, Carlén (1999) informed subjects comprehensively about the background of the emissions trading experiment. The framing of the decision situation should have no influence on individual behavior from an economics viewpoint. However, the question whether it is necessary to implement a "neutral" story for an emissions trading experiment has to be answered by control experiments.

The following DA experiment considers selected aspects of the abovementioned methodological differences and generates a number of independent observations which are adequate for nonparametric tests. Our aim is a comprehensive analysis of the question whether the DA is able to suppress market power.

3 Experiment

3.1 Design

In the laboratory experiment, subjects traded emissions permits (in the following "permits") in a computerized Multiple Unit Double Auction (MUDA). Within a period of 10 minutes' length, subjects could submit bids to buy and offers to sell or accept (part of) other subjects' bids and offers. Bids and offers were price-quantity bundles on the demand and supply side of the market. The MUDA allowed for speculation, i.e. subjects could submit both bids and offers according to their endowment. The order book, i.e. the list of submitted bids and offers, and the list of transactions was public information. Subjects got information about prices,

[12] Usually this procedure is justified by the fear of emotional reactions of subjects who are confronted with the environmental frame. See Muller et al. (2002) for details.

quantities, time of transaction, and IDs of trading partners.[13] The instructions to subjects[14] contained (1) written instructions with information about the background of the experiment, the valuation for permits, the MUDA rules and the structure of the market,[15] (2) a test of understanding, and (3) a training period not relevant to the payoff. The experiment was divided into three identical trading periods of ten minutes' length each. Banking of permits was not allowed.

Table 1. Parameters for supply, demand, profit, and total profit (in LD)

	net sellers					net buyers				
subject number	1	2	3	4	5	6	7	8	9	10
1. MRV	68	70	72	74	76	77	76	75	74	73
2. MRV	52	57	61	64	66	72	71	70	69	68
3. MRV	35	37	39	41	45	67	65	63	61	59
4. MRV	25	27	29	31	33	57	55	53	51	47
5. MRV	20	21	22	23	24	40	35	31	28	26
6. MRV	15	16	17	18	19	24	22	20	18	16
profit in COMP	96	89	83	78	74	311	317	323	329	337
profit in ML			-1,180			311	317	323	329	337
profit in MN	96	89	83	78	74			17		
total profit in COMP*	400	400	400	400	400	400	400	400	400	400
total profit in ML*			564			344	346	348	350	356
total profit in MN*	344	346	348	350	356			564		

* Benchmark

Preferences were induced via marginal redemption values (MRV).[16] The MRV was the payment in LabDollar (LD) which a subject received when she redeemed a permit with the appropriate MRV at the end of a period. The MRV was therefore the maximal willingness to pay for buying or the minimal compensation for selling a permit. The total profit of a subject in a period was equal to the sum of MRVs for permits which were in her possession plus the sales revenues plus an exogenously assigned profit minus the expenditures for purchasing. The information of subjects about their MRVs, the holdings of permits, and the current total profit was of a private nature. The payment subjects received at the end of the experiment was computed based on the sum of total profits in all three periods.

[13] The price development over time in the current period and all previous periods could be easily reconstructed by a graph and a table; in addition, the mean transaction price was indicated.

[14] We recruited the subjects from the general student population in economics through classroom advertisements. Subjects who dispose of market power were selected by chance from the subject pool. If market power can actually evolve in DA markets, then "ordinary" subjects should be able to exploit this advantage too.

[15] Each subject knew how the market shares were distributed. The instructions are available upon request.

[16] See Smith (1976) and Sturm and Weimann (2006) for the induced value concept.

There are three different market environments: (1) competition, (2) monopoly, and (3) monopsony. In the competition environment (COMP), there were five subjects who received six MRVs each without a permit in their initial endowment (net buyer), and five subjects, who received six MRVs each with a permit in their initial endowment (net seller).[17] The initial profits assigned to each subject were computed in a way that the total profit after trade for all subjects was equalized in the competitive equilibrium. Net buyers therefore had a higher profit than net sellers (see Table 1). The aggregated demand and supply functions (see Figure 1) were derived by aggregation of the MRVs without and with permits. In the monopoly environment (ML), the endowments of all five net sellers were aggregated and assigned to one subject, who possessed 30 MRVs with permit. Analogously, the endowments of the five net buyers were aggregated in the monopsony environment (MN).[18]

Table 2. Treatment variables

variable		*frame*	
		emissions	business
market structure	monopoly	ML-emi (12)	-
	monopsony	MN-emi (6)	MN-bus (6)
	competition	COMP-emi (6)	-

ML:	monopoly	COMP:	competition
MN:	monopsony	bus:	business frame
emi:	emissions frame	(·):	number of independent observations

There are two treatment variables in the experiment (see Table 2):

1. The *frame* of the decision situation. In the specification "emissions", subjects received additional information about the climate effect, the Kyoto Protocol, and emissions trading. In the specification "business", a pure business terminology which did not include any reference to the concept of emissions trading was chosen.[19]
2. The *market structure* with a specification "competition", "monopoly", and "monopsony".

[17] The labeling of subjects as "net sellers" or "net buyers" refers only to the initial endowment and the position of the subjects in the competitive equilibrium since each subject could both sell and buy permits according to its endowment with permits and LD in the market institution.

[18] It was ensured that the subject with market power has the same payment in the competitive equilibrium (400 LD) as the other subjects by deducting a fix amount (4 x 400 LD = 1,600 LD) from the initial endowment in LD. The payment for the market power subjects in the market power benchmarks was 564 LD.

[19] The framing effect was only analyzed in the monopsony environment. The framing aspect was restricted to this environment because both market sides, and therefore the allocation and distribution of total profits in the monopoly and monopsony, were symmetric.

3.2 Benchmark values

The benchmark values are depicted in Table 3. In the no-trade case, subjects earn their profit in the initial endowment plus their MRVs for permits in their possession. The competitive equilibrium (CE) is characterized by the price-quantity combination $\{p_{CE} = 45\text{-}47, q_{CE} = 20\}$ and maximizes the aggregated total profit (see Figure 1).[20] Therefore, the gains of trade, i.e. the difference between the aggregated total profit in the case of trading and the no-trade benchmark, are maximal in the CE with 766 LD.

Table 3. Benchmark values

benchmark	net purchases	price	total profit (in LD) buyers	sellers	market	gains of trade (in LD)	*Eff*	*M*
no trade	0	-	1,617	1,617	3,234	0	0	-
CE	20	45-47	2,000	2,000	4,000	766	1.00	-
monopoly	14	61	1,744	2,164	3,908	674	0.88	1
monopsony	14	31	2,164	1,744	3,908	674	0.88	1

The market power benchmarks, monopoly and monopsony, are the allocations where a single seller or buyer maximizes its total profit by choosing a uniform price. The monopolist maximizes its total profit by selling permits at a price as long as marginal costs are not above marginal revenue. The monopoly equilibrium is therefore $\{p_{ML} = 61, q_{ML} = 14\}$. Compared to the CE, the total profit of the seller side increases to 2,164 LD, while the total profit of the buyer side decreases to 1,744 LD. The gains of trade are 674 LD and the efficiency is 0.88. The efficiency of an allocation, *Eff*, is defined as the fraction of realized gains of trade on the maximal gains of trade in the CE, i.e. $Eff = \left(\Pi - \Pi^{IA}\right) / \left(\Pi^{CE} - \Pi^{IA}\right)$, where Π is the aggregated total profit, Π^{IA} is the aggregated total profit in the initial endowment and Π^{CE} is the aggregated total profit in the CE. Due to the symmetry of aggregated demand and supply, the monopsony equilibrium $\{p_{MN} = 31, q_{MN} = 14\}$ is computed analogously. The excess burden (EB) for both market power environments amounts to 92 LD and is marked in Figure 1.

[20] Since the market institution allowed for speculation, there may be a distinction between net sales and total transactions. The difference between net sales (q_{net}) and total transactions (q_{tot}) is referred to as speculation s, i.e. $s = q_{tot} - q_{net}$.

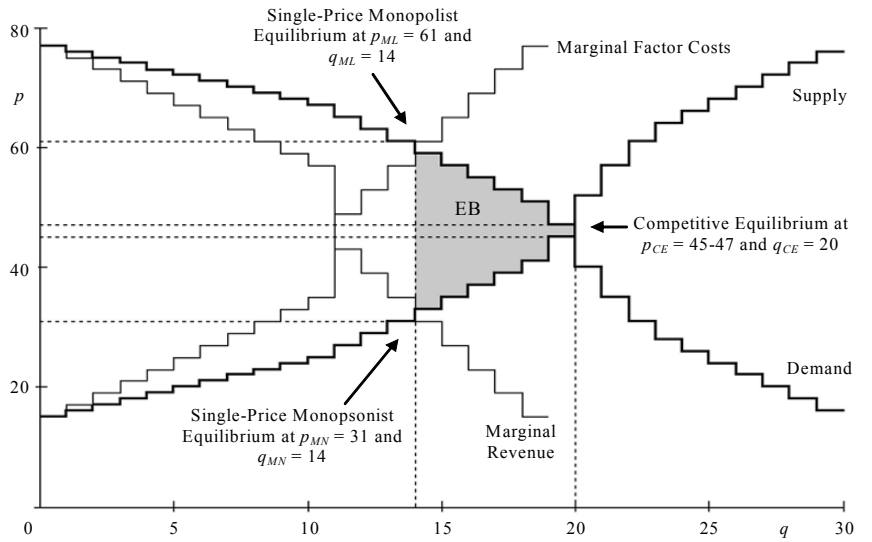

Fig. 1. Aggregated demand and supply

Note that the benchmarks in Table 3 should not be interpreted as predictions of outcomes in the experiment, because the subjects were not restricted to a single price for each transaction. As mentioned above, the MUDA institutions allowed for price discrimination, i.e. subjects with market power could boost their total profit above the market power benchmark. We use the "index of market power effectiveness" (*M*) as a measure for the ability of the strong market side to profit from an increase of prices above (monopoly) or below (monopsony) the competitive price.[21] The index *M* is computed as the relation of the realized supracompetitive total profit of the strong market side to its supracompetitive total profit in the appropriate market power benchmark, i.e. $M = \left(\pi - \pi^{CE}\right) / \left(\pi^{MP} - \pi^{CE}\right)$, where π is the realized total profit of the market power subject, π^{CE} is its competitive total profit, and π^{MP} is its total profit in the market power benchmark. Note that *M* is 1 for the market power benchmark (see Table 3), but *M* may be above 1 for the case of successful price discrimination or below 1 if the strong market side realizes a smaller total profit than in the market power benchmark. In the event of perfect price discrimination, *M* is 2.34 in monopoly as well as in monopsony.

[21] See Davis and Holt (1993) for details.

3.3 Hypothesis

From the viewpoint of standard theory, the behavior of subjects should not be influenced by the framing of the decision situation, i.e. it is irrelevant which frame is chosen in the experiment.[22] Therefore, *hypothesis H 1* can be formulated:

> *H 1:* The framing of the decision situation has no influence on individual behavior, i.e. there are no significant differences in the results of MN-emi and MN-bus.

The argument that the DA is able to suppress market power is based on its sequential nature and information disclosure during the trading process (Bohm 2000; Carlén 1999). In the case of market power on the seller side, the sequential nature of the DA allows for intertemporal price discrimination by the monopolist. The monopolist will, ceteris paribus, sell permits as long as the price is above its marginal abatement cost. The marginal price reduction increases profits because the loss in value for the sold permits is not borne by the monopolist itself but by the buyers of these permits. Therefore, closing prices in a period should eventually attain the CE price. However, this price discrimination discloses information about the CE. If the CE is common knowledge, buyers will anticipate the price cut of the monopolist in the next period and will refuse to buy at prices above the CE price, i.e. buyers will withhold their demand to make a snip at the end of the period and to purchase the permit at the CE price.[23] *Hypotheses H 2* follows from this line of reasoning:

> *H 2:* The strong market side successfully practices intertemporal price discrimination in the first period, i.e. prices decline (monopoly) or rise (monopsony) over time and closing prices are at the CE price. The distribution of profits is clearly shifted in favor of the strong market side while the efficiency is high. In the following periods, the degree of price discrimination decreases and median prices approach the CE price. The distribution of profits converges to the CE distribution of profits.

[22] However, in dilemma situations a framing effect was observed (Andreoni 1995): subjects contributed more to a public good than they abated contributions to a public bad.

[23] Of course, the monopolist could anticipate the negative consequences of price discrimination and should therefore trade off the additional profit from price discrimination with its future costs. For instance, the monopolist could simulate high marginal abatement costs and keep prices high this way. See Tirole (2003) for the intuition of the Coase conjecture, which is very similar to the optimization problem mentioned here. However, we suppose in line with hypothesis *H 2* that the monopolist actually behaves myopically and practices price discrimination in the first period. Finally, the question to what extent subjects with market power anticipate the consequences of their behavior has to be answered again by means of experiments.

3.4 Results

All in all, 204 subjects took part in the experiment with a standard between-subjects design and 6 or 12 independent observations per cell in Table 2. The sessions lasted about two hours and the mean payment was 22 €.[24] All parameter values are depicted in Table 6 in the appendix. If not otherwise stated, differences in parameter values are valid for all periods.

3.4.1 Aggregate results over all periods

Observation 1 summarizes the results of the treatments MN-emi and MN-bus:

> There are no significant differences between MN-emi and MN-bus regarding the analyzed parameter values (two-sided Mann-Whitney U-Test, p = 5%).
> Therefore, the MN-emi and MN-bus observations are aggregated to 12 independent observations for the monopoly environment (MN). Figure 2 depicts the mean values of the opening, median, and closing prices over all three periods for each environment.

Observation 2 summarizes:

a Opening and median prices are higher in monopoly and lower in monopsony than in the competition environment. The differences are significant (MW U-Test, 5%) for all but one period.[25] There are no significant differences for the closing prices except for one period (MW U-Test, 5%).[26]

b Median prices in the competition environment do not differ from the CE price (two-sided t-Test, 5%). Median prices in the market power environments are significantly different from the CE price (t-Test, p = 0.1%) but there is, except for one period, no significant difference to the market power benchmark price.[27]

c Opening prices of the market power environments are above (monopoly) or below (monopsony) the market power benchmark. The difference is significant (t-Test, 0.5%) for all but one period.[28] There are no significant differences between the closing prices in the market power environments and the CE price (t-Test, 5%).

[24] The sessions were conducted at the Magdeburg Experimental Laboratory (MaXLab). The session time of two hours was divided into 75 minutes of instructions and 45 minutes of experiment. For comparison only: The average earnings for a student's job in Magdeburg are about 8 € per hour (in 2004).

[25] Opening prices, period 1, monopoly-competition.

[26] Period 1, monopoly-monopsony.

[27] Period 1, monopsony.

[28] Period 1, monopoly.

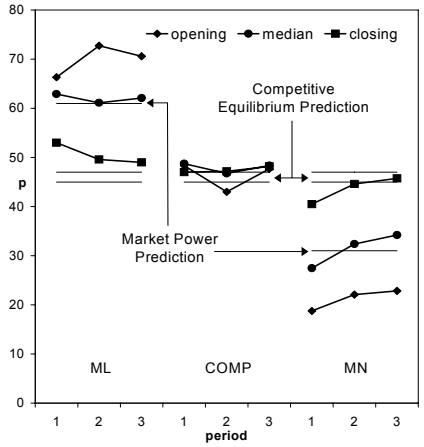

Fig. 2. Mean prices

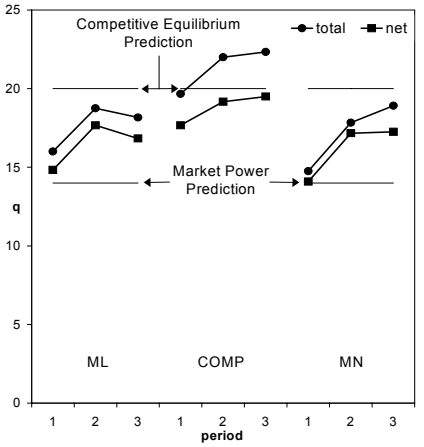

Fig. 3. Mean quantities

Observation 3 sums up the results regarding the mean quantities (see Figure 3):

a The net quantity in the competition environment exceeds the values in the market power environments. However, the difference is only significant for monopsony (MW U-Test, 0.5%). The net quantity in both market power environments is above the market power benchmark. The difference is significant for period 2 and 3 (t-Test, 5%).

b The fraction of speculation on the total quantity is higher in the competition environment than in both market power environments. However, the difference is significant only for period 2 (MW U-Test, 0.5%).

Figures 4 and 5 depict the mean total profits and the mean efficiency of the allocation after trade.

The results can be summarized in *observation 4*:

a There is no significant difference between the total profit of both market sides in the competition environment and the CE values (t-Test, 5%).

b In both market power environments, the strong market side realizes a significantly higher total profit than in the CE (t-Test, 5%). The realized total profit exceeds even the market power benchmark in all but one period. However, the latter difference is only significant for period 2 in monopsony (t-Test, 5%).

c In both market power environments, the total profits of the weak market side are significantly below the CE values (t-Test, 1%). There is no significant difference between the total profits of the weak market side and the market power benchmark (t-Test, 5%).

d There are no significant differences between the efficiency in all environments (MW U-Test, 5%). In both market power environments, an efficiency (not significantly) below the market power benchmark is realized in period

1. In period 2 and 3, the efficiency of both market power treatments is (significantly for monopoly) above the market power benchmark (t-Test, 5%).

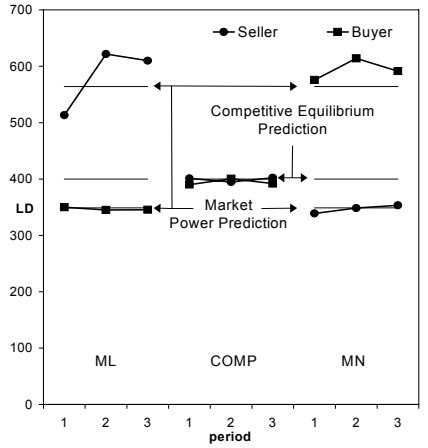

Fig. 4. Mean total profits

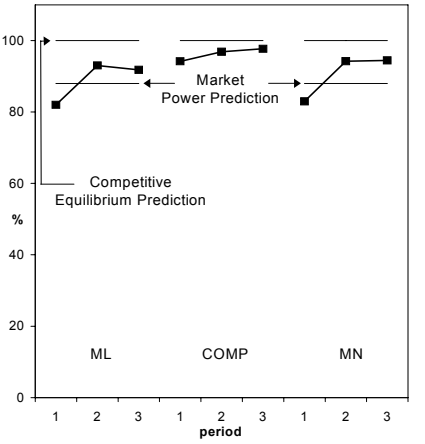

Fig. 5. Mean efficiency

The results regarding the standard deviation of prices around the CE price, α, can be summarized in *observation 5*:

There are no significant differences between the α values of both market power environments. The α values for both market power environments exceed the values for the competition environment significantly (MW U-Test, 5%).

Observation 6 sums up the results for the index *M*:

There are no significant differences between the *M* values of both market power environments (MW U-Test, 5%). The index *M* exceeds the value 1 for both market power environments except for one period.[29] However, the difference is only significant for period 2 in monopsony (t-Test, 5%).[30]
Figures 2 to 5 and the values in Table 6 indicate some interesting changes over the course of the experiment. We use the Wilcoxon matched pairs test (two-sided, p = 5%) because the data within a session are not statistically independent.

Observation 7 summarizes the significant results regarding the market power environments:

a While median prices in monopoly remain virtually constant, they increase in monopsony from period 1 to 3.[31] There are no changes in opening and clos-

[29] Period 1, monopoly.
[30] One subject with market power apparently did not grasp the decision task in the monopoly sessions ML-S05. She sold only five permits on average. Omitting this observation the difference between the observed *M* und *M* = 1 is significant also for period 2 and 3 in monopoly.
[31] The difference between period 1 and 2 and between period 2 and 3 is significant too.

ing prices for both market power environments.[32] Net quantities in both market power treatments increase from period 1 to 2.

b In both market power treatments, efficiency increases from period 1 to 2.[33] The weak market side is able to increase its total profit in monopsony from period 1 to 3. The total profit of the weak market side in monopoly remains virtually unchanged over the course of the experiment.

c For both market power environments, the α values decrease from period 1 to 2.[34]

3.4.2 Regression analysis

The regression analysis in Table 4 generates information about the price development within, as well as over, periods for each session. We analyzed whether there was a structural change in the price patterns over the periods by estimating the following model for each of the $i = 1, \ldots, 12$ session of both market power environments

$$p_i = \alpha_{1,i} + \alpha_{2,i} D_{P2} + \alpha_{3,i} D_{P3} + \left(\beta_{1,i} + \beta_{2,i} D_{P2} + \beta_{3,i} D_{P3}\right) X_i + e_i$$

where p_i is the price observation in a period and X_i is the cumulated relative fraction of all transactions in a period of session i. D_{P2} and D_{P3} are the dummies for period 2 and 3. e_i is a potentially autocorrelated error term. The estimated coefficients for the dummies D_{P2} and D_{P3}, $a_{2,i}$ and $a_{3,i}$, indicate whether there is a structural change in the opening price level (opening price effect) between period 1 and 2 or 3. The estimated coefficients for the interaction dummies $D_{P2}X_i$ and $D_{P3}X_i$, $b_{2,i}$ and $b_{3,i}$, show a potential change in the slope of the price path (slope effect) during the experiment.

[32] The surprising (but not significant) rise in opening prices from period 1 to 2 in monopoly results from three sessions with a very low opening price in period 1. See Table 4.

[33] The rise in efficiency from period 1 to 3 is only significant for monopsony.

[34] The decline from period 1 to 3 is only significant for monopsony.

Table 4. Regression analysis

Monopoly Sessions S_i, i = 1, …, 12						
S_i	Const. ($a_{1,i}$)	$a_{2,i}$	$a_{3,i}$	$b_{1,i}$	$b_{2,i}$	$b_{3,i}$
S_{01}	29.814*	47.375*	34.698*	.404*	-.683**	-.419*
S_{02}	66.984**	-2.109	-2.506	-.182	-.031	-.018
S_{03}	50.618**	20.898	24.641*	-.135	-.124	-.140
S_{04}	74.760**	1.091	1.192	-.276**	-.002	.049
S_{05}	90.500**	-6.873	-11.283*	.008	-.315**	-.286**
S_{06}	82.477**	-5.135	-5.266	-.350**	.029	.067
S_{07}	47.829**	18.916*	28.388**	.047	-.229	-.397**
S_{08}	65.611**	7.141	18.006**	-.023	-.164	-.302**
S_{09}	63.297**	12.297**	8.340**	-.159**	-.178**	-.139**
S_{10}	78.682**	-9.871**	-4.434	-.334**	.108*	-.064
S_{11}	78.868**	-1.442	-2.145	-.063**	-.012	-.068**
S_{12}	74.847**	.009	-.991	-.261**	.000	-.030
Monopsony Sessions S_i, i = 1, …, 12						
S_i	Const. ($a_{1,i}$)	$a_{2,i}$	$a_{3,i}$	$b_{1,i}$	$b_{2,i}$	$b_{3,i}$
S_{01}	17.241**	3.359	6.469	.083**	.148	.025
S_{02}	13.834**	-1.767	1.803	.294**	.028	-.010
S_{03}	17.148**	.773	4.942**	.104**	.023	.036
S_{04}	7.624**	4.576**	5.905**	.349**	-.054*	.006
S_{05}	16.982**	.438	1.868	.224**	.061	.066
S_{06}	17.832**	7.338*	19.380**	.282**	-.040	-.125*
S_{07}	18.924**	.566	-.424	.245**	.033	.027
S_{08}	18.619**	9.200	9.048**	.289**	-.082	-.085*
S_{09}	20.407**	-.684	-1.625	.103*	.180**	.154
S_{10}	8.676*	4.344	6.755	.439**	-.035	-.044
S_{11}	14.556**	1.877	.381	.298**	-.111	.054
S_{12}	24.371**	-.387	-.206	.091	.116	.211*

Remarks:
(1) The level of significance is indicated (**: p < 1%, *: p < 5%).
(2) The estimation of the model is corrected for first-order serially-correlated residuals using the Prais-Winston transformation and robust to heteroscedasticity using the Huber/White/sandwich estimator of variance. The transformed model is tested for first-order autocorrelation with a nonparametric runs test. In two cases (ML-S09 and ML-S12) this test failed and we had to reject the null hypothesis that the runs of the residuals are random. However, a graphical and correlation analysis did not yield any further hints of first-order autocorrelation in these cases and we therefore did not exclude the data from our analysis.
(3) Because the computation of the F statistic and the R^2 is not appropriate in our case we only refer to the significance of the coefficients here. See Gujarati (1995) and StataCorp (2003) for details.

Observation 8 summarizes the significant results:

a The picture for the monopoly sessions is mixed. We observe a decreasing price pattern over the periods for the majority of sessions. However, there is only one session where a negative opening price effect is combined with a decreasing slope effect. There are also some sessions with a positive opening price effect and a decreasing slope effect and one session with a negative opening price effect but an increasing slope effect.

b The transaction price follows an increasing and stable pattern in the majority of monopsony sessions beginning with period 1. The mean value of $b_{1,i}$ (over the significant values) is .246. There are four sessions with a positive opening price effect, but in three of these the slope of the price path becomes simultaneously flatter. In two sessions, only the price path becomes steeper during the experiment. There is no session where a positive opening price effect is combined with an increasing slope effect.

4 Discussion

The results of the competition environment confirm the stylized facts of previous DA experiments. Median prices and net quantities are near the CE allocation and efficiency attains values clearly above 90%, i.e. subjects are able to lift the bulk of the efficiency gains in a MUDA market institution. In this context, the frequent use of the possibility to speculate is remarkable since this important design feature of DA markets in the field is still not a standard element of laboratory DA markets.[35] The framing of the decision situation, i.e. the choice between a "neutral" and an "environmental" frame, has no influence on individual behavior in the experiment. *Hypothesis H 1* cannot be rejected. This (not surprising) conclusion shows that the choice of the presentation in emissions trading experiments has no influence on the control of individual preferences by monetary incentives. It is therefore not necessary to design specifically neutral frames for future emissions trading experiments. *Observations 2* to *8* indicate that, in general, the MUDA is not able to suppress market power effectively, although market power is more a problem of the distribution of payoffs than of efficiency. The realized efficiency is high and above the market power benchmark (for period 2 and 3). However, the strong market side can realize market power through successful and persistent price discrimination. The market power index *M* is (for period 2 and 3) clearly above 1. This stable pattern is observed even though the information that the strong market side is able to realize profitable transactions at the CE price is common knowledge.

The development of median prices over periods indicates an interesting asymmetry. While in monopsony the weak market side is able to influence median prices at least slightly in its favor, there is no such effect in monopoly. However, the influence of the weak market side in monopsony on median prices leads only to a rarely perceptible increase in total profits without greatly harming the payoffs of the strong market side. The distribution of total profits is strongly shifted in favor of the strong market side over the course of the experiment. The weak market side realizes, in all periods, significantly less total profit than in the CE, i.e. the "tacit collusion" of the weak market side fails. The results of the regression analysis confirm this conclusion. We observe only a few sessions with an opening price effect or a change in the slope of the price path in favor of the weak market side.

[35] See, for instance, the DA experiment in Cason et al. (2002).

Therefore, the data support the first part of *hypothesis H 2*, which states that price discrimination is observed in the first period. However, the second part of *hypothesis H 2*, which claims that market power erodes in the course of the experiment, has to be rejected.[36]

Table 5: Total profits and distribution of profits for sellers (S) and buyers (B)

Environment	Total Profits	Period 1	Period 2	Period 3
Monopoly	Total $Profit_S$ in LD	2,113.25	2,221.83	2,209.92
	Total $Profit_B$ in LD	1,748.92	1,724.83	1,727.50
	Sum	3,862.17	3,946.67	3,937.42
	Total $Profit_S$ in %	54.72	56.30	56.13
	Total $Profit_B$ in %	45.28	43.70	43.87
	Sum	100.00	100.00	100.00
Monopsony	Total $Profit_S$ in LD	2,175.67	2,214.08	2,191.42
	Total $Profit_B$ in LD	1,694.00	1,741.83	1,766.08
	Sum	3,869.67	3,955.92	3,957.50
	Total $Profit_S$ in %	56.22	55.97	55.37
	Total $Profit_B$ in %	43.78	44.03	44.63
	Sum	100.00	100.00	100.00

In our experiment, practically no erosion of market power is observed (see Table 5). In both market power treatments, the efficiency increases from period 1 to 2 remarkably, i.e. an additional total profit is realized (+84.50 LD in monopoly and +86.25 LD in monopsony), and changes only slightly in the transition from period 2 to 3. The Figures in Table 5 confirm the observation that in period 2 and 3 the strong market side in monopoly performs slightly better than in monopsony both in absolute and relative terms. This observation is consistent with the development of median prices in Figure 2. In the experiment, sellers are therefore in a slightly better position to exploit market power and to shift the distribution of total profits in their favor than buyers.

5 Conclusions

Our experiment, which is based on a larger number of independent observations than in previous studies, generates two main results. Firstly, the framing of the de-

[36] The argument that three periods is not a sufficient number of periods to reveal the erosion of market power in a MUDA may be an objection to this conclusion. However, there are two counter-arguments to this objection. First, Muller et al. (2002) also observe persistent price discrimination in their MUDA experiment in an environment with 10 periods. Second, it is, a-priori, not clear why subjects in this environment with a transparent information disclosure should change their behavior just after the third period.

cision situation does not influence the behavior of subjects in an emissions trading experiment. Secondly, the emissions trading market realizes a high degree of efficiency even under market power conditions. However, the MUDA is, in general, not able to restrict market power. We observe persistent price discrimination in both market power environments, i.e. the distribution of profits is strongly shifted in favor of the strong market side without greatly harming efficiency. We conclude that price discrimination may pose a serious problem in the field, particularly for regional emissions trading markets, which are vulnerable to market power. Therefore, the possibility of price discrimination has to be taken into account in the design of the market institution or the arrangement of the initial allocation of permits because the distribution of profits may affect the political feasibility of regional emissions trading markets with a high potential for market power.

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Appendix

Table 6. Results over all periods (1, 2, 3)

	q_{net}			q_{net}			p_{mean}			p_{median}			p_{open}			p_{close}		
Treatment	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
MN-emi	14.5	17.5	18.5	14.2	16.7	16.7	26.8	30.8	33.9	25.1	30.8	34.7	19.3	20.2	21.0	39.5	40.3	41.5
MN-bus	15.0	18.2	19.3	14.0	17.7	17.8	30.4	33.7	34.4	29.8	34.0	33.8	18.2	24.0	24.7	41.5	48.8	50.0
	total Profit$_{i}$			*total Profit*$_{ij}$			$\overline{MV}$			M			α^1			s/q_{net} (in %)^2		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
MN-emi	335	345	354	594	625	579	0.83	0.94	0.93	1.18	1.37	1.09	20.8	17.7	15.1	2.8	5.0	9.6
MN-bus	343	351	353	557	603	604	0.83	0.95	0.96	0.96	1.24	1.25	18.2	15.3	15.1	7.2	2.7	7.0
	q_{net}			q_{net}			p_{mean}			p_{median}			p_{open}			p_{close}		
Environment	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
ML	16.0	18.8	18.2	14.8	17.7	16.8	62.1	61,1	61.0	62.9	61.1	62.1	66.3	72.8	70.6	53.0	49.6	49.0
MN	14.8	17.8	18.9	14.1	17.2	17.3	28.6	32.3	34.1	27.5	32.4	34.2	18.8	22.1	22.8	40.5	44.6	45.8
COMP	19.7	22.0	22.3	17.7	19.2	19.5	47.7	45.8	49.1	48.8	46.8	48.3	48.3	43.0	47.7	47.0	47.2	48.2
	total Profit$_{i}$			*total Profit*$_{ij}$			$\overline{MV}$			M			α^1			s/q_{net} (in %)^2		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
ML	513	622	610	350	345	346	0.82	0.93	0.92	0.69	1.35	1.28	20.5	17.3	17.7	8.2	5.4	7.1
MN	339	348	353	576	614	591	0.83	0.94	0.94	1.07	1.31	1.17	19.5	16.5	15.1	5.0	3.9	8.3
COMP	401	395	411	390	401	385	0.94	0.97	0.98	-	-	-	11.5	9.8	7.8	9.6	12.8	12.3

[1] Standard deviation of prices around the CE price.
[2] The difference between net sales (q_{net}) and total transaction (q_{tot}) is referred to as speculation s, i.e. $s = q_{tot} - q_{net}$.
[3] The M values without ML-SOS are 0.77 (1), 1.53 (2) and 1.36 (3).

The influence of the allocation method on market liquidity, volatility and firms' investment decisions

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Abstract

When taking incomplete information and risk into account, it is likely that the primary allocation method has an impact on static efficiency and also on firms' investment and innovation decisions. Market liquidity and allowance price volatility are crucial factors in this respect. Benchmarking is, from a simple analytical finding, more conducive to a liquid market in the first years of an ET system than grandfathering. This in turn influences firms' expectations about the future market development, including volatility. A liquid market is more conducive to all abatement approaches that are connected to investment, including to innovation. The degree of this effect depends, among other things, on the availability of non-investment abatement approaches, the nature of the price shocks and the precise risk treatment by firms.

Keywords: Primary allocation, grandfathering, benchmarking, investment, innovation, liquidity, volatility.

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1 Introduction

Static and dynamic efficiency are among the primary criteria for economic comparisons of environmental policy instruments. Market-based instruments like charges and tradable allowances are usually valued highly with respect to these criteria. In the case of tradable allowances, however, the exploitation of the efficiency potentials requires a liquid market on which demand and supply interests can be fulfilled in a reasonable time-span without significantly influencing the price to be paid. Another important factor is price volatility, which is influenced by liquidity, and vice-versa. The higher the volatility, the more difficult it is for participants to infer the marginal abatement costs of all participants from the allowance price, which reduces allocation efficiency. Furthermore, it is likely that especially those participants who consider investing in advanced technology, which would as a rule leave them with spare allowances to sell, are more willing to undertake such investments when they can be reasonably sure about the allowance price they obtain in the future when the investment is in operation.

The extent of liquidity and volatility is influenced by several design factors. Among the most important is the primary allocation method. In this paper, two variants are compared: free allocation according to historical emissions ("grandfathering") and free allocation according to a "benchmarking" approach ("performance standard").

The analysis focuses on the prospective impact of this design choice on liquidity and volatility in the allowance market, and adds considerations on the potential effect of the design choice on firms' investment decisions under uncertainties regarding liquidity and volatility. Two central assumptions for the analysis are that firms act, on aggregate, risk-averse[1,2] and that abatement is at least partially irreversible, that is, the abatement measure can not be dismounted and sold for a salvage value that is at least equal to the original investment expenditure[3].

The remainder of this paper is organised as follows: Section 2 describes the main allocation methods discussed in the literature, including the two variants presented here. Section 3 defines liquidity and volatility and presents a market model for making presumptions about the link between the two. Section 4 explains the concept of the analysis. Section 5 investigates the influence of benchmarking and grandfathering on liquidity and volatility, using a graphical analysis and incorporating concepts of abatement options primarily embodied in new equipment

[1] For a systematic description of risk aversion in economics, see Machina and Rothschild (1998). For deeper insights into the discussion about whether firm executives do indeed act risk-averse, see for example MacCrimmon and Wehrung (1984). The presumption of risk aversion being predominant on an aggregate level risk-attitude is supported by the fact that "equities have historically had higher average returns than bonds, suggesting that investors have had to be induced with higher rewards in order to get them to make riskier pruchases." (Sharpe et al. 1995, p. 167 f.).

[2] The terms uncertainty and risk are used synonymously in this paper.

[3] Ideally, one would have to compare the discounted salvage value with the investment expenditure.

("putty clay"). Section 6 discusses the potential effect of volatility on firms' investment decisions. Section 7 concludes and gives an outlook to still unresolved questions.

2 Different methods of primary allocation and efficiency

The major distinction has, for a long time, been between auctioning and free allocation (see, for example, Bader 2000). Under auctioning, participants themselves determine their individual allocation, by bidding in the auction. Under free allocation, in contrast, a metric has to be chosen. Usually, historical emissions are suggested as allocation basis (Endres 1985); this method has been named "grandfathering" by Tietenberg (1980). An alternative is to allocate according to a "benchmarking" approach, which means a performance formula, e.g., according to heat input or production output of each firm in the past, multiplied by an industry average efficiency factor. This efficiency factor would then be tons of emissions per Joule of heat input or per ton of production output (Harvey and Mingst 2003). In this case, firms who have undertaken emission abatement efforts before the years taken as base years for the allocation, receive a form of reward for these "early actions". Under grandfathering, in contrast, they would be "penalised" for their early actions by receiving less allowances than those firms who have not undertaken such actions. Furthermore, as will be investigated in detail in section 5, there are considerable differences between the two methods in terms of each firm's allocation's proximity to its actual emissions: When the reduction target is not very tight (as is, for instance, the case in the EU CO_2 trading regime for the years 2005-2007), then under grandfathering every firm receives allowances in an amount very close to its actual emissions. Under benchmarking, in contrast, a firm which has performed early abatement measures will receive more allowances than its current emissions status, while a firm that has not performed early actions receives less than its current emissions.

While all three major cap-and-trade systems in the USA apply benchmarking principles, the National Allocation Plans (NAP) of most EU Member States under the EU emissions trading scheme rely primarily on grandfathering (although several of them, like the Netherlands, Austria, Portugal and Germany include some benchmarking elements).[4]

Montgomery (1972) demonstrated theoretically that under a perfectly functioning allowance market, the method of allocation does not affect the efficiency of emissions trading, since the optimum (under equalised marginal abatement costs

[4] Further variants not discussed in this paper are allocation according to expected rather than past emissions (or combining the two), and "updating" the historical base period. The former approach has been applied at least on a sector basis in several EU Member States' National Allocation Plans for the EU CO_2 trading scheme for 2005-2007, see the homepage of the European Commission, DG Environment for details. The latter is currently applied in some US states, e.g., Massachusetts, under the NO_x Budget Trading Program (see Harrison and Radov 2002).

over all participants) will always be reached. In other words, the government can seek a "fair" allocation and/or act according to political wishes, without having to worry about reducing the efficiency of the program (see also Weimann 1998).

Subsequently, however, several papers pointed to potential cases in which the independence of efficiency from allocation can no longer be sustained: Hahn (1984) showed this for the use of market power in the allowance market; Misiolek and Elder (1989) extended it to strategic misuse of allowance market power to exclude competitors in product markets, and Stavins (1995) added the analysis of the consequences of transaction costs associated with allowance transfers.

Another potential obstacle to achieving efficiency is the existence of illiquid and volatile allowance markets: thus, Hansjürgens and Fromm (1994) note that a volatile allowance price makes it difficult for the firms to determine the "real" allowance price that reflects the underlying social marginal abatement costs. This leads to individual marginal abatement costs differing from each other, and thus to efficiency losses compared to the optimum. Furthermore, Endres and Schwarze (1994) describe the potential that the fear of illiquid markets may lead participants to "hoard" allowances, which would also mean that they do not "reach" other firms who have higher abatement costs and would buy them under perfectly functioning markets.

However, liquidity and volatility may not only affect static efficiency in the market, but also have dynamic impacts, namely by changing the participants' investment and innovation decisions when these are at least partly irreversible.

The point I want to make in this paper is that market circumstances can not only determine the degree to which efficiency outcomes depend on the allocation, but that there is also a likely influence of the allocation on the market circumstances. This point has been made theoretically by Liski (2001), and implicitly by Hansjürgens and Fromm (1994) who point out that under free allocation, only those allowances that firms want to sell and buy are "on the market", while under an auction, all allowances are transferred via the (auction) market. I will apply Liski's argument to the precise case of benchmarking versus grandfathering and explore more deeply the implications for firms' investment and innovation decisions.

3 Liquidity and volatility: a model describing their interdependence

3.1 Definition of liquidity and volatility

The central problem in the context of this article is named by Endres and Schwarze (1994, p. 184). On a market with a low trading volume, they claim, accidental and unique factors play a substantial role. The price signals on a "thin" market are therefore highly ambivalent and uncertain. This hampers the foresight of, and planning with, future developments and makes participants "overcautious". (translation by F.G.). A thin market is often also labeled "illiquid".

Definition of liquidity: As Rudolph and Röhrl (1997, p. 177) state, there is no unanimous use of the term liquidity; however, a common basic understanding has developed (ibid.). I use the definition of liquidity by (Schwartz 1991, p. 127): "Liquidity refers to the ability of individuals to trade quickly at prices that are reasonable in light of underlying demand/supply conditions." Harris (2003) describes liquidity as the degree of "immediacy" with which a desired trade can be executed without changing the market price (i.e., how long one has to wait) or, vice versa, how much "market impact" (change in price to one's disadvantage) one has to accept to trade a desired amount immediately. It can be split into three dimensions, again defined by Schwartz (ibid.):

> "*Depth*: A market is deep if orders exist at an array of prices in the close neighborhood above and below the price at which shares are currently trading. [...]
> *Breadth:* A market is broad if the best buy and sell orders exist in substantial volume (that is, if the orders are sufficiently large). Market impact is slight when a market has breadth.[5]
> *Resiliency*: a market is resilient if temporary price changes due to temporary order imbalances quickly attract new orders to the market that restore reasonable share values. Trades are less apt to be made at inappropriate prices when a market is resilient."[6]

The fact that I quote the statement by Endres and Schwarze together with the definition of liquidity suggests that liquidity is *identical* to trading volume. This is, however, not the case. In contrast, liquidity is the prerequisite for large volumes to take place – i.e., that large volumes can be sold or bought – without the price reacting substantially to each major trade wish. Of course, when large volumes are traded, there is a high chance that an immediate trade wish can also be performed without large market impact in the "next moment". One can therefore also interpret liquidity as something intangible, which can only be "measured" at the moment of trade execution. These notions point directly to the link of liquidity and volatility.

Definition volatility: Volatility is "expression of the degree and frequency of fluctuations" (Lattemann and Zuber 2001, p. 77) of an asset price.

The link between liquidity and volatility: The suggested link between liquidity and volatility has been outlined in the description by Endres and Schwarze at the beginning of this chapter. Schwartz similarly notes that low liquidity, together with "price discovery errors", lead to high price fluctuations. Harris, however, states that the link is not automatic and points to "uninformed traders" who cause price fluctuations, which however are corrected by "informed traders". It is not entirely clear, however, how this would "break the link" between liquidity and volatility.

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[5] Rudolph and Röhrl (1997, p. 177) apply the two terms depth and breadth the other way round, but, apart from this, appear to use the same understanding of the contents.

[6] Schwartz (ibid.) notes that not all of these dimensions are necessarily fulfilled at one point in time.

Price movements can be the result of new information, or price errors, or both. It is likely that after the arising of new information, uncertainty about the "true" price will be higher, and price discovery errors are more frequent. From the EU CO_2 (forward market) allowance price given by Point Carbon, one can get a good idea of what market liquidity can mean for volatility[7]: In March 2004, when news about the first EU Member States' National Allocation Plans emerged, prices went down from 13 Euros per ton of CO_2 to just above 8 Euros in four weeks. This occurred at low volumes compared to those traded in late September 2004, when the news of Russia planning to ratify the Kyoto Protocol emerged. The price move this time was only 15 cents up. Even though the two information changes are by no means directly comparable, the case is seen by this author as an indication of the price-stabilising effect of liquidity.

How can we measure liquidity and volatility? *Indicators* for liquidity are:

1. trading volume (since, as mentioned, it shows a high chance that liquidity will be there in the near future);
2. the "bid-ask spread": some agents work as "market makers" and offer the service of buying and selling assets at rates defined by them (Rudolph and Röhrl 1997, p. 174). Since they are bound by these rates, and must be compensated for taking the risk of purchasing a certain amount and having to resell it, the rates for purchases and sales differs. When they differ more, this is a sign of illiquidity;
3. market impacts of single observed trades.

Volatility can be "measured" as historical volatility (measuring the standard deviation of the allowance price over a past period) or as "implicit" volatility in option prices: options, which are an asset that offers to its owner the right, but not the obligation to purchase or sell an asset at a future date (see below), are the more expensive, the higher the market volatility is.

3.2 Extending the perspective to hedging possibilities and "effective" volatility

While the daily trades of the allowances themselves are done on the spot market, this market is supplemented by the forward markets. The two elementary forms of hedging on forward markets are either by means of forwards or futures, and alternatively by the use of options. Forwards or futures mean that two trading partners secure a deal for a defined allowance amount being traded at a defined date in the future for a price defined today, in advance. Thereby, both partners can be sure

[7] See the price chart for 2004 as given, for example, in the 8 October 2004 issue of Carbon Market Europe, and the market comments therein.

about the price they will pay/receive at the future date, no matter what the actual (spot) price will be by then.[8]

Still, should this spot price turn out to be more favourable for one trading partner than the forward price, he incurs a foregone profit. This foregone profit can be prevented by purchasing an option instead. Then, the buyer acquires the right to buy ("call option") or sell ("put option") a predefined amount at a predefined date (or in a time interval until a certain date). Should the market price be below the predefined purchase price of a call, the option is not used, but its owner acquires the allowances cheaper than he had done by means of a forward contract, and at the same time he had the certainty of not having to pay more than specified in the option.

Obviously, the use of such hedging mechanisms can substantially reduce the risk from price volatility, and thus reduce "effective" volatility as it is felt by the participating firms. However, this use is costly, and it is likely that the costs will be higher when the market is illiquid. Therefore, and central to this paper, the costs of hedging are, in part, endogenous to the market uncertainty itself. As a result, design variants may exert an influence also on hedging costs. First, as for options, it is evident that these are more expensive under illiquid and volatile markets, since the sellers of the options - who often have to acquire the allowances that they pledged to deliver on the spot market when the option is exerted - need to be compensated for the higher risk on less liquid (and/or more volatile) markets.

For forwards and futures, the point of higher costs when liquidity is low is more complex. First, as Endres and Schwarze (1994) and Stavins (1995) note, transaction costs, e.g., search costs, are higher on illiquid markets, and this is likely to apply to forward trades, too. The number of "middlemen" (Liski 2001) such as brokers or exchanges, who can reduce search costs, is likely to be higher under a liquid market (ibid.).[9] Secondly, the credit risk of counterparties failing to deliver is regarded an important issue (see Byers 2004), not least for forward trades. The fact that anonymity is valued high appears to aggravate this problem. Exchanges or clearing houses often bear the credit risk (Hansjürgens and Gagelmann 2004). However, they require a high trading volume to run profitably, making use of economies of scale (Betz 2003). In sum, there appear to be several positive feedback trends.

A further factor is the question how many years forward contract markets cover. As a tendency, the market gets more illiquid the longer the time span con-

[8] The difference between forwards and futures is that the latter are traded at exchanges, and traders need to be registered and submit an "initial margin" that is adjusted daily according to the spot market price.

[9] Liski does not mention explicitly why more intermediaries would enter the market when it is more liquid. Two explanations are plausible: first, the intermediaries incur economies of scale. This can be seen quite clearly from the cost estimations for an exchange in Betz (2003, p. 247 f.), which shows that it requires a minimum trade volume to run profitably. Second, intermediaries can - apart from matching trades on behalf of other actors – also trade on their own behalf. The thicker (more liquid) the market, the lower the risk of incurring a loss due to low liquidity and/or high volatility (personal information Stefan Ulreich, E.on, 10 May 2004).

cerned (see for example Evolution Markets "Monthly Market Updates" on the Acid Rain Program or the NO_X Budget Program for illustrations).

Finally, both Liski (2001, p. 296 f.) and Janssen (2003) point out that *expectations* of low trading levels/liquidity can affect the firms' plans to rely on the market and enhance their tendency to rely on internal compliance instead. This reduces their sale or purchase levels and thus leads to a "self-fulfilling prophecy". These points are summarised in the following figure 1.

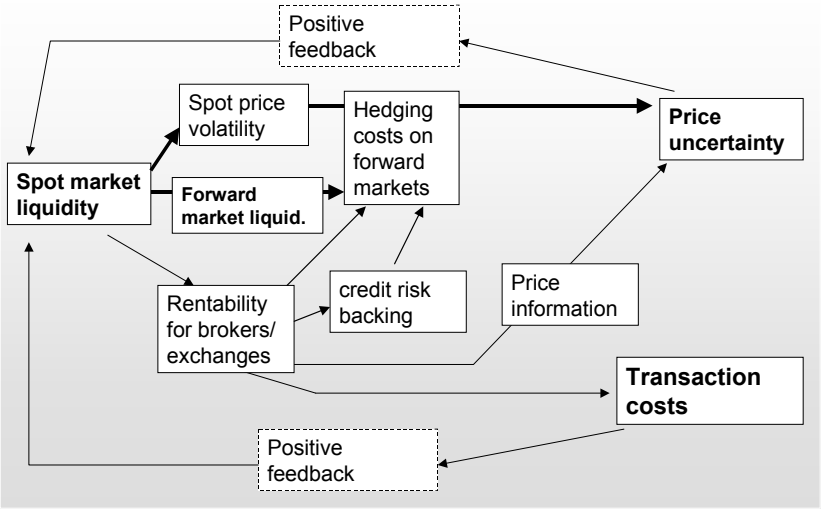

Fig. 1. A model of the interdependence of liquidity, hedging, volatility, and market intermediaries
Source: Own illustration

4 A conceptual framework

How can primary allocation and banking provisions influence firms' investment decisions under allowance market uncertainties?

Under perfect information about the future allowance market or if they were risk-neutral, firms would base their abatement decisions – including investment and innovation decisions – entirely on the known allowance price (or, in the case of uncertain values but risk-neutrality, on expectation values). However, as noted in sections 1 and 2, uncertainties about market liquidity and price volatility are likely to have some impact on firms' investment and innovation decisions. Since this is the case, an investigation of the investment and innovation effects of the two allocation methods grandfathering and benchmarking must – firstly – incorporate the effect which they have on market liquidity and price volatility. Secondly, the precise effect of liquidity and volatility on firms' decisions must be explored. These two steps work out the "indirect" effect by a two-step approach. Thirdly,

and most complex, the two allocation methods may lead to different "direct" impacts on the decisions under allowance market uncertainty – that is, decisions under uncertainty may be different under benchmarking from those that would be taken under grandfathering. The investigation therefore involves three steps, which are illustrated in the following figure 2.

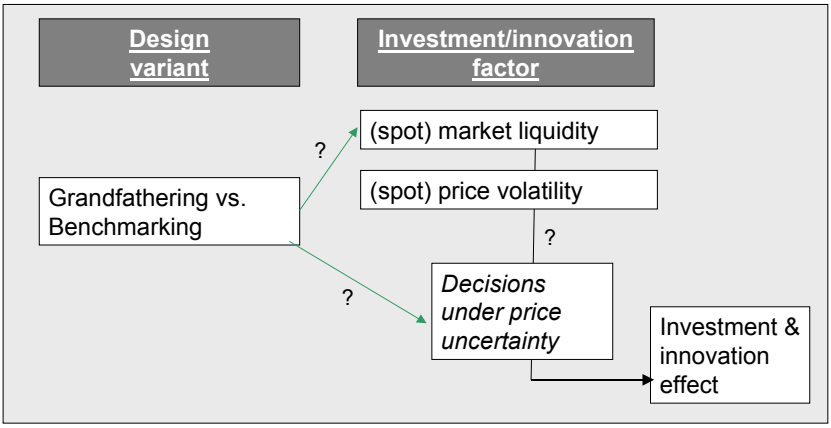

Fig. 2. Concept of the analysis
Source: Own illustration

5 Primary allocation and allowance market liquidity

Which factors influence trading volume and liquidity? Next to the differences in marginal abatement costs between the participating firms, which determine the degree of their market activity for compliance reasons (and therefore are likely to stimulate speculator' activities, which increase market volume further), another factor for trading volume is the difference between the allocated allowances and the allowances "needed" for compliance by each firm.

Liski (2001) suggests that a primary allocation which is very close to the "final allocation" in equilibrium (i.e., the allowance holdings when all profitable trades have been conducted, so that firms' marginal abatement costs are equalised), requires relatively little trading. It therefore will result in a thinner (less liquid) market than a primary allocation which leaves much to trade. This is of high importance for all free primary allocation methods since, as noted before, only spare and needed allowances enter the "secondary" market, i.e. the trading between firms or between brokers and firms.

Liski's consideration is general and has to be applied to "real world" primary allocation methods. It is applied here to the comparison of grandfathering and benchmarking. I use a graphical model with numerical examples and with two groups of firms, A and B. All firms in group A and all firms in group B are assumed to be identical, and firms in group A differ from those in group B only in terms of their abatement cost curve – group A firms have lower marginal costs.

All firms are assumed to have identical production output (to abstract from complications resulting from size differences).

Figure 3a illustrates the case of grandfathering under a cap that is equal to firms' historical emissions (i.e., no emission reduction is required in this case). This is a plausible assumption for the CO_2 markets' introductory phase and can be found in the great majority of National Allocation Plans 2005-2007 of the EU Member States (see European Commission DG Environment homepage). The marginal abatement cost (MAC) functions – which are modelled as increasing in the abatement level and parallel between A and B – are plotted on the y-axis against the abatement level on the x-axis. The line "e=0" denominates 100% abatement (zero emissions). As can be seen, under grandfathering, no trade occurs since every firm receives as many allowances as it needs.

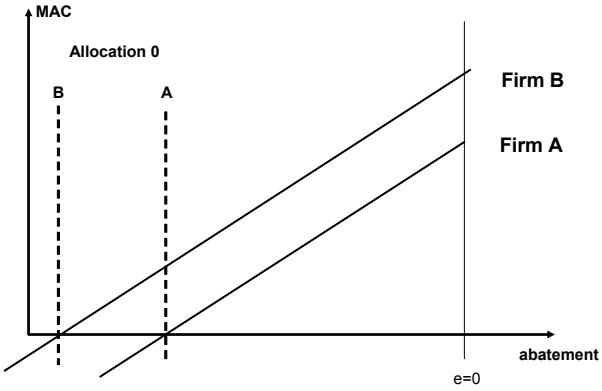

Fig. 3a. Trading volume with grandfathering and a 0% emission reduction cap
Source: All figures in this chapter are own illustrations

With benchmarking, firms A have spare allowances which they sell to firms B. No additional abatement occurs in this case, but some trading takes place (Figure 3b).

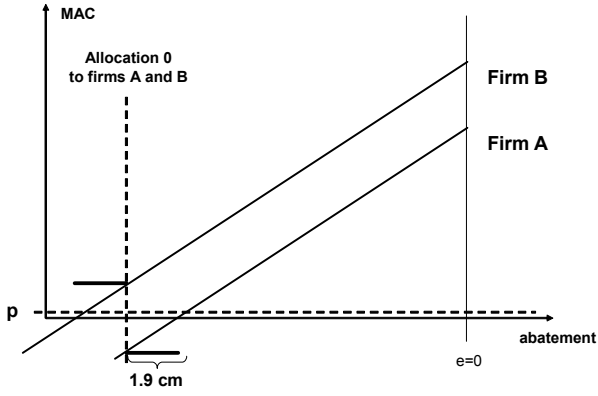

Fig. 3b. Trading volume with benchmarking under a 0% emission reduction cap

What happens when targets are tightened by the regulator? The answer depends on the type of abatement chosen by the firms, which in turn depends, in part, on the reason for why the efficient firms had undertaken their early emission reductions in the first place. In the following I will present several cases.

The first case is abatement on the same abatement cost function; this means abatement using the same equipment and not investing in new equipment (which would shift the MAC curve down). Abatement with the same equipment can be done, for example, by using existing abatement installations more intensively – an option not currently available for CO_2 reductions since no economic end-of-pipe options exist –, by changing fuels (where possible), by undertaking organisational changes[10], or by reducing production.

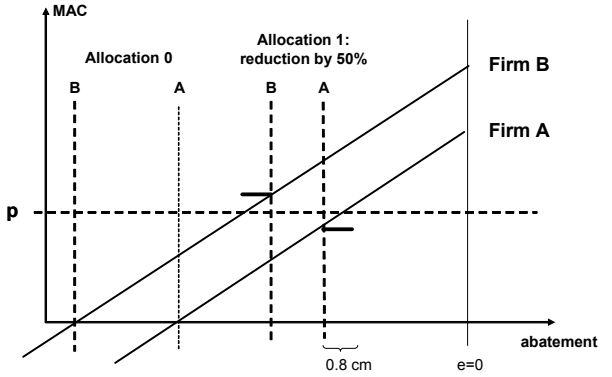

Fig. 4a. Trading volume with grandfathering under a 50% emission reduction cap and both firms A and B using the existing equipment

One can see that abatement and trading takes place. However, figure 4b shows that still more trading occurs under benchmarking.

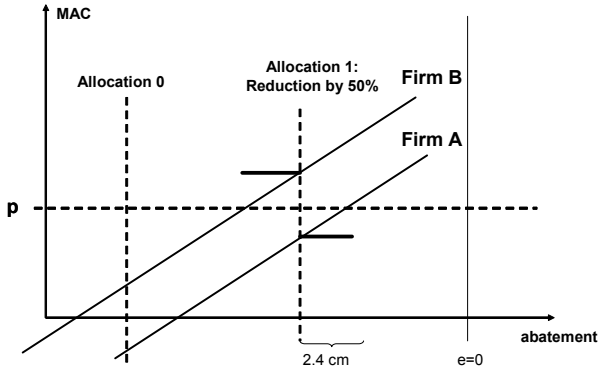

Fig. 4b. Trading volume with benchmarking under a 50% emission reduction cap and both firms A and B using the existing equipment

[10] Burtraw (2000) and Swift (2001) show the importance of abatement through organisational changes in the U.S. emissions trading schemes covering SO_2 and NO_X.

I now incorporate equipment change, i.e. downward shifts of the MAC curves. The first case would be that both firms purchase new equipment and accordingly reduce their abatement costs, but that firms A still abate cheaper than firms B. Then benchmarking still stimulates more trade, since the qualitative relations between firms A and B in terms of abatement costs and allocation are the same as in figure 4.

The second case would be that both groups choose the same new technology equipment, and abatement curves are identical. Then no trading occurs under benchmarking, while trading occurs under grandfathering, since both firms have the same abatement costs but receive different allocations. The difference is not, however, as large as the difference in favour of benchmarking in the settings stated before.

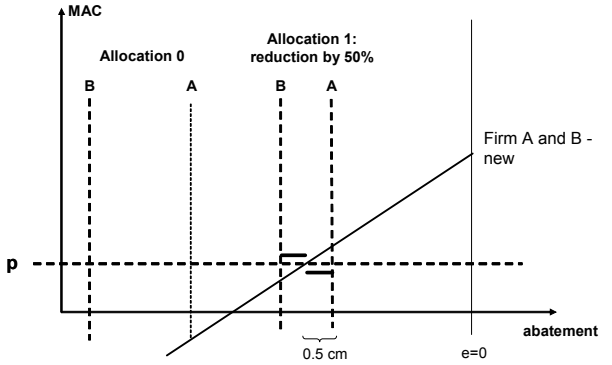

Fig. 5a. Trading volume with grandfathering under a 50% emission reduction cap and both firms A and B using the same new equipment

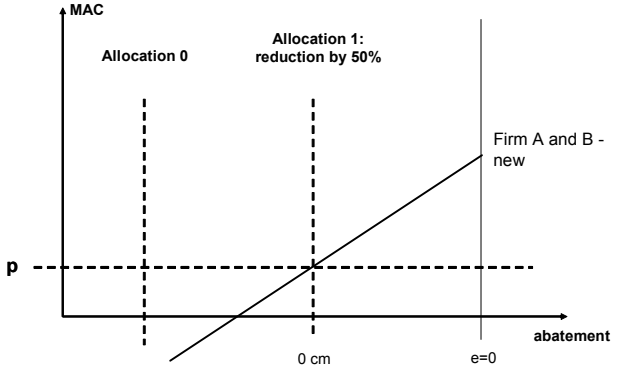

Fig. 5b. Trading volume with benchmarking under a 50% emission reduction cap and both firms A and B using the same new equipment

The third case is that firms B choose a new technology while firms A do not purchase new equipment and keep their abatement function (Figure 5). This case is plausible for the following reason: especially in energy intensive industries, it is

often claimed that new technology is "embodied" in the production equipment (see, e.g., Letmathe and Wagner 2003). In other words, later "vintages" of equipment "automatically" embody a more efficient technology. So far, I have not discussed why firms A would instantly have lower abatement costs. The reason can be that they have recently invested in new production equipment, which is more efficient than the older equipment of firms B. Since B's equipment is older (and possibly "written off"), they are more apt to purchase new equipment because their saved energy costs and allowances are greater than for firms A. In this case, and if the MAC difference between A and B is exactly reversed, grandfathering results in a slightly higher trading volume.[11,12]

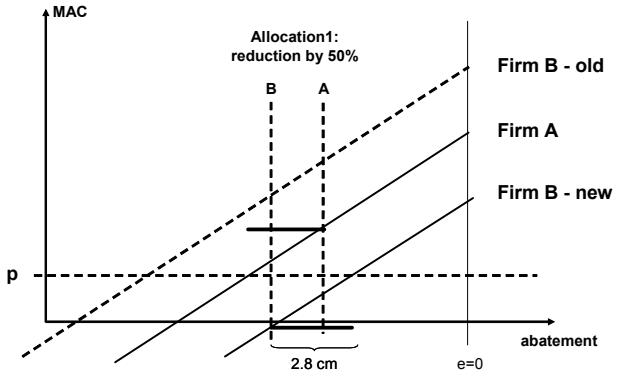

Fig. 6a. Trading volume with grandfathering under a 50% emission reduction cap and firms B using new equipment

[11] It could be suggested that equipment changes be modelled not by a shift *of* the MAC curve, but instead by an upward move *on* the MAC curve. In the latter case, however, one would i) not differentiate between those abatement options involving equipment change and those not involving equipment change, ii) treat all abatement as being the same in terms of technical progress. In this way, one would not incorporate the fact that some equipment changes have lower MAC than other options and that technical change is often "embodied" in new equipment. First plausibility considerations indicate that modelling shifts *on* the MAC curve yield the same results as those presented here.

[12] McHugh (1985) points out that single abatement techniques often do not represent a continuously differentiable MAC line, but rather a very short MAC line, i.e., a short range of combinations of cost and abatement level which is determined by the characteristics of the abatement technique. In this way, when maintaining the modelling concept of downward MAC shifts to incorporate technical progress, one would have to represent the option to use different new models of equipment as several short lines which all lie below the MAC line of the old equipment and can be linked to form themselves a kind of new MAC line: A new power plant with 47% generation efficiency is plausibly more expensive than one with 44%. Furthermore, through these MAC points, several MAC lines run which represent other abatement options possible with this technique. Before an equipment choice is made, a firm can select between several of the MAC lines; afterwards only changes on one line can be made.

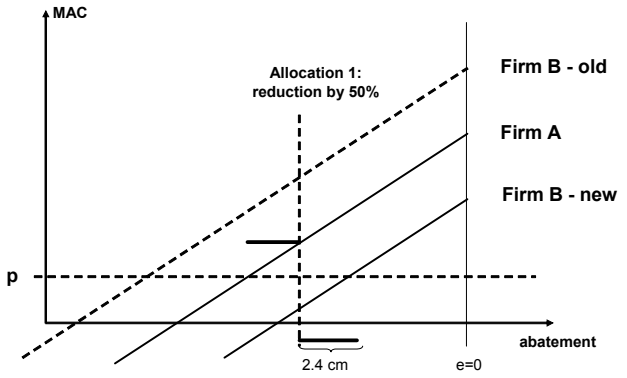

Fig. 6b. Trading volume with benchmarking under a 50% emission reduction cap and firms B using new equipment

The trading amount increases when the cost difference in favour of B with the new technology increases. One can show that the results in figures 5 are robust for other, e.g., tighter reduction caps such as 70%.

Can we draw a general conclusion from these findings? I have described and illustrated before why the allowance market may well be subject to positive feedback and "self-fulfilling" prophecies regarding liquidity. If this is the case, the first year(s) of an emissions trading scheme could have an impact on its long run functioning, too. The question is, then, whether firms B invest already at the beginning, or whether they wait for some years. Reasons for them coming in later could be a very close timetable for the introduction of the trading scheme (as was the case for the EU CO_2 system), and/or the desire of firms to "wait and see" how the market (and the allowance price) develops before investing. This behaviour can be explained by real option theories and is the more relevant, the more uncertain the future becomes. Emissions trading is a completely new policy instrument which the firms are confronted with, and uncertainties are therefore considerable.

6 Firms' decisions under allowance price uncertainty

6.1 Analysing the basic effects

In chapter 3, I have derived the link between allowance market liquidity and allowance price volatility. Here, I describe how risk-averse firms may react to price uncertainty.

If investment is irreversible and firms are risk-averse, firms who consider undertaking an activity which would result in spare allowances will compare their marginal abatement costs with a lower (fictitious) allowance price than its expected value, thereby applying an implicit risk premium. Figure 6 illustrates this. In this figure, for illustration purposes I assume both firms A and B to have differ-

ent MAC functions, but the same abatement level before trading starts ($\hat{e}_A = \hat{e}_B$).[13] Firm A and B expect an allowance price of E(p). Under certainty or risk neutrality, firm A would abate according to the long bar and sell this amount to B. But when A is risk averse and the price is uncertain, it applies a risk premium, which in this graph takes the form of a "minimum" price which the firm expects to occur with a high certainty. This could, for example, be a price that resembles $^2/_3$ of the expected standard deviation downwards. When A calculates its abatement level according to such a price, it abates less than under certainty (the short bar). Companies B act analogously but compare their marginal abatement costs to a higher fictitious allowance price than the expected value and abate more than under certainty. They purchase fewer allowances than they would under certainty.

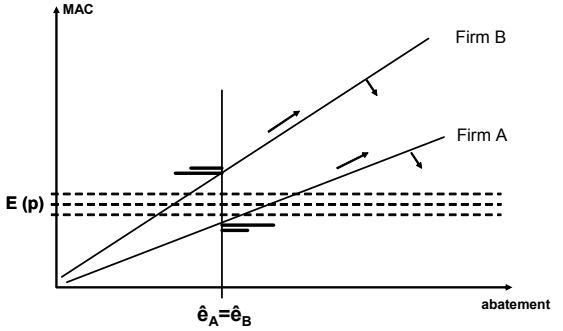

Fig. 7. The impact of risk aversion on abatement and trading
Source: Own illustration

Ben-David et al. (2000) have made this point formally. On an aggregate level, they note, allowance supply will be reduced, but so will demand. In other words, the supply curve as well as the demand curve shift to the left. Figure 7 illustrates this point. That is, when participants expect high price volatility, then reduced trading volume can be expected.[14] This is in accordance with the suggestions made in section 3.

[13] This could be, for example, due to higher product revenues and higher production for firms B.

[14] The overall effect on the allowance price depends on the precise demand schedules as well as the strength of the reactions, which in turn depend on the firms' different risk propensities (Ben-David et al. 2000, p. 593).

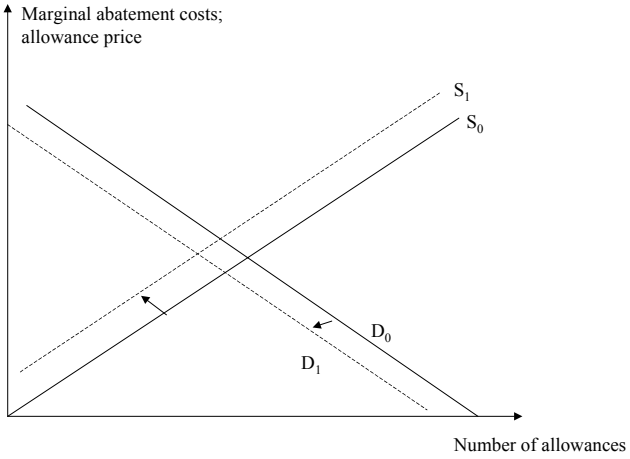

Fig. 8. Aggregate trading effect of risk-aversion
Source: Own illustration following the argument by Den-David et al. (2000)

I now discuss in three steps the prospective consequences for total abatement, investment and innovation.

Overall abatement effect: Under emissions trading, total emissions must be the same with risk-averse firms as with risk-neutral ones, since the overall cap has to be met in both cases.[15] Individual firms may contribute different "shares" under the two circumstances, however.

Overall investment effect: The overall investment effect is more complex: If all abatement would come by investments, then risk aversion should not be able to affect overall investment. However, abatement can also be done by "reversible", non-investment options: by using existing abatement installations more intensively, by changing fuels (where possible), by undertaking organisational changes or by reducing production. It is likely that such non-investment abatement makes up for a significant share of total abatement at least in the first years - and therefore overall investment is lower. An important reason for this is real option values (see Dixit and Pindyck 1994; Herbelot 1994) accruing from the delay of irreversible investments.

Overall innovation effect: The innovation effect is the third and most complex consideration. To the extent that innovation is regarded as investment driven (either in research and development or in acquiring equipment with new or advanced

[15] This would change if banking or borrowing is allowed. Borrowing, i.e., exceeding today's emissions beyond the cap and pledging to make up for the gap in the next period (usually in combination with handing in additional allowances as "interest") could lead to less or more abatement in the first years, probably to less abatement (since firms with the most irreversible components of abatement wait, leading to overall lower abatement). Another exception would be if banking, i.e., saving allowances for later use, were allowed, because then participants could either run down their banks from previous periods, keep them in store, or build up new banks, and they might show a different behaviour in this respect under risk aversion compared to risk neutrality.

technology), less investment should also mean less innovation. An exception might be such innovations that do not involve (major) investments, and instead occur in organisational changes, fuel shifts, and potentially a higher utilisation of existing equipment. From Burtraw's (2000) and Swift's (2001) descriptions of the Acid Rain Program and the NO_X Budget Program, one can draw the conclusion that this is exactly what happened.

A second consideration is firms being differently capable or willing to invest in advanced technology equipment or in R&D, and differently prepared to accept risks on the allowance market. More specifically, larger firms participating in a tradable allowance scheme can be suggested to be more "innovative" in terms of R&D expenses and/or technology adoption than smaller participating firms, and also to act less risk-averse and use the market more intensively (for example, due to higher resources for continuously monitoring the market). These arguments appear to be supported by empirical findings. Firstly, empirical evidence in general lends support to the notion that larger firms are quicker technology adopters (see Geroski 2000, p. 612). In addition, interviews, which I conducted in the USA for experiences under the Acid Rain Program and NO_X Budget Program, revealed the suggestion that smaller participants perform little or no R&D, and that they started later to actually use the allowance market as a compliance tool.

Under these assumptions, one can derive the following two conclusions:

- smaller firms are likely to be primarily buyers. They abate and (potentially) invest more when the price uncertainty is higher in order to reduce their reliance on the market;
- since the technologies that the smaller firms apply tend to be relatively less innovative.- the larger firms, who invest less than under certainty, would have used more innovative technology - the overall innovation level under higher price uncertainty is lower than under price certainty.
  This proposition, however, has to be verified, for example by analysing German companies' R&D investments and their equipment purchases.

6.2 Including direct effects of grandfathering and benchmarking on firms' decisions under uncertainty

With regard to direct effects of grandfathering and benchmarking on firm's decisions under uncertainty only preliminary suggestions can be given here. Lambie (2002) investigates the differences in firms applying real option values under a situation where they receive allowances for free and where they have to purchase allowances. While his investigation is made to analyse the potential impact for "new entrants" (i.e., when they have to buy on the market versus receiving a free new entrants reserve), it can also be transferred to grandfathering versus benchmarking. Lambie finds that investment will be slower (due to real option values) when the firm has to purchase allowances, compared to when it receives them for free. He does not explicitly address the case of a firm receiving more allowances than it needs (at present), as is the case for some firms under benchmarking. Still,

if Lambie's finding holds, those firms under benchmarking that have to buy allowances will retard their investment. Since, as noted above, the overall cap is fixed, the abatement has to take place by non-investment abatement or by other firms abating more. The question is now whether one can theoretically derive the real option value impact of receiving more allowances than needed – whether or not it makes a change, as opposed to receiving one's need exactly.

7 Conclusions and further research questions

An initial and tentative conclusion is that benchmarking is more conducive to a liquid market in the first years and, therefore, influences a firm's expectations about the future market development, including volatility. This liquid market is more conducive to such abatement that is connected to investment, and plausibly to innovation. The following issues still need to be investigated more deeply:

- whether the link between liquidity and volatility is as one-dimensional as described in this paper, and, if not, when it does not hold;
- whether there are other - institutional - market arrangements that can increase liquidity and/or reduce price expectation/price discovery errors;
- analysing Lambie's investigation further as to whether grandfathering and benchmarking differently affect investment and innovation decisions under uncertainty;
- and potential differences in the real option values regarding the reasons for, and nature of, the price shocks (i.e., to what extent allowance demand and supply fluctuations are mean-reverting processes); and whether such considerations are relevant only for the real option value, or also for risk premiums resulting from risk aversion.

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Part B

Investment and corporate decisions

Studying the effects of CO_2 emissions trading on the electricity market: A multi-agent-based approach

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Abstract

In this paper, we present a basic approach for modeling electricity and emissions markets under the paradigm of agent-based computational economics (ACE). Different market players will be modeled as independent entities using autonomous software agents; they operate and communicate independently on power markets and on markets for emission allowances. The agent types involved and their relationships are described. The aim of the model is to investigate the interplay between the market players, with a focus lying on the dynamics in a market for CO_2 emission allowances and its effects on the electricity markets. Simulations with this model will enable us to draw conclusions about the economic performance of different possible emissions trading design options.

Keywords: Agent-based computational economics (ACE), liberalized electricity markets, multi-agent-based simulation, emissions trading, CO_2 allowance markets

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1 Introduction

The EU-wide emissions trading scheme, which started at the beginning of 2005, constitutes a new challenge for power generators and other players in the electricity market. The introduction of a price on CO_2 emissions will change the merit order of power plants, as well as long-term investment decision patterns, resulting in a shift in power production structures. Participants in the power market will react differently to these new market conditions. Each actor has varying starting conditions, as well as an individual willingness to innovate and to take risks. Accordingly, each market player develops his own strategy. The actors will learn from their experience gained in the market and dynamically adapt their strategies in order to maximize their individual profits and to enhance their market positions. The resulting actor-specific behavior is decisive for the development of power markets under an emissions trading scheme.

As a consequence of the distributed structure of these processes of change, it is difficult to predict the outcome that can be expected from the emissions trading scheme in terms of innovation, transformation in power production structures, and new emissions situations. Thus, new methods of modeling and simulating power and emissions markets are required in order to understand market dynamics and the respective decision-making structures. A new approach for addressing distributed problem solving processes of that kind is agent-based computational economics (ACE), in which multi-agent systems (MAS) are applied. MAS originate from the research field of distributed artificial intelligence (DAI) and are increasingly applied in economic research for coordination and simulation problems. The special features of software agents make it possible to model decentralized, distributed problem solving processes. Multi-agent-based simulation, thus, constitutes a promising approach for addressing market coordination problems.

In this paper, we present a basic approach for modeling electricity and emissions markets under the paradigm of agent-based computational economics. The paper is organized as follows: section two gives a brief overview of the basic concepts of software agents, multi-agent systems and agent-based computational economics. In the third section, the first steps in modeling a multi-agent-based simulation of the German electricity and emission allowance markets are described. A closer look is taken at the emissions trading part of this model, focusing on representation of the allowance trading process and its implications for power plant investment decisions. The fourth section gives an outlook on the expected outcomes of the model implementation, and finally section five concludes.

2 The multi-agent approach

The field of autonomous agents has been a fast growing area of software technology development in recent years. In the meantime, the technology is converging with other branches of software development, such as Peer-to-Peer networks (Grasmugg, Schmitt, Veit 2003) and web services (e.g. Burg 2002). Another ap-

plication of software agents is an emerging type of bottom-up simulation, in which multi-agent systems are applied for the computational study of complex systems. This section gives a brief overview of the agent-based simulation paradigm and introduces its constituting concepts.

2.1 Software agents and multi-agent systems

As the applications for software agents are manifold, there is no standard definition of what actually constitutes an agent. However, many attempts to specify characteristics of software agents exist. Jennings and Wooldridge (1996) define some key characteristics that multifarious software agents have in common; these are: autonomy (agents require no direct intervention from humans or other agents), social ability (ability to interact with other software agents and humans), responsiveness (agents are able to perceive their environment and respond to changes which occur in it), and proactiveness (ability to exhibit opportunistic, goal-directed behavior and to take the initiative). In their comparison of different agent approaches Fraenklin and Grasser (1997) propose to classify agents according to the properties that they exhibit, of which they regard four (reactive, autonomous, goal-oriented and temporally continuous) as obligatory. The other properties (communicative, learning, mobile, flexible, and character) are supplementary characteristics that produce potentially useful classes of agents for various tasks.

When a set of software agents act in a common infrastructure, this ensemble can be referred to as a multi-agent system (MAS). The interaction of the autonomous agents might take the form of cooperation, of competition, or of some combination of both. Decision making in a MAS is processed at the level of each single agent, without any central control unit deciding on the agents' actions. Likewise, knowledge about the state of the world in a MAS is stored in a decentralized manner and each agent collects individual information according to its perception and interpretation of the environment. In addition, multi-agent systems may provide some protocols and languages for the agents to communicate with each other. This enables them to send and receive messages, e.g. for the purpose of negotiation or participation in an auction. In the following, we will concentrate on MAS used for simulation, or more precisely for economic simulation. For a more general overview of multi-agent systems the reader is referred to a concise and detailed introduction provided by Vlassis (2003).

Multi-agent-based simulation uses the aforementioned concept of software agents for modeling individual behavior of specific individuals constituting the real-world system to be analyzed, e.g. a market, a society, or the electric power industry. The emerging structure from a repeated interaction of individual autonomous agents in the simulation system is in the centre of interest for the modeler. By explicitly modeling individual choices and social interaction, agent-based simulation can be more flexible and responsive than alternative modeling methods. The application areas of agent-based simulation are manifold and range from the analysis of social structures and institutions over physical and biological systems to all kinds of software systems (Luck, McBurney, Preist 2003).

2.2 Agent-based computational economics (ACE)

The agent-based bottom-up analysis of economic systems constitutes the new research field of agent-based computational economics, which is a promising approach for complex economic research questions such as the interaction of markets for emission certificates and electric power markets. As Tesfatsion (2003) puts it, "Agent-based computational economics (ACE) is the computational study of economies modeled as evolving systems of autonomous interacting agents." This approach enables the modeling of learning effects and a relaxation regarding the strict assumption of many conventional models (e.g. perfectly rational players, perfect information or symmetry of knowledge, static environment, equal size of firms). It facilitates the analysis of how global regularities result from the repeated local interactions of self-seeking autonomous agents that represent individual players in the studied economy. ACE models also offer the possibility of testing alternative structures and market designs ahead of their introduction into the real-world economy. They can, thus, serve as experimental venues for market designs or political instruments and help to derive conclusions about market results under different environmental conditions without changing the real-world settings. These derived findings set the basis for qualified recommendations that help companies, regulatory authorities, customers or other market participants to best use/design the market in their interests.

The ACE approach has been applied to many fields of economics, such as entertainment and automated internet exchange systems, financial and electricity markets, labor, retail and business-to-business markets and markets for natural resources (Tesfatsion 2003). For the case of ACE research on electricity markets, many studies focus on the question of market power and price formation in restructured electricity markets (Bower, Bunn 2001; Bunn, Oliveira 2001; Day, Bunn 2001; Koesrindartoto, Tesfatsion 2004; Nicolaisen, Petrov, Tesfatsion 2001; P. Visudhiphan, Ilić 2002). Others use MAS as experimental venues for policies and market mechanisms for power markets (Atkins et al. 2004; North et al. 2002), or concentrate on the general design and the agent architecture, or on learning techniques for agent-based power market simulations (Bagnall 2004; Koesrindartoto 2002; Richter, Sheblé 1998).

3 A multi-agent electricity and emissions market simulation model

In the following, an agent-based model for simulating electric power markets and markets for CO_2 emission allowances will be presented. This bottom-up model uses and develops methods from agent-based computational economics and is constantly developed within the PowerACE project[1].

[1] For details see www.powerace.de

Electricity systems are formed by many players, each carrying out different functions along the electricity value chain. Vertically integrated power companies or holdings, such as utilities, unite several of these functions, e.g. generation, distribution, and the trading of electricity, as well as the provision of energy services and electricity supply for end-users. In order to manage the complexity of the simulation model and to keep track of the impact of the agents' decisions upon the market outcome, some effort is advisable to keep agents simple. Thus, in our model market, players are represented by a set of one or more simple agents, each of which is designed to carry out one function in the power market. These functions include, for example: producing electricity, operating an auction for power reserve procurement, bidding or negotiating in different power markets, and buying or selling emission allowances. In order to represent a company that unites several market functions, the single agents constituting this company are able to exchange preferential information with each other, thus forming an entity.

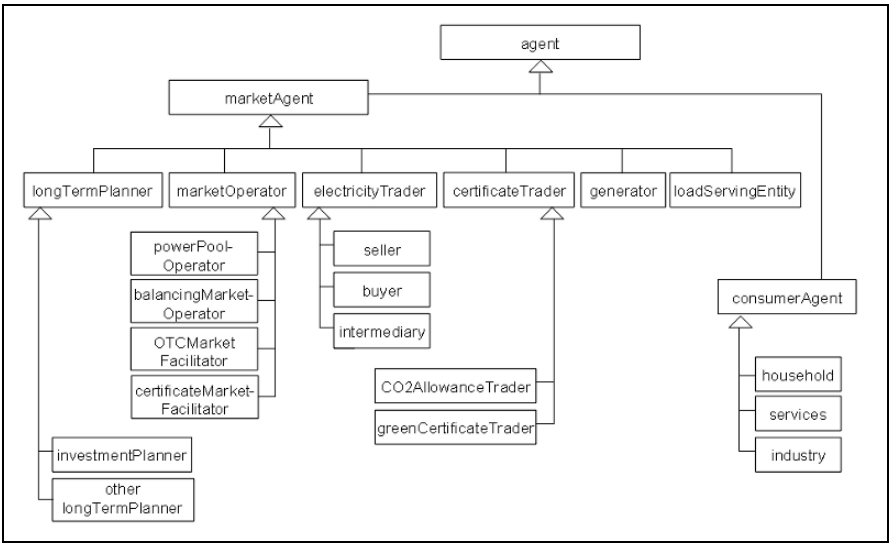

Fig. 1. Model structure

The use of inheritance concepts of object-oriented programming languages leads to the following agent structure that groups similar agents to suitable categories. The abstract agent class, as depicted in Figure 1, defines basic attributes and methods characterizing every agent of the simulation model. These are the representation of knowledge about the environment, the learning algorithm, and communication protocols. More specific categories of agents acting on power and emission allowance markets are specified in subclasses of the basic agents. The types of agents defined in the PowerACE model include

- generators, who run one or more power plants and are responsible for the unit commitment; they determine a price range for the bids that "their" traders place on different markets;

- load serving entities, who serve the load for their customers (consumers) and purchase required electricity on the markets via "their" traders;
- electricity traders, who bid on several power markets[2] either on behalf of their company or as autonomous intermediaries;
- long-term planners, e.g. investment planners;
- market operators, which can take the roles of pool, balancing market, or bilateral market operators;
- certificate traders, i.e. traders for CO_2 emission allowances or for green certificates;
- consumer agents with the subcategories households, service companies, and industrial consumers.

The simulation model is currently implemented with Java and RePast[3], a free open source toolkit specially developed for agent-based social simulations (for a comparison of RePast with other agent-based simulation toolkits, see Tobias, Hoffmann 2004).

3.1 Considered markets and scope of the simulation model

The PowerACE model considers both short-term and long-term aspects. On a daily level, the supply and demand side can trade electricity on a spot market and on balancing power markets (for minute reserve) by submitting bids to the respective daily auctions. The implemented spot market is geared to the spot market concept at the European Energy Exchange EEX. Similarly, the balancing power markets are implemented according to the market concepts that are in place in the different balancing zones. These procurement auction markets are operated by the local transmission system operators, who simultaneously appear as the only buyers, each in their balancing zone. In Germany, there are currently four balancing zones operated by RWE Transportnetz Strom, E.ON Netz, Vattenfall Europe Transmission, and EnBW Transportnetz, respectively.

Agents also have the possibility of trading electricity via bilateral contracts. These can cover both intra-day trading and medium or long-term forward contracts. Bilateral trading can be represented as a black board where buyers and sellers can post bids for a specified amount of electricity, and for certain contract durations. However, the realistic representation of bilateral trading and matchmaking in forward trading is still subject to further research.

Besides electricity markets, the PowerACE simulation model also represents markets for CO_2 emission allowances. As the issue of emissions trading, as well as the interplay between emission allowance markets and power markets, is a focus of interest in the model, these markets will be described in more detail in the next section. In a further stage of the model implementation, other markets and configurations, such as market-based instruments for the promotion of renewable en-

[2] See section 3.1 for the considered markets

[3] Recursive porous agent simulation toolkit; http://repast.sourceforge.net

ergy sources via Green certificates, can be included into the simulation. Figure 2 gives a recapitulating overview of the different markets within the described model.

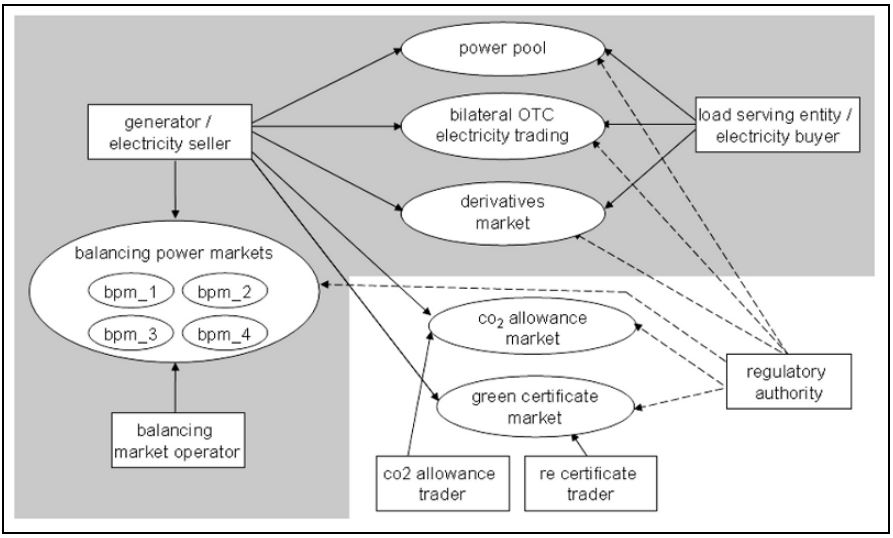

Fig. 2. Markets covered by the PowerACE model

The system's boundaries are defined as the limits of the German national power market. Electricity generation and demand in neighboring countries are represented as aggregate supply and demand functions. The long-term perspective of the described model will comprise capacity expansion, plant decommissioning, and merger. These decisions are left to the long-term planner agents who obtain the necessary information for their decisions from the agents acting on short and medium-term markets and from the environment.

3.2 Representation of emissions trading in the simulation model

An important part of the implementation of emissions trading is the provision of a market platform where CO_2 certificates can be traded. Some companies have started to operate trading platforms that facilitate CO_2 allowance trading, each with different market concepts; examples are the European Energy Exchange EEX[4], the Energy Exchange Austria EEXA[5], the Climex platform provided by New Values[6], or the allowance exchange platform jointly announced by the French Powernext, Euronext, and Caisse des Dépôts. However, it is yet unclear how emission allowances will be traded, whether other platforms will be intro-

[4] http://www.eex.de
[5] http://www.exaa.at
[6] http://www.climex.com

duced in the course of the first trading period, and which trading forms will prove most successful. Therefore, different designs of allowance markets will be tested with the help of the described simulation model, and evaluated with regard to their respective market performance, the market outcomes, and their impact on the electricity markets.

Following the approach used in the emissions trading simulation SET UP, carried out by the Fraunhofer Institute for Systems and Innovation Research, the University of Karlsruhe and Takon GmbH (Schleich et al. 2002), the CO_2 market will be implemented as a double-auction with closed order book and uniform price calculation, where trading takes place twice per year. Bids for buying or selling CO_2 emission allowances in these auctions consist of the set of specifications: {*buy/sell price, quantity, period*}. The *price* value sets the maximum (minimum) price that a buyer (seller) is willing to accept for the specified quantity of allowances to be traded. For the case where forwards on allowances can be traded, the year for which the traded allowances should be valid is defined in the specification *period*. All other trading conditions (e.g. the authorization of banking) correspond to the real-world emissions trading design as described in the national allocation plan for Germany.

In order to deal appropriately with the newly introduced emissions trading scheme, electricity market players may have established emissions trading departments within their companies, or leave this task to another trading department. In the presented model these departments are represented by the *CO_2AllowanceTrader* agents. The allowance traders are characterized by their respective initial endowments and their total emissions in the base year. During the simulation, they have to be able to carry out the following methods: determine the deficit/surplus in the emission budget, calculate short term emission abatement costs, forecast prices for CO_2 emission allowances, generate bids for buying or selling allowances, and adapt the bidding strategy according to trading results (learning). Each allowance trader agent is characterized by individual initial attribute values. Non-energy companies that are within the scope of the EU emissions trading scheme are represented in an aggregated manner over industry sectors.

An important consequence of CO_2 emissions trading is the effect that certificate prices have on trading strategies. On the level of electricity trading, the cost for emission allowances is likely to increase bid prices and affect the merit order of power plants for dispatch. This rise in prices depends on the bidding strategies and on the power plant portfolios of the individual market players. These effects are one aspect to be examined through the described simulation model.

As far as the long-term level is concerned, the additional cost of CO_2 emissions alter the projected cash flows of investment alternatives as compared to a case without emissions trading. In order to account for this cost in investment decisions, the long-term planner agents request information about allowance prices and price projections from their associated CO_2 allowance traders. Having knowledge about different investment alternatives and being able to calculate the respective due emission payments associated with these alternatives, the long term plan-

ner can then make investment decisions that appropriately include CO_2 emission costs.

4 Expected results

The main goal of the described project is to provide a simulation platform which can be used to test the impact of different market designs and policy measures on market outcomes and the development of the electricity sector. This implies that the agents' strategies in the simulation model realistically represent the real-world agents' actions. Thus, the trading strategies developed by the software agents in the simulation have to be carefully monitored and validated. When the strategies can be considered realistic for a base case, different market designs can subsequently be tested and compared for deriving conclusions to the research questions that are treated.

For the analysis of markets for CO_2 emission allowances, an interesting question is whether the agents in the simulation find the cost-efficient solution, i.e. an allowance allocation after trading that equals marginal abatement costs for all participating CO_2 emitters. In a further step, an important question to be answered is which allowance market design leads to what quantitative market outcome. The underlying hypothesis of this question is that the market outcome (e.g. efficiency, profit allocation, overall emission reduction costs) depends on the design of the market for emission allowances. In this stage, we apply the market engineering approach for a structured design of electronic (allowance) markets, as described in (Weinhardt, Holtmann, Weinhardt 2003) and (Neumann 2004).

In an allowance market with high initial allocation, as this is the case for the first (2005-2007) phase of the EU emissions trading scheme, liquidity can be expected to be low. Here, simulation results should show whether this is the case, and what consequences this entails for price formation. Another issue in this context is the fear that some agents may be able to influence market prices. Agent-based simulation has proven to be an efficient instrument to assess market power in electricity markets (e.g. in Nicolaisen, Petrov, Tesfatsion 2001) and will most likely also deliver results to this question for CO_2 allowance markets.

5 Summary and outlook

The present paper first provides a brief overview of the field of agent-based computational economics in electricity markets. This new research approach allows dynamic bottom-up modeling in economic research and is an especially promising methodology also for research on electricity and emissions markets. We show that agent-based modeling offers advantages over traditional approaches by including aspects that can only be traced analytically with difficultly, e.g. imperfect information, different risk preferences, the players' expectations, and learning effects.

Subsequently, we describe the first steps in implementing an agent-based model for simulating electric power markets and markets for CO_2 emission allowances within the EU emissions trading scheme. A focus lies on the emissions trading part of the model; the involved agents - *CO_2AllowanceTrader* agents and *ElectricityTrader* agents on the short-term level and *LongTermPlanner* agents on the long-term level - and some of their attributes and methods are specified.

The aim of the research project and the simulation model under development is to assess the impact of emissions trading on power markets and to get a better understanding of the interplay between the considered markets. Additionally, different market designs for emission allowance markets, but also for electricity markets can be simulated and examined in reference to the parameters of interest. Besides the short-term market view, long-term simulations of the electricity sector are foreseen and will include aspects such as capacity expansion, plant decommissioning, and merger.

Some agent-based economic models have proven successful in reproducing real-world markets. However, there is little experience in modeling several different interrelated markets and their connections. Furthermore, to the knowledge of the authors, no emissions trading market has been simulated with agents representing the affected industrial players, so far. Mizuta and Yamagata (2002) present an agent-based gaming simulation of the international emissions trading scheme defined in the Kyoto protocol; in this model, agents represent countries and do not have internal trading strategies or any ability to learn from trading results. Thus, it is yet to be proven that agent-based simulation delivers realistic results for the planned emissions trading and power market simulations. On this account, a sound model validation and verification is of high importance and will be conducted with accuracy.

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Real options analysis for renewable energy technologies in a GHG emissions trading environment

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Abstract

Green house gas (GHG) emissions have been tied to global climate change. Governments are seeking ways to help improve performance of their countries on this environmental issue through introduction of various policy instruments. One popular policy instrument that seems to have gained credibility with explicit mention of its application in the Kyoto Protocol is the use of permit trading and cap-and-trade mechanisms. Various political regions, countries, and even corporations have introduced, are introducing or seek to introduce this mechanism. Organizations functioning within this environment will need to manage their resources appropriately to remain competitive. Organizations will either have the opportunity to purchase emissions credits (offsets) from a market trading scheme or seek to reduce their emissions through different measures. Some measures may include investment in new technologies that will reduce their reliance on GHG emitting practices. In many countries, large organizations and institutions generate their own power to operate their facilities. Much of this power is generated (or bought) from GHG producing technology. Specific renewable energy sources such as wind and solar photovoltaic technology may become more feasible alternatives available to a large percentage of these organizations if they are able to take advantage and incorporate the market for GHG emissions trading in their analyses. To help organizations evaluate investment in these renewable energy technologies we introduce a real options based model that will take into consideration uncertainties associated with the technology and those associated with the GHG trading market. The real options analysis will consider both the stochastic (uncertainty) nature of the exercise price of the technology and the stochastic nature of the market trading price of the GHG emissions. Managerial and policy implications will be discussed.

Keywords: GHG emissions trading, real options, photovoltaic technology

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1 Introduction

Global warming has recently seen headlines throughout the academic and popular press. Businesses and corporations have been greatly influenced by global warming occurrences and politics (e.g. Carey 2004). There is general agreement among the scientific community that a substantial portion of global warming has been caused by man-made events with carbon dioxide (CO_2) and other greenhouse gas (GHG) emissions, such as methane and nitrous oxide, causing the preponderance of this warming (IPCC 2001). Internationally, governments and corporations have been seeking ways to address this issue by limiting the emissions that are spewed out of industrial and consumer practices.

As part of the international effort, the Kyoto Protocol was introduced in 1997 to reduce 1990 levels of GHG emissions an average of approximately 5% by the year 2012. The Protocol went into effect when the Russian government officially ratified it in March 2005. This treaty needs the support of 55 industrialized countries accounting for at least 55 per cent of global emissions in 1990 and Russia was the remaining country (other than the United States) that could allow this goal to be reached. There are no plans for the U.S. Government to ratify this treaty, but certain programs have been put into place by various regional governments within the U.S. to help achieve goals set forth by the Kyoto Protocol.

Politics aside, it is a reality that the organizations have to address the issue of global warming. Policies will be developed by various governments to help meet their country's goals. Various policy instruments have been recommended to help achieved the Kyoto goals. Policies include command and control regulations, taxes, permit allowance trading, and market certificates as examples of approaches. These policy instruments will require organizations to rethink how they may execute managerial decisions in response.

Even though numerous industries can be targeted for reducing country GHG levels, the energy industry is one of the prime sources (almost 80% in the U.S.) of GHG. According to the EPA:

"Energy-related activities were the primary sources of U.S. anthropogenic greenhouse gas emissions, accounting for 85 percent of total emissions on a carbon equivalent basis in 2002. This included 97, 36, and 16 percent of the nation's carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) emissions, respectively." (EPA 2004, p. 37).

A third of all CO_2 emissions are directly from electricity generation. This result is comparable throughout the world (see http://www.eia.gov). Thus, the introduction of technology that would help reduce the reliance on fossil-fuelled electricity generating alternatives is an approach that can greatly reduce GHG emissions. The introduction of market mechanisms to reduce GHG emissions will significantly influence the investment in various renewable energy technologies that minimize these emissions.

Business and industry are cognizant of these changing winds and need to be able to function in such a way to take advantage of evolving technology and the potential for a growing market in GHG allowance trading, where such markets are introduced. Stakeholders and stockholders also are cognizant of the risks, oppor-

tunities and exposure of companies to GHG emissions. Yet, the investment in technology in these uncertain and dynamic situations is not an easy task. The uncertainty arises from the potential costs of allowances as well as the uncertainties of the costs of various renewable energy technologies. To manage these uncertainties in the investment we propose a real option analysis methodology based on uncertain asset prices and exercise prices. This situation is different than just the evaluation of uncertainties due to the asset price and requires that we use a slightly more advanced methodology based on quadranomial lattices for solution.

In this paper we focus on a renewable energy for electricity generating technologies, photovoltaics that have seen growth in popularity and decreases in investment costs, but may not have achieved the required investment returns for immediate investment. In our evaluation we begin our discussion outlining the policy environment facing GHG emissions and the various mechanisms with an emphasis on cap-and-trade programs that may play a role with how our investment decisions are made. Before introducing the real options methodology to evaluate organizational investments in PV technology, we provide an overview of the costs and benefits of this and other renewable energy technologies. We then introduce the characteristics and issues facing the investment decisions and solution model. Using realistic data approximations, an evaluation of the alternative technologies will be completed. Implications of this illustrative case and evaluations for policy and organizational decisions makers are then made.

2 Market-based mechanisms and cap and trade programs

Many types of environmental policy instruments exist to help monitor and regulate environmental practices of organizations. The Kyoto Protocol mentions three mechanisms to enable Annex I countries to reduce the costs of their emission limitation commitments by means of transactions abroad. These so-called 'flexible instruments' or 'Kyoto Mechanisms' include:

- Joint Implementation (JI) offers the opportunity to an Annex I country to achieve (part of) its Kyoto commitment through investments in GHG abatement projects in another Annex I country.
- Clean Development Mechanism (CDM) encourages the sustainable development of Annex-I countries by means of capacity building and technology transfers. CDM should enable Annex I countries to meet part of their Kyoto commitments cost-effectively through abatement projects in Non-Annex I countries.
- Emissions Trading allows Annex I countries to exchange part of their emission commitment and, hence, to redistribute the division of allowed emission between them.

Bemelmans-Videc et al. (1997) provide an overview of economic instruments (carrots), traditional regulatory instruments (sticks) and informational devices (sermons). Jordan et al. (2001) have defined four categories including (1)

traditional regulatory instruments, (2) voluntary agreements (3) market-based instruments (such as eco-labels, eco-taxes and tradable permits), and (4) informational devices and/or instruments of moral suasion (such as government advertising campaigns). In the case of cap-and-trade (tradable permits) we focus on the third category of market-based instruments, and, specifically, that of tradable permits and allowances, and its meaning to internal organizational decision making. Even though the focus of these categories is for policy makers, the response of corporations to these instruments may require a variety of decision tools. In this paper we focus on one such managerial tool, real options analysis. A brief background of tradable permits and cap-and-trade programs is followed by the application of the real-options analysis tool to be described and applied in this paper.

Cap-and-trade mechanisms have seen great support and success in the U.S., which has the most experience in this type of program. It was one of the first countries to implement this policy instrument when it introduced the 1990 Amendments to the Clean Air Act that established a system of tradable permits for SO_2 emissions, the cause of acid rain. This program allows facilities to emit up to a permitted amount (allowance) of SO_2 in a given year. If the facility wants to go beyond its allowance, it can go to a market and purchase additional allowances from other sources. Extra allowances also can be sold or carried over for future use or sale. The total amount of emissions allowed in the market is set by the government and is typically less than or equal to previous years overall market emission allowances. Costs of pollution thus are internalized by having a market price associated with emitting GHG over the permitted allowances. This cap-and-trade program provides flexibility to organizations either to incorporate policies, programs, processes and/or technology to reduce the emissions or to purchase the allowances. According to the U.S Environmental Protection Agency (USEPA) SO_2 emissions went down from an annualized amount of 9.7 million tons in 1980 to 4.7 million tons in 1998 (three years after the regulations went into effect) for the 263 largest utilities in the U.S. (USEPA 1999). Utilities and energy providers were used in this reduction evaluation because they are, by far, the largest emitters of sulfur dioxide in the U.S. Utilities and energy providers are also the primary organizations to be influenced by any regulations resulting from the implementation of the Kyoto Protocol for GHG emissions.

The United Nations Kyoto Protocol brought to the forefront the issue of global warming and GHG emissions. It also indicated the need for countries to start reducing these emissions to below 1990 levels. For example, the Protocol requires the U.S. to reduce their GHG emissions to 93% of 1990 levels by the 2008-2012 time period. This requirement essentially means estimated decreases of over 20% of current emissions. How countries can do this is flexible, through one of many types of policy instruments described in the previous paragraph. Cap-and-trade seems to have had the most support from U.S. delegations, with European countries supporting eco-taxes, yet many Annex B[1] countries, including the European Union, are leaning toward adopting cap-and-trade programs.

[1] Annex B countries are primarily developed countries and are listed in Annex B of the Kyoto Protocol along with the reduction amounts required of these countries. Annex B

The European Union (EU) has proposed a mandatory cap-and-trade emissions trading scheme that is expected to begin operation in 2005[2]. The EU's proposal focuses on a mandatory scheme that is limited to core industrial sectors and applies to CO_2 emissions from electricity generators directly within the proposed scheme, rather than as indirect emissions on the part of downstream consumers. Under the proposal, member states will allocate permits free of charge rather than on an auction basis.

Individual countries within the EU also have been in the process of establishing their own cap-and-trade programs for GHG and other areas of publicly controlled resources/emissions. Jordan et al. (2001) provide a review of what four EU countries are completing with respect to these programs. Germany has seen some resistance for these trading programs from industry (especially the chemical industry), who argue that voluntary agreements are doing the job well. The German government has used the EU's proposal to form a directive on tradable permits to help gain industry cooperation. This directive was published at the end of 2001. The Netherlands has a history of tradable permits with such things as milk quotas and NO_2 (nitrogen and oxygen based chemical formulation) emissions. They have been studying the GHG trading area. In 2000, Austria adopted a tradable permits scheme for electricity produced by small hydro power stations

The United Kingdom is probably the furthest along in terms of tradable permits for GHG emissions. In April, 2002, the UK opened the first emissions trading market with 34 businesses that, for government incentive money, agreed to cut their greenhouse gas emissions by more than 4 million tons of carbon dioxide equivalent over the next five years, in return for 53.37 British pounds per ton over a five year period. A more complete market of 6,000 businesses is expected to open in the fall of 2002 (Buchan 2002).

Rozenzweig et al. (2002) also detail the Danish cap and trade market that was introduced by the government in 1999 within the CO_2 Quota Act. This act imposed a cap on power sector CO_2 emissions of 23 million metric tons of CO_2 in 2000. This cap is to be reduced by 1 million metric tons per year through 2003, where a target level of 20 million metric tons is set. The system covers only electricity producers operating in Denmark, except those relying entirely on renewable energy generation and those emitting less than 100,000 metric tons of CO_2 per year. Participants in the trading scheme must notify the Danish Energy Agency whenever they want to transfer allowances. Companies may bank any differences until 2003.

countries are: Australia, Austria, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechtenstein, Lithuania, Luxembourg, Monaco, the Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, the United Kingdom of Great Britain and Northern Ireland, and the United States

[2] Initially the EU favored Eco-taxes with which they have had significant experience. It was the U.S. that fought for emission trading as a possible option for cutting greenhouse gases (Grubb et al. 1999).

Rozenzweig et al. (2002) mention a number of examples at the sub-national level, including the state of Massachusetts, which will require reductions of CO_2 emissions from power plants and will allow sources to use trading as a means of compliance. In Ontario, Canada, the pilot emissions reduction trading project is a joint industry and government initiative to explore and promote emissions trading as a tool to reduce emissions of various gases including GHG emissions.

Several private sector and nongovernmental organizations also have developed initiatives to help build the market and to create and take advantage of trading opportunities. They include the Partnership for Climate Action, the Emissions Market Development Group, and the Chicago Climate Exchange (Rozenzweig 2002). At least 23 transnational companies have begun to develop in-house permitting systems, even in countries where governments have been slow to act (Jordan et al. 2001). In September of 2004, the European Climate Exchange (ECX), formed by an agreement between the Chicago Climate Exchange (CCX) and London's International Petroleum Exchange (IPE), will offer European companies a place to trade emissions credits for greenhouse gases.

PriceWaterhouseCoopers, (2004) claims that only 18% of Europe's utility firms have already integrated climate-change and emissions-trading strategies into their business plans. Based on a survey of 75 major European utilities, only 22% of respondents admitted they have no climate-change strategy at all, only 45% of the companies polled have implemented a strategy, either partially or fully. The report states that "Carbon trading needs to be integrated with energy-trading and risk-management activities; carbon needs to be factored into investment, and mergers and acquisitions decisions and processes; legal, compliance and tax issues need to be addressed; and accounting and disclosure implications considered. Companies also need to be prepared for possible shock risks, such as grid crisis, extreme weather conditions or market shortage, which could leave them in breach of their emissions limits." (PriceWaterhouseCoopers 2004, p. 15).

The first phase of the ETS will run for three years, from 2005 to 2007. A second phase will run from 2008-2012 coinciding with the first commitment period under the Kyoto Protocol on climate change. Further five-year periods are expected subsequently. At the end of each year, emissions from installations are measured. Operators then give up allowances equal to their emissions. Organizations have three choices: meet the limit; reduce emissions below the limit and sell the surplus (or keep it for future use); or let emissions remain higher than the limit and buy allowances from others in the schemes to cover the difference. Strategies companies adopt will depend on the price of allowances in the Europe-wide carbon trading market, which will be created by the scheme, compared with the costs of reducing their own emissions. Failure to cover emissions with allowances will lead to fines of 49€ per ton of CO_2 in the first phase and 100€ per ton from 2008 (Nicholls 2004). There are numerous issues associated with these markets and development ranging from developing protocols for determining GHG emissions inventories (either current or 1990 rates) to allocation of allowances among nations and organizations. We will not focus on these issues in this paper, but will assume that they have been suitably addressed to develop an efficient market.

The use of appropriate organizational risk management tools to function within this regulatory environment has also been recommended. Consideration of emissions reductions alternatives and justifying those alternatives for organizations will be critical during these time periods (PriceWaterhouseCoopers 2004). We now introduce one technology that will aid in GHG reduction and some issues surrounding its development, before we apply an investment analysis tool to help in its generalized evaluation.

3 Renewable energy strategies and photovoltaic energy sources

A primary strategy for organizational reduction of GHG emissions is through introduction of renewable energies. Renewable energy sources are more environmentally sound from a number of dimensions, albeit they do have alternative implications for environmental issues. Solar, wind, biomass, hydro, geothermal, hydrogen and fuel cell, technologies are all types of green or renewable energies that are available (see http://www.nrel.gov for detailed descriptions of each of these energy types). The major focus of our study will be on Solar energy with a primary emphasis on photovoltaic energy rather than solar thermal energy. The analysis and comparisons presented in this paper may be extended to other renewable energies where the uncertainties and costs associated with these other energies must be determined.

- The amount of GHG gas reductions from introducing renewable energies is based on the tradeoff or marginal improvements of renewable energy technologies when compared to fossil-fueled generation of electricity. Table 1 shows the life cycle emissions (including gathering and processing of fuel, and the construction and decommissioning of plants). For photovoltaic (PV) technology emissions are almost all (99%) from the non-energy producing portions of the life cycle. Other estimates have shown that on an annual "per kilowatt" basis, PV offsets or saves up to 16 kilograms of nitrous oxides (NO_X), 9 kilograms of sulfurous oxides (SO_X), and 0.6 kilogram of other particulates, and between 600 and 2.300 kilograms of carbon dioxide (CO_2) per year. These savings vary with regional fossil fuel mix and solar insulation (IER 1997; Moskowitz 2000).

Table 1. Average life cycle emissions grams per kilowatthour (kWh) of major fuel types

Energy Source	SO_X [gSO_X/kWh]	NO_X [gNO_X/kWh]	C in CO_2 [gC/kWh]
Coal	3.400	1.8	322.8
Oil	1.700	0.88	258.5
Natural Gas	0.001	0.9	178.0
Nuclear	0.030	0.003	7.8
Photovoltaics	0.020	0.007	5.3

Source: Sandia, 2002

- For our case, we have estimated the average amount of tons of emissions per megawatthour (MWh) of electricity generated through traditional oil, gas and coal (fossil-fuel) electricity production averaging the mixture of these fuels from the Energy Information Agency (EIA) data (EIA 2004). In 2002 the EIA estimated that 2%, 18%, and 50% of all energy is generated by Oil, Natural Gas, and Coal fuels, respectively. EIA estimates that these amounts will be 2%, 23%, and 53% in 2025. Overall, using these EIA estimates we arrive at 0.639 metric tons and 0.483 metric tons of CO_2 emissions in 2002 and 2025 respectively for an average utility plant in the U.S. These estimates are also based on improved efficiencies from fossil fuel power generation plants and technologies over this time period. These values will be important in our later analysis when we seek to determine the emissions offsets from introduction of renewable energy technologies. Photovoltaic technology will be the specific technology considered.

4 Photovoltaic technology and costs

Photovoltaic solar energy systems convert sunlight directly into electricity, and deals with all PV-generations. The basic element of photovoltaic technology is the solar cell (typically 10 cm x 10 cm square). Solar cells are constructed by joining two dissimilar layers of semiconducting materials, referred to as p-type (positive) and n-type (negative) semiconductors. A solar cell is constructed by joining these two semiconductors in a "p-n junction", producing an electric field. The photovoltaic effect is enacted when sunlight, comprised of positively charged photons, is absorbed by the solar cell, transferring energy to the electrons that then become part of a current in an electrical circuit. A PV module is an array of packaged solar cells that convert solar energy directly into direct-current (dc) electricity. There are two major types of PV cells, Crystalline Silicon and Thin-Film PV. These are the core elements and costs with PV equipment. Ancillary equipment referred to as the balance-of-system (BOS) needs to be included in costing these systems. BOS requirements are site-specific due to power, reliability, environment, and power storage needs. BOS components may include: mounting equipment, tracking systems to follow the sun, dc/ac power inverters, power storage batteries, and protective electrical hardware. (Notton et al. 1998; Harmon 2000).

Thus, there is no truly representative costs for these systems and may depend on the alternatives and characteristics of the installation and PV technology choice and their efficiencies. Estimates are that the BOS may represent $^{2}/_{3}$ of the costs of a system. Yet, this ratio may not remain the same since there are differences in the 'learning curves' for PV modules and BOS, where the learning for PV modules is global and BOS learning is local (Shaeffer and de Moor 2004).

The life cycle cost (LCC) of a PV system includes costs for site preparation, permits, system design and engineering, installation labor and operations and maintenance (O&M). O & M costs for entire PV systems vary significantly, rang-

ing between as low as $0.01/kWh to $0.10/kWh. Most maintenance costs lie at the lower end of this range (Thomas et al. 1999). The most significant replacement cost will likely be the battery-lasting between five and nine years, depending on use. O & M costs have been found to be approximately 2% of total hardware costs (Notton et al. 1998). In the U.S. (EIA) still calculates that in 2012, PV costs in the best locations will still be at 9 cent/kWh.

An example calculation for PV technologies is provided by Sandia Labs in the U.S (Sandia 2002). Estimates begin with determining the radiant power from the sun, which to most of the populated earth surface, after atmospheric reflection and absorption, averages 644 watts per square meter (m²). It's available for over 5 hours per day on stationary PV panels, installed so they receive maximum sunlight. One thousand square meters (m²) of PV panels, having 10% power conversion efficiency, can generate about 64 kW for 5 to 8 hours a day. That's an electrical energy yield well exceeding 10,000 kWh per month. Most PV panels cost less about $4 per watt output, and are guaranteed for over 20 years. Total PV panel cost, in this example, would be $256.00. So their lifetime electric power output costs about ($256.00) / (10,000 kWh/mo)(12 mo/yr)(20 yr) = $0.10 per kWh. Life cycle costs, efficiencies, amount of peak solar power will all vary in this calculation, depending on the assumptions. This is important for site specific considerations and evaluations. In our study we will focus on average costs. We will use estimates from Schaeffer and de Moor (2004) which makes estimates on costs for PV technologies based on learning and experience curves. Figure 1 shows some of these estimates. The cost reductions are expected to be anywhere from 1% to 6% per year over the next few years.

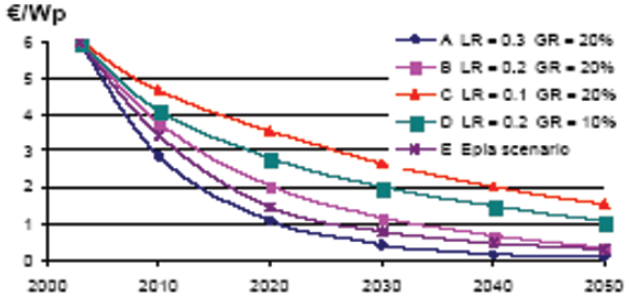

Fig. 1. PV technology cost estimates based on experience and learning curves.
Source: Schaeffer and de Moor (2004)

Even though there may be benefits of reducing GHG emissions, PV technologies do have other life cycle environmental burdens and costs that should be considered (Moskowitz 2000). We will not explicitly consider these factors in our discussion, but organizations need to be aware that they exist.

For organizations seeking to invest in renewable energies and accumulate allowances, three methods can be used to assess credits for GHG emissions, including direct replacement (Scope 1), indirect replacement (Scopes 2 and 3) (Hanson and Raganathan 2003).

Scope 1 emissions are direct corporate emissions controlled by an organization as defined by the GHG protocol include:

- on-site production of electricity, heat, or steam;
- physical or chemical processing (e.g., cement, ammonia manufacturing);
- transportation of materials, products, wastes, and employees in company-owned or company-controlled vehicles; and
- fugitive emissions such as the intentional or unintentional release of GHGs from seals, coal mines, and air conditioning equipment.

On-site renewable energy sources for industrial heat and steam applications can help reduce a company's Scope 1 emissions.

Scope 2 and Scope 3 missions are indirect emissions, (those that are a consequence of the reporting company's activities but that occur from sources owned or controlled by another entity). Scope 2 specifically accounts for indirect emissions associated with the generation of purchased electricity (from the grid), heat, or steam. Scope 3 accounts for all other indirect emissions, such as employee travel on scheduled flights, employee commuting, and contract manufacturing.

From a policy and business perspective the type of emissions allowed for credit purposes may have profound repercussions as to who and what type of investments are to be made by organizations. In terms of renewable energy investments the best situation is to allow for flexible scopes, but the difficulty arises when there are 'double-counting' situations that may occur. In our situation we will assume that Scope 1 and Scope 2 conditions exist where organizations may get credit for emissions for introducing renewable energy (PV) technologies either to replace their own electricity generating facilities or from 2nd party electricity generators.

5 Investment appraisal using real options

Investment appraisal decision and 'business case' tools exist to explicitly evaluate various environmental technologies and especially for renewable energies. These tools are available to do organizational technology investment analysis (Austin 2003) and market based analyses from a policy perspective (ECN 2003). They rely on various policy scenarios related to GHG trading and pricing, and provide some insights to both investments and policy. Yet they rely on traditional financial models such as discounted cash flow techniques, e.g., Net Present Value (NPV) We expand these situations by applying real options analysis, which can and should be introduced to these and other decision tools. Even though, it has seen limited application and development, real options for environmental and natural resources management in general (e.g. Insley 2002; Kitabatake 2002; Louberge 2002) and corporate environmental evaluation in particular (Brennan and Schwartz 1985; Cortazar et al. 1998; Edelson and Reinhardt 1995; Lundgren 2003) has seen increasing application.

6 Real options example applied to PV technology

Our purpose now is to illustrate a real options approach using case study data. We introduce a complication by assuming that there are two sources of uncertainty. The first source is the exercise price of the option to invest. This cost is the life cycle costs of the renewable energy technology (PV) and the uncertainty in these costs occurs from the uncertainty in the speed of learning or experience effects from greater production. The other source of uncertainty is the savings in the cost of the emissions credits not needed if the new technology is installed. The option value depends critically on both sources of uncertainty.

- To model the NPVs, we use the quadranomial approach as outlined in Copeland and Antikarov 2001. In this approach all outcomes are nodes on a two-variable binomial lattice. We assume that both sources of uncertainty follow a multiplicative binomial process and are independent. These assumptions are important. Sources for this model are Cox, Rubenstein & Ross (1979) and Hull (2000). As did Edelson and Reinhardt (1995), we use one year as the time step. We caution that our model is not exact because of the large time step we employ. That is, the model we are using is only close to being exact if terms in Δt^2 and higher powers of Δt are ignored. Obviously if $\Delta t = 1$ in years, error creeps in because Δt is not small. Furthermore, we only carry out the lattice for 4 periods. Although the quadranomial lattice is recombining, with two sources of uncertainty the number of nodes grows quickly (at a rate of $(t+1)^2$). By the 4^{th} year, there are 25 nodes. Our purpose is to present only a real options example rather than exact values, and policy implications may still be drawn.
- We assume that the risk-free interest rate is the approximate current yield on 20 year U. S. Treasury bonds and is equal to 4.5%. We assume that whenever the technology is installed, its cost will remain the same for 4 more years as well as how many offsets it can generate. Thus, for valuation we need to find present values of 4 year annuities, the present value factor of which is $PVIFA_{4,r}$ where 4 is the number of periods and r is the appropriate discount rate.

An example of how the price of the credit moves through the lattice will serve as an illustration for both the credit price and for the cost of installation of the new technology since the process is the same for both, only the parameters are changed. Using a current value, C_0 of \$10/ton and, although the credits are not yet traded, a multiplicative binomial process will be used. Also using some published data and assumptions (e.g. British Petroleum in its internal trading program assumed a 3.3% increase, others have shown widely varying estimates, (Springer and Varilek 2004)) we use the long-term real growth rate of 3.3%, as this is the estimate. We assume expected inflation at 2% so that our nominal growth rate is 5.366%. The value of a credit either moves up with probability q by a proportional amount u or moves down with probability 1-q by a proportional amount d. Since

there is no a priori reason to assume any particular probability, we use $q=^1/_2$. The size of u is $e^{\sigma\sqrt{\Delta t}}$ and $d = {}^1/_u$. We set μ=5.366%, the long term growth rate of the credits, so that the expected price of the credit can be calculated. The expected price of the credit at the end of the first step is C_1 and is given by:

$$C_1 = C_o e^{\mu\Delta t}. \quad (1)$$

On a binomial lattice the expected credit price at the first time step is:

$$qC_0u + (1\text{-}q)C_0d. \quad (2)$$

Thus, setting the two equations equal and solving for σ we obtain σ as a function of μ. Because we have an estimate for μ, 5.366%, our volatility σ is estimated as well. The estimate of σ is 0.3305. This value is not much different than the volatility of many stocks, but we realize it is just an estimate of the process. Moreover, it is a large value, as two up moves in a row will almost double the value of the allowances. Still, because the market for allowances could be erratic, we want to error on the side of high volatility.

We use a risk-neutral valuation procedure in which the value of the option is the discounted expected value under risk-neutral probabilities. This procedure will produce arbitrage-free values in a complete market. We make no claim that the market is complete, and thus, the values we obtain are not arbitrage-free. McDonald (2003) terms these 'fair prices.' The risk neutral probability for an up move, p, is given by:

$$p = (e^{r\Delta t} - d)/(u - d). \quad (3)$$

The estimates are C_0 = \$10/ton, r = 0.045, μ = 0.05366, and q = ½,. In addition we assume 0.639 tons of tradable permits from 1 MWh of renewable energy produced and will go down by 0.009 per year.

The parameters for the cost of the new technology are 2% annual inflation and 1% for the lowering of the annual cost as firms learn to produce the technology more efficiently, as discussed in our section titled "Photovoltaic Technology and Costs", above.

Let us call the risk-neutral probability for an up move (down move) in the credits as u_1 (d_1) and u_2 (d_2) as the risk neutral probability of an up move (down move) in the re-injection technology. Recall the assumption that the price processes are independent so that the risk neutral probability of each branch is equal to the product of the risk neutral probabilities of each source of uncertainty. (Dependence can be modeled by the quadranomial lattice also, but not surprisingly, it is more complex.) Then the risk neutral probability of both processes moving up is u_1u_2, of credits moving up while the technology goes down in value, u_1d_2, of credits moving down while the technology increases, d_1u_2, and finally the risk neutral probability of both price processes going down is d_1d_2. The value of the option to install the new technology is designated as V. Its value in period i is the discounted value of its value in the succeeding period as given by:

$$V_i = (u_1u_2V_{u1u2} + u_1d_2V_{u1d2} + d_1u_2V_{d1u2} + d_1d_2V_{d1d2})/(1+r_f) \quad (4)$$

We constructed 4 years of time steps. From any node on the lattice, there are four possible new branches for the next period in the quadranomial lattice (see Figure 2). The number of nodes is 4 for year 1, 9 for year 2, 16 for year 3, and 25 for the 4th year. The formation of the lattice then can be determined by backward induction. We start at the last period, the 4th. The NPV here is simply the value of the costs associated with production of 1 MWh of electricity for the next 4 periods (whether the costs are due to purchasing permits and traditional fossil fuel electricity generation, or the electricity costs from production using PV). The option, of course, has the same value at this point. From the final period we work back through the lattice.

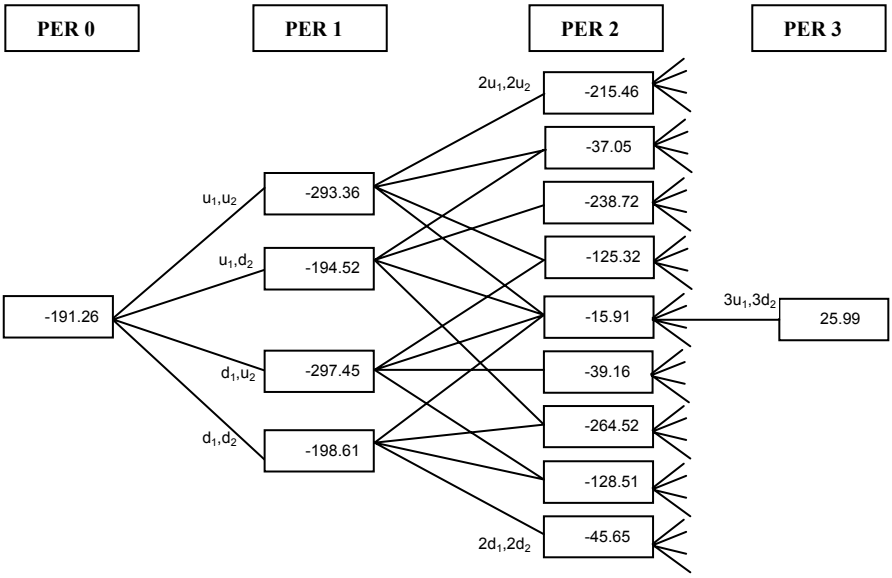

Fig. 2. Early time periods of quadranomial lattice value calculations for savings by exercising option to invest in PV technology.

In the final period:

$$NPV_T = C_T E_T - I_0 \tag{5}$$

$$V_T = max[NPV_T, 0] \tag{6}$$

where T is the final time period, the starting point in our analysis in the lattice, E_T is the emissions savings in tons in the final time period, and V_T is the option value in the final time period.

A numerical example from our results can help explain the method. In period 4 after 4 up moves in both the credits and in the cost of the new technology, we have a value for emissions of \$275 per MWh, i.e., $\{[\$10e^{(4*0.3306)}][0.639 - (0.009)^4] + 50(1.045)^4\}(PVIFA_{4,0.045})$.

Or in general:

$$C_t=\{C_0e^{((j-k)\sigma)}][0.639 -(0.009)(t)] + \text{(initial cost of traditional electricity generation)}(1+r_f)^t\}(PVIFA_{4,0.045}) \quad (7)$$

where C_t is the value for the cost of 1 MWh generation of emissions at time period t, j is the number of up moves and k is the number of down moves. Thus, the value of the cash flows this period is \$275 per MWh. The new technology has a cost of \$621 per MWh this period. The NPV is negative. Since this is the last period, the option has a value of zero.

In a similar fashion the cost of the new technology PV is given by:

$$PV_t=\{PV_0e^{((j-k)\sigma)}] (PVIFA_{4,0.045}) \quad (8)$$

Here, once again, at time period t, j is the number of up moves and k is the number of down moves for PV. Note in this equation, the σ is for the uncertainty in PV and has a value using our parameters of 0.137. The value of PV after 4 up moves in the new technology is \$621 per MWh i.e.,

$$100e^{4(0.137)}(PVIFA_{4,0.045}) \quad (9)$$

The optimal time to exercise the option, i.e., install the renewable energy technology equipment, would be the first period in which the NPV of installation is greater than the value of the option to delay. Initially, the value of the option is greater than the NPV of installation. Higher allowance values increase the NPV of installation and the value of the option. The value of the option, however, increases at a lower rate, and thus, there is a crossover at some point in which the NPV becomes greater than the value of the option. If the value of the allowances does not rise, however, the NPV will never reach the level of the option value. Of course, with uncertainty in the cost of the renewable energy technology, exercising the option also depends on this changing cost also. The more this cost decreases, the more likely is exercise of the option.

It is of interest to examine our lattice for nodes where exercise, i.e. purchase the new technology, is optimal. There turns out to be few of these nodes. In fact, the option has value in just a few places. Looking at the 4th period, we see that the option has positive value only after in three branches, namely (1) after 4 increases in the value of the emissions credit and 4 decreases in the cost of PV where the option has a value of \$60 per MWh (2) after 3 increases in the value of the emissions credit and 1 decrease (note that, in general, the order of these increases and decreases does not matter) and 4 decreases in the cost of PV where the option has a value of \$21 MWh and (3) after 2 increases and 2 decreases in the value of the emissions credit and 4 decreases in the cost of PV where the option has a value of \$0.77 MWh. Because this is the last period in our scenario, the option would be exercised in these 3 cases.

Going to the 3rd year we find only one branch where exercise is optimal, namely after 3 up moves in the value of the emission credit and 3 down moves in the cost of PV. In this case the firm will gain \$25.99 per MWh in present value by exercising, going to the new technology. Actually in the remaining 15 branches in this period, there is only one other node where the option has a positive value and that occurs after 2 up moves and 1 down move in the value of the emission credit

and after 3 down moves in the cost of PV. At this node, it is better to delay than to install the new technology. In the remainder of the lattice there is no other branch where exercise is optimal. A further note of minor interest is that the option to delay has a value of $1 per MWh generated at time zero with our parameters.

The implication is that there will be a substantial amount of time before companies use new technology to curb pollution instead of trading for the emissions credit, unless the costs of the technology greatly decrease or the costs of the tradable permits (offsets) is greater than we initially estimated.

A typical industrial establishment (assumed to be a single facility or plant) in the U.S. uses about 81,000 MWh per year. Given a savings of $30 per MWh for switching to the new technology can save this typical establishment almost $2.5 million.

7 Conclusions and future research

What we have presented here is a model that can be used by organizations for technology justification of GHG emission reduction technologies based on the various uncertainties in the market for tradable permits and technologies. We specifically chose PV technology to evaluate because of the uncertainty in its costs and growth over the next two decades when the Kyoto protocol is meant to take effect and many nations are turning to tradable permits for mechanisms to reduce GHG emissions. The model we propose is a real options approach that explicitly takes into consideration these uncertainties and can help management more effectively time the introduction of the new technology such that it will be the best economical choice. We applied a quadranomial lattice approach to solve our problem. We arrived at the conclusion that over the next four years, there are opportunities to introduce this technology, but this will not occur immediately without reduction in costs of the technology or growth in the value of tradable permits. Both of these issues have managerial and policy implications.

There are numerous directions that we still need to pursue in this on-going work. Foremost is a sensitivity analysis to determine how various scenarios play out based on the many estimated parameters that we used in this case example including initial starting prices, volatility and growth rates. Policy scenarios may also need to change including the scope of emissions savings allowed for tradable emissions.

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The European electricity market – impact of emissions trading

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Abstract

The greenhouse gas emission allowance trading scheme, agreed upon by the European Community, will affect energy-intensive companies, and especially power generators, all over Europe. The objective of this paper is therefore to present the development and application of a model for the interregional electricity and certificate market. The model results show that German power companies will become net sellers of emission allowances, and that electricity production in gas-fired combined cycle gas turbines (CCGT) could increase drastically in the next years.

Keywords: European electricity market, investment and long-term production planning, linear optimisation, emissions trading, national allocation plan (NAP).

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1 Introduction

Under the Kyoto Protocol of 1997, industrialised countries for the first time committed themselves to limiting their greenhouse gas emissions. The entire EU agreed to reduce its greenhouse gas emissions by 8% during 2008-2012 compared to 1990 emission levels. This emission reduction objective was broken down to the reduction targets of the different countries of the EU in the so-called EU Burden Sharing (EU BS) agreement. But as monitoring reports state, e.g. by the European Environmental Agency, recent trends in greenhouse gas (GHG) emissions indicate a significant compliance gap (Gugele et al. 2002, p. 22). Therefore, the Commission decided to establish a European greenhouse gas emissions allowance trading scheme for CO_2 emitting installations (COM 2003).

As CO_2 is a joint-product of fossil fired energy production the establishment of such a greenhouse gas emissions allowance trading scheme will influence investment strategies in this sector. In terms of emissions, the sector "energy conversion and transformation" is the biggest; this is why electric utilities will be most affected. Furthermore, investment strategies in the electricity sector are due to be dealt with now because of a massive demand for new capacities, partly caused by the phase-out of nuclear power production in Germany.

2 Demand for new power plants in Germany and Europe

In Figure 1 the existing power capacities in Germany are shown. As determined by the average lifetime of the different power plants, the decline in capacities over the next fifteen years has been calculated.

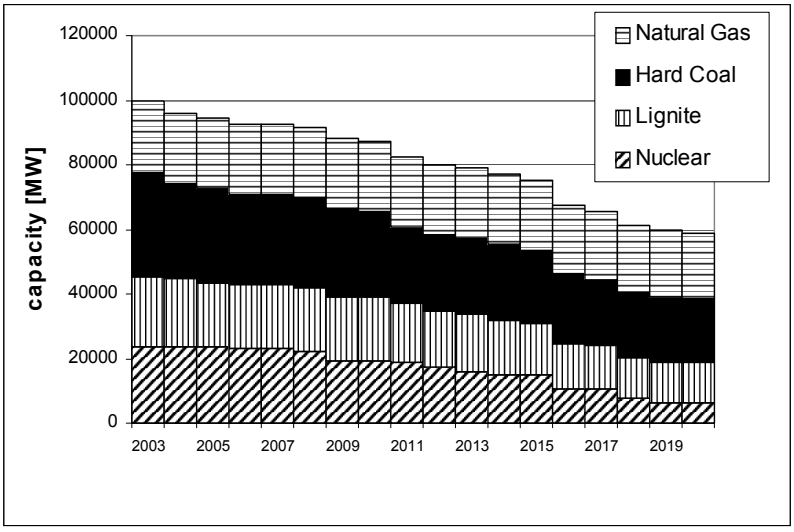

Fig. 1. Existing power plant capacities in Germany and their decline

If, additionally, the increase in demand is considered, it can easily be seen that by 2020 more than 40,000 MW (40 GW) of new capacities are needed in Germany (see also Pfaffenberger et al. 2004, p. 3-12 ff.). This means that about 40 new power plants have to be built. If the whole of Europe is considered about 300 GW of new capacities are needed within the next 20 years. In light of the fact that it takes years to get the necessary authorisation for, and to build, the power plants, the corresponding investment strategies have to be dealt with now.

Of course, these investment strategies must be developed in consideration of the framework conditions of the liberalised European electricity market. Whereas we had regionally separated monopolies in the past, now – at least in some regions – all power generators compete on a free market for the regional electricity demand. This means that, due to the liberalisation process, the entire European electricity market is nowadays relevant for the investment and production planning of an electric utility company. Furthermore, as a result of the greenhouse gas emission allowance trading scheme, the production of CO_2 emissions will also have to be integrated into the investment and production planning process of electric utilities in Europe.

3 A model to analyse the implications of emissions trading for the electricity sector

In order to analyse the implications of a European emissions trading scheme for investment strategies in the electricity sector, general requirements for a methodology developing investment strategies in the electricity market have to be identified first. In the electricity sector pure investment planning is not sufficient. Without considering the output of an energetic unit as a decision variable, the investment decision could lead to wrong conclusions, as the profitability of a new energy supply unit strongly depends on its utilisation and the corresponding payments, e.g. for primary energy carriers. The utilization, in turn, depends on the energetic units already available and the demand profiles to be met. Another reason why production planning has to be considered is that emissions trading will alter operating costs in the power generation sector and will therefore have an influence on the operation of generation capacities (leading to a different *merit order*).

In the liberalised electricity market, electric utilities compete on free markets for the regional electricity demand that has to be met. Therefore an electricity producer cannot take for granted that all customers located in his region will be supplied by him, and on the other hand each electricity company can try to find new customers all over Europe. This means that investment planning in an electric utility cannot ignore the competition and the customers. This already shows that investment planning in the electricity sector is a rather complex task, which is becoming even more complex due to the fact that the effects of emissions trading also have to be considered.

Of course there are different possibilities for analysing the impact of emissions trading, but in order to consider the interdependencies between production and

investment planning, a comprehensive model is needed. In the energy sector quite a few different model approaches exist already (see Fichtner 2005, p. 49 ff.). There are so-called top-down models, which realise a macro-economic approach. But due to the fact that these models take into consideration not only the energy sector, technical characteristics cannot be modelled adequately. Because of this shortcoming, so-called bottom-up models seem to be more promising in analysing the implications of emissions trading for the electricity sector. A first group of bottom-up models uses game-theoretical approaches, searching for a Nash-equilibrium. But again technical characteristics can hardly be modelled adequately with these models. There are only two kinds of models which seem to be appropriate for a detailed techno-economic evaluation of the impact of emissions trading on the electricity sector. The first kind of approach refers to so-called system dynamic models, as second there are optimising energy models. As complex interdependencies among rules for decision making can hardly be considered in system dynamic models, an optimising energy model, based on a technology-oriented bottom-up approach, has been selected to analyse the impact of emissions trading on investment strategies in the European electricity market.

It is thus the general objective of the developed energy system model PERSEUS-CERT (Program Package for Emission Reduction Strategies in Energy Use and Supply - CERtificate Trading) to provide an analysis tool for the quantification of the economic and technological impact that a CO_2 trading system may have on technology choices, electricity prices, certificate (allowance) prices and interregional power exchanges. PERSEUS-CERT is an energy and material flow model applying a multi-periodic linear programming approach. The target function requires a minimisation of all decision-relevant costs within the entire energy supply system (1). This basically comprises fuel supply and transport costs, fixed and variable costs of the physical assets (operation, maintenance, load variation costs etc.) and investment costs for new plants. The relevant techno-economic characteristics of the real supply system have been considered by implementing equations covering technical, ecological and political restrictions. The planning model can be outlined as follows (for more information see the Appendix):

$$\min \sum_{t\in T} \alpha_t \cdot \left(\begin{array}{l} \sum_{f\in F}\left[\sum_{seas\in S}\left[\sum_{p\in P} (Xi_{p,f,t,seas} \cdot Cvar_{p,f,t,seas} + \sum_{reg\in R} (Xout_{p,reg,f,t,seas} \cdot Cvar_{p,f,t,seas})) \right]\right] \\ + \sum_{seas\in S}\sum_{p\in P} PL_{p,t,seas} \cdot Cvp_{p,t,seas} \quad + \sum_{u\in U}\left[Cap_{u,t} \cdot (Cfix_{u,t} + Cinv_{u,t}) \right] \end{array} \right) \tag{1}$$

$$Cpo_{u,t} + Cap_{u,t} \geq \sum_{p_u} \left(\frac{PL_{p_u,t,seas}}{h_{seas}} \right) \qquad \forall u \in U, \forall t \in T, \forall seas \in S \tag{2}$$

$$Xi_{p,f,t,seas} = \frac{in_{f,p} \cdot PL_{p,t,seas}}{\eta_{p,t}} \qquad \forall p \in P, \forall f \in F, \forall t \in T, \forall seas \in S \tag{3}$$

$$PL_{p,t,seas} \cdot out_{f,p} = \sum_{reg} Xout_{p,reg,f,t,seas} \qquad \forall p \in P, \forall t \in T, \forall seas \in S, \forall f \in F \quad (4)$$

$$\sum_{p_{out}} Xout_{p_{out},reg,f,t,seas} \geq ID_{f,reg,t,seas} \qquad \forall reg \in R, \forall f \in F, \forall t \in T, \forall seas \in S \quad (5)$$

$$Xi_{p,f,t,seas} \in \mathrm{R}^{+} \qquad \forall p \in P, \forall f \in F, \forall t \in T, \forall seas \in S \quad (6)$$

$$Xout_{p,reg,f,t,seas} \in \mathrm{R}^{+} \qquad \forall p \in P, \forall reg \in R, \forall f \in F, \forall t \in T, \forall seas \in S \quad (7)$$

$$Cap_{u,t} \in \mathrm{R}^{+} \qquad \forall u \in U, \forall t \in T \quad (8)$$

$$PL_{p,t,seas} \in \mathrm{R}^{+} \qquad \forall p \in P, \forall t \in T, \forall seas \in S \quad (9)$$

Let the energy system consist of a set **u** of existing and possible future energy conversion units. Each of these energetic units **u** has at least one technical process **p** that stands for a possible mode of operation. These processes represent the transformation of input into output. The exogenously given electricity demand **ID** is the driving force of this model, which has to be fulfilled in each period **t** in each region **reg** in each time slot **seas**. Each period **t** is divided into time slots **seas**, with the help of which the so-called load curves of typical days are represented. Therefore, each time slot represents a time range of a typical day, for example the time range from ten to twelve on a summer working day. To satisfy the electricity demand a certain flow **X** of electricity is needed (5). In order to produce this electricity flow, the process activity levels **PL** of the energetic supply units have to be at the corresponding levels (4). Constraints number 3 link the process activity level with energy flows being input of this process, taking into account the efficiency **η** and the share of this energy carrier from the whole input of the process. Constraints number 2 ensure that enough capacity is available to satisfy the activity level for the modes of operation of these units.

However, the objective of analysing the impact of emissions trading for investment strategies requires the integration of a second market layer, the emissions trading market. This market has been integrated into this linear model by means of the following additional constraints:

$$Evol_{reg,t} = \sum_{p_{reg} \in P} \sum_{seas \in S} \sum_{ghg \in GHG} PL_{p_{reg},t,seas} \cdot Emiss_{ghg,p_{reg},t} \cdot GWP_{ghg} \qquad \forall reg \in R, \forall t \in T \quad (10)$$

$$DEmiss_{reg,t} = Evol_{reg,t} - Erights_{reg,t} \qquad \forall reg \in R, \forall t \in T \tag{11}$$

$$\sum_{reg} DEmiss_{reg,t} = 0 \qquad \forall t \in T \tag{12}$$

$$Evol_{reg,t}, Erights_{reg,t} \in \mathrm{R}^{+} \qquad \forall reg \in R, \forall t \in T \tag{13}$$

$$DEmiss_{reg,t} \in \mathrm{R} \qquad \forall reg \in R, \forall t \in T \tag{14}$$

With the help of equations 10 the greenhouse gas emissions in one region during one period are calculated by multiplying the process activity levels by emission factors and by the Global Warming Potential factors. In equations 11 **DEmiss** is calculated, that is the difference between emissions produced in one region during one period and emissions allowances allocated to that period. Of course, the sum of all **DEmiss** in the different regions has to be zero (12), in order to fulfil the emission reduction obligation according to the emission cap.

This set of restrictions has been used to set up a model covering the electricity system of 42 regions in Western, Middle and Eastern European countries, in some cases even splitting one country into several company specific subsystems. All power generators within one region compete on a free market for the regional electricity demand that has to be satisfied. However, at the same time there is also direct competition between different regions, given that neighbouring regions are connected via interconnection lines.

The model described above has been implemented as a PC version that can be run on most commercial PCs. However, due to its high complexity and the resulting large problem size, it requires state-of-the-art hardware components. The model is equipped with an MS Access based data management system that permits easy data handling and a fully automated link to the mathematical module. The model itself is programmed in GAMS (Brooke et al. 1988). Formatted and structured results become available in MS Excel spreadsheets. In order to solve the problem, commercial solvers like CPLEX are applied. The model has about 1 million equations, about 3 million variables and about 5 million non-zero elements. Calculation time ranges from 1 to 20 hours, basically depending on the chosen time horizon.

4 Model results

In the following, some exemplary results of the PERSEUS-CERT model are highlighted for the reference scenario without CO_2 emissions trading (and without CO_2 emission reduction obligations) and an emissions trading scenario, which considers emissions trading within the 15 Member States and the 10 (former) Accession

Countries (see also Enzensberger 2003, p. 161 ff.). In the emissions trading scenario (ET) it is assumed that emissions trading continues after 2012. Furthermore, the following cap for the period 2005-2007 has been fixed: Stabilisation of CO_2 emissions on the level of the years 2000-2002, which is more or less what the German allocation plan for 2005-2007 indicates for Germany. For all periods after the first trading period the emission caps are calculated according to the reduction obligations of the EU BS. That means that in Germany the CO_2 emissions in the electricity sector would have to be reduced by 21%, compared to the emissions in the electricity sector in 1990; this corresponds to a reduction of about 2.5% compared to 2002. The detailed national allocation plans (NAPs) as well as the option to use project-based flexibility mechanisms (Joint Implementation (JI) and Clean Development Mechanism (CDM)) have not been integrated into this ET scenario. Due to uncertainties regarding the storage of CO_2, technologies to capture carbon dioxide have also not been considered. Furthermore, it was assumed that nuclear power plants can only be built in Great Britain, France and Finland and that the incentives for the use of renewable energies will be taken over from emissions trading. In the following some results for entire Germany are presented – in addition it would be possible to present the results for the four big utility companies in Germany separately, as their power stations have been modelled individually.

The results of the reference scenario show a rather diversified energy mix for electricity production in Germany. In the periods starting in 2005 and 2010 about 2 GW of combined cycle gas turbines (CCGT) are commissioned respectively. Then – above all – in the period starting at 2015 lignite and hard coal power stations are built, mainly to replace electricity production from nuclear plants. The model indicates that German power operators should produce more electricity than needed within the German regions and export electricity. From 2015 onwards these exports are reduced because the power stations are needed to replace nuclear energy production in Germany, which declines due to the politically decided nuclear phase-out.

In the ET scenario, in which the (former) Accession Countries will join the EU emissions trading scheme from 2008, the model shows the following results: Within the European market, the different national electricity sectors show very different trade characteristics regarding their net sales volumes. Power companies from Germany, Great Britain, France and the (former) Accession Countries (especially Poland) become the major net sellers of emission allowances, whereas companies from Spain, Italy and the Netherlands evolve to be the principal net purchasers in the market (see Figure 2).

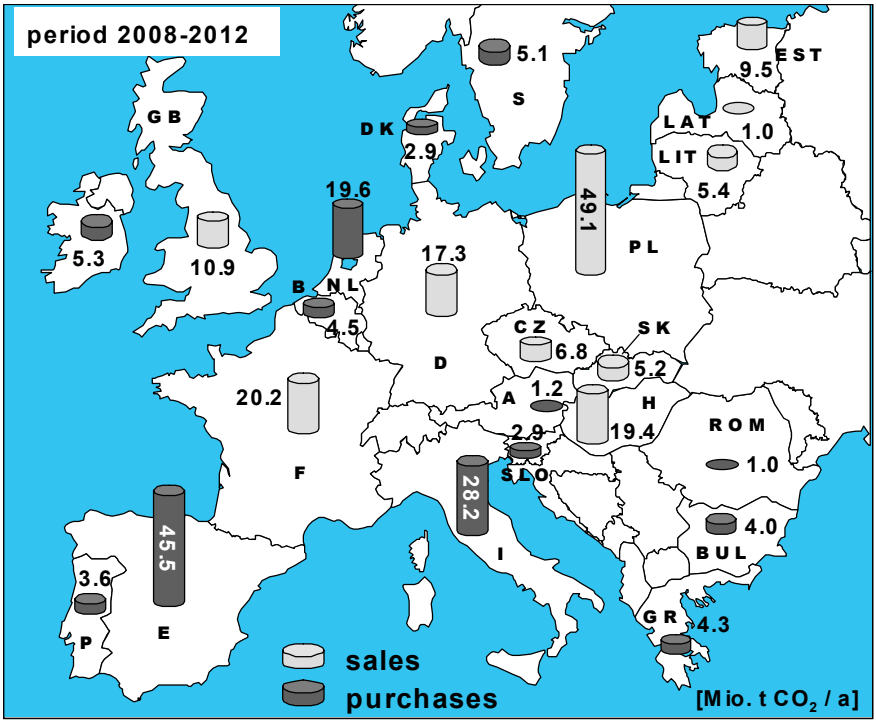

Fig. 2. Sales and purchases of emission certificates in the ET scenario

Due to the rather lax emission caps in the period from 2005 to 2007 the certificate price will be low (about 3€/t CO_2) and only few trading activities can be expected. But if Europe wants to fulfil its EU Burden Sharing agreement the certificate prices will increase drastically to about 12.5€/t CO_2 in the first commitment period 2008-2012. Due to increasing primary energy prices the certificate prices will then rise to about 16€/t CO_2 in 2013-2017 (see Table 1).

Table 1. Certificate prices in the ET scenario

period	2005-2007	2008-2012	2013-2017
[€/t CO_2]	2.7	12.5	15.7

Compared with emissions trading only within the 15 Member States in the first period nearly nothing changes, but in the following periods the allowance prices do not rise as significantly. This is due to rather old power stations in the (former) Accession Countries, which offer the possibility of investing in efficient technologies within the normal investment cycle.

After 2010, nuclear power generation in Germany declines. In the reference scenario, this production reduction is compensated by the construction of new coal- and lignite-fired steam power plants. In the case of an additional emission reduction obligation, however, this capacity loss is basically compensated by new

gas-fired combined cycle power plants as well as increased net electricity imports (see Figure 3).

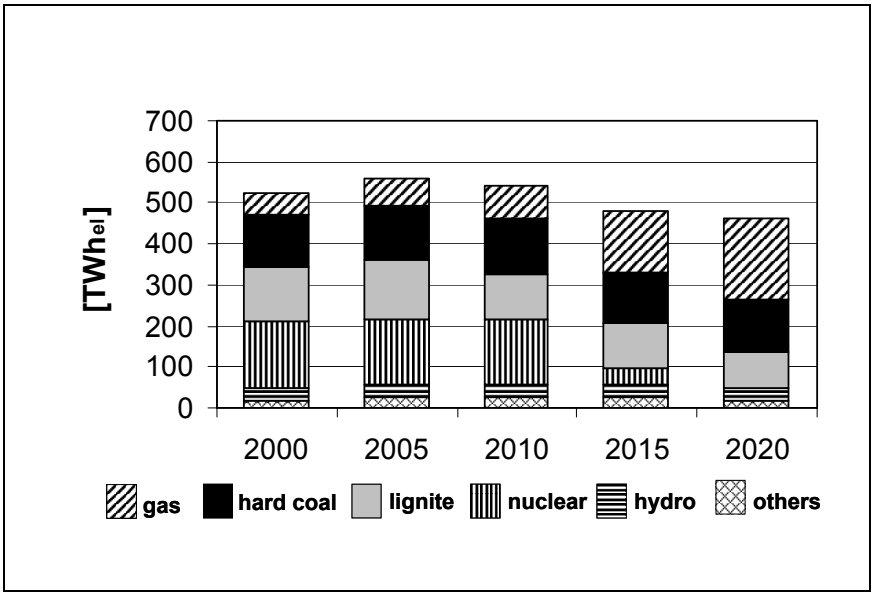

Fig. 3. Electricity production in Germany in the ET scenario

Furthermore, different sensitivity analyses, e.g. in regard to the development of gas prices, have been realised. Nevertheless, all scenarios lead to the conclusion that, under a European emissions trading scheme (German), utilities will invest in, above all, CCGT if the EU BS obligations are taken seriously.

5 Assumptions of the analysis

When developing this model the following assumptions had to be made:

- With regard to the technologies modelled it was assumed that there are no non-linear interrelations, although it is obvious that there are non-linear interrelations in reality, for example the interdependence between efficiency and actual utilisation intensity. Ignoring these interrelations seemed to be necessary for a European model, which could hardly be solved if it was a mix-integer or even a non-linear optimisation model.
- With regard to electricity demand it was assumed that there will be no reduction in useful energy demand due to rising energy prices.
- The most critical assumption is that there will be perfect competition in electricity and CO_2 emissions allowance markets. There is especially one requirement for perfect competition that has to be discussed critically, i.e. the existence of a multitude of suppliers. Due to the fact that in the PERSEUS-CERT

model operators from all European countries compete on a free European market, there are actually quite a lot of different competitors. Nevertheless, if you look at the German electricity market, there are four major power generators, producing about 80% of German electricity. But it can be argued that the power market is contestable, as innovative technologies lead to a market with relatively low barriers of entry and exit. Furthermore, perfect competition requires non-discriminatory access to the transmission grid all over Europe, which is certainly not fulfilled at the moment. Here it was assumed that in the long term we will have a regulated access to the grid all over Europe, an issue that has been mentioned in the Acceleration Directive of the European Commission. Finally it was assumed that electricity and emission certificates are homogenous goods and that consumers don't have any preferences.

- With regard to the national allocation plans (NAPs), the assumption was that in the long-term the NAPs will lead to a perfect emissions trading scheme. Therefore, until now details of the NAPs, with the help of which the total quantity of allowances to be allocated as well as the criteria for allocation to operators are determined, have not been considered in the model. Of course it has to be mentioned that the actual allocation rules used in the different European countries do not reflect an efficient allocation system. Within the allocation schemes the problem is not the allocation to existing installations; the problem is the allocation to new power plants. In most countries fuel-specific benchmarks are used, which means that most plants receive, more or less, as many allowances as they need. If a new CO_2-emission intensive installation receives more allowances than a new less CO_2-emission intensive power plant according to fuel-specific benchmarks, the economic incentives from the allocation will - to a certain extent - eliminate the intended incentive structures.
- When analysing the model results it has to be considered that there will be other criteria than costs in developing investment strategies – this also has not been considered in the model. For example, security of supply will be one of the most important criteria in the near future, which could lead to a much better position for coal. Coal can be sourced from various areas around the world, thus running a much lower risk of disruptions as a result of political instability.

6 Conclusions

The greenhouse gas emission allowance trading scheme agreed upon by the European Community resulted in a new input factor for CO_2 emission intensive companies. In order to analyse the impact of emissions trading on investment strategies in the electricity sector, the PERSEUS-CERT model has been developed and used. The model results indicate that German electric utility companies will become net sellers of emission allowances in the market. However, these net sales would be based, in part, on a reduction in power generation in Germany. Further-

more, all results obtained with the model showed that electricity production with gas will increase in the next years.

Up to the present in all PERSEUS model studies, natural gas could be bought at the world market for a fixed price. To realise a more realistic representation of the costs of gas supply, a new research project has just been realised. Within this project the PERSEUS model has been enlarged in order to represent the European gas market. Furthermore, new analyses have been started considering technologies to capture and store CO_2 (CCS (Carbon Capture and Storage)). This is due to the fact that these technologies seem to be very promising, as long as the predicted reduction of the investment costs can be realized. Finally, the PERSEUS model is actually being enlarged by integration of the allocation rules of the European NAPs in order to model e. g. the incentive structures of fuel-specific benchmarks. First results indicate that, under these conditions, generators would build more coal and lignite plants while investments in gas are less attractive compared to the scenario with an efficient allocation system.

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Appendix

indices

t := time period
f := energy carrier
seas := time slot
reg := region
p := process; standing for one operation mode of a unit
u := unit; a unit is a real physical capacity of an energy conversion technology
p_u := process belonging to the unit u
p_{reg} := process in the region reg
p_{out} := process producing final energy to satisfy demand
ghg := greenhouse gas

sets of indices

S := time slots
T := time periods
P := processes
U := units
R := regions
F := energy carriers
GHG := greenhouse gases

parameters

α := discount factor
ID := final energy demand
η_p := efficiency of the process p
in := input share
out := output share
Cvar := specific variable costs of energy carriers (e.g. fuel costs and carriage)
Cvp := specific variable costs of processes
Cfix := specific fixed costs of units
Cinv := specific investments of units
h_{seas} := hours of the time slot seas
Cpo := remaining capacity of a unit installed before the time horizon of the model
GWP := global warming potential factor
Emiss := emission factor
Erights := emissions allowances allocated

optimisation variables

PL := activity level of a process
Xi := flow of an energy carrier into a process
Xout := flow of an energy carrier out of a process
Cap := new installed capacity
Evol := emissions volume
DEmiss := volume of emission allowances traded

A case study on risk and return implications of emissions trading in power generation investments

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Abstract

This paper explores quantitative implications of the European Union Emissions Trading Scheme (EU ETS) on power capacity investment appraisal in a deregulated market. Risk and return of three different types of power plants, a gas-fired condensing power plant; a hydro power plant with a reservoir; and an off-shore wind power farm, are studied and compared in the regulatory environment of Finland. A single-firm exogenous and stochastic price model is used to simulate possible market outcomes. The model runs suggest that emissions trading increases the expected return of all three power plant technologies. The increase in risk is significant only in the case of the gas-fired power plant.

Keywords: Investment, power generation, emissions trading

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1 Introduction

An opportunity cost for greenhouse gas (GHG) emissions has become a new factor influencing investments in power generation capacity globally and, in particular, in countries with an emissions trading system. The European Union Emissions Trading Scheme (EU ETS) launched in January 2005 is the most prominent example of a greenhouse gas emissions trading system. The EU ETS introduces a considerable and fundamental price risk to the investment problem ("what is the value of emission allowances of different vintage?") (see e.g. Springer and Varilek 2004). The character of the price risk is somewhat different from that of fuels or electricity, which can be considered "genuine necessities" and are already traded in large volumes ("will emissions trading continue after 2012?"). IEA (2003, p. 31) characterizes the price risk as a "potentially critical uncertainty in power generation investment". This price risk is present in all green-field investments and power plant retrofits within the European Community. It is also present in acquisitions and divestments of either power production licenses or capacity.

Exposure of different types of power plant technologies to the risks of emissions trading differs (Table 1). For example, *a combined-cycle gas turbine (CCGT)* is a technology characterized by *control* and *operating flexibility* regarding production (e.g. IEA 2003; Moreira et al. 2004). The plant can fairly well be adjusted to the changing market conditions on a weekly and monthly level. It is run only, if its *spark spread*, i.e. the revenue from electricity production minus the variable cost, is positive. Thus, it can capture a large proportion of the best hours for producing electricity, while avoiding the unprofitable hours. It has a valuable *option to alter operating scale* (e.g. Hsu 1998; Laurikka and Koljonen 2005; Fleten and Näsäkkälä 2004; Näsäkkälä and Fleten 2004; Tseng and Barz 2002). However, there is a *fuel price* risk (e.g. Bolinger et al. 2004; Weber and Swider 2004). The EU ETS brings along direct additional risks through the impact of surrendered allowances, market price of power, and the free emission allowances (Laurikka and Koljonen 2005). A value for carbon dioxide emissions can have either a positive or a negative impact on the value of a CCGT.

A *wind power farm* is a technology characterized by low flexibility regarding optimization of production due to its intermittent nature (e.g. IEA 2003). In many countries, e.g. Germany, the output price risk (for the investor) is eliminated through the fixed feed-in tariffs provided by the government. In others, e.g. Finland, the value profile of the electricity produced depends on the correlation of the local winds with power prices. On the other hand, the allowance price risk is present only through the market price of electricity and potentially subsidies.

The adjustability of *hydro power plants with reservoirs* on a daily level is good. The technology is characterized by a *stochastically limited* flexibility regarding optimization of production, since the annual precipitation is stochastic, and the ability to transfer production from a year to the next is often limited due to the size of the reservoir. It must also be noted that correlations of wind and precipitation conditions can differ.

Table 1. Total risk factors of the power generation technologies examined

Total risk factor	Combined cycle gas turbine (CCGT)	Wind power plant	Hydro power plant with a reservoir
Technical (availability) risk	X	X	X
Public acceptance	X	X	X
Power price risk	X	X	X
Fuel price risk	X	-	-
Allowance price risk[1]	X	-	-
Allowance allocation risk	X	-	-
Subsidy risk / Windfall profit tax risk	-	X	X
Production volume risk	-	stochastic on a daily level	stochastic on an annual level

[1]direct impact

This paper explores quantitative implications of the EU ETS on power capacity investment appraisal in a deregulated market. Applying a single-firm exogenous and stochastic price simulation model[1], I examine risk and return of the three power plant types above in the regulatory environment of Finland. Whereas the CCGT and the off-shore wind power farm are realistic green-field plant options, valuation of hydro power has more relevance in acquisitions due to the highly exploited technological potential. The objective is to quantify the change in risk and return and to compare the technologies.

Section 2 briefly reviews literature on risk management in power generation investments. Section 3 presents the model used in the case study. Data applied in modeling are presented in Section 4, and the results of modeling are discussed in Section 5. Finally, the implications of the results are discussed in Section 6.

2 Risk Management in power generation investments

The Modigliani-Miller paradigm[2] of finance implies that investors able to hold a well-diversified portfolio of assets would generally not benefit from corporate-level actions to mitigate risk. In standard financial theory, the expected return on any asset is assumed to depend on its risk level. The total risk of Table 1 on the other hand comprises *systematic* and *unsystematic* components. Systematic risk, also called "the *market* risk" influences a large number of assets, and is determined through the underlying factors of the economy, such as interest rates, recessions and wars. In contrast, unsystematic risk (also: *asset-specific* or *unique* risk) affects at most a small number of assets. An investor with a large portfolio of assets can thus diversify away the unsystematic risk. For this reason, the expected return of an asset should only depend on the systematic part of the total risk.

[1] For a taxonomy on energy system models, see Ventosa et al. (2005).

[2] The paradigm says that in an idealized world without, for example, transactions costs, taxes and information costs, managers could not benefit their shareholders through active risk management.

However, companies *do* manage total risk, e.g. through the use of derivatives (see below). Several hypotheses ranging from cost of financial distress, investment policies and taxes to managerial utility maximization have been made by financial economists as to why corporate-level risk management could be rational or value-enhancing (e.g. Froot et al. 1993; Tufano 1996; Fatemi and Luft 2002). It has also been argued that closely held companies would be more likely to engage in risk management than companies with diffuse ownership (Mayers and Smith 1982).

In the power generation industry, many companies are still closely held and one can ask if the investors - in many cases municipalities, for example – really do have well-diversified portfolios. Under these circumstances, corporate-level risk mitigation may matter, since the investors cannot (or *do* not) diversify away all of the conventional asset-specific risk. For power generation, such non-diversifiable asset-specific risk could include the price of electricity or (some part of) the price of an emission allowance. A portfolio of different fuels and/or technologies would reduce the risks related to individual plants or "*plant-specific"* risks, such as technical availability or local wind speed. It would also reduce the risk related to the variable costs (e.g. fuel price, value of emission allowances to be surrendered). However, it would not get rid of all of the asset-specific risk, which would eventually be present in the market price of electricity. The electricity market then again partly reflects the market value of emission allowances. This remaining risk could also be called a "*business-specific"* risk, since it can only be diversified away through investments outside the business.

Financial hedging instruments, such as forwards, futures, swaps and options, can be used to decrease the total risk (e.g. Keppo 2002; Tanlapco et al. 2002; Vehviläinen and Keppo 2002). However, the use in the investment problem is – at least in the current situation - restricted by liquidity. This insufficiency has two dimensions. First, the time horizon of investments is very long, whereas financing instruments are principally available for periods up to three years ahead (IEA 2003). Second, emissions trading can make inclusion of new and even more illiquid financing instruments, such as weather derivatives, more important (Biello 2004). As the EU ETS introduces totally new risks to the investment project (allowance price, number of free allowances[3]), hedging also becomes more challenging than before.

Another way to secure future income is through an appropriate diversification of tangible assets (Hoff and Herig 1996; IEA 2003, p. 49). Awerbuch (e.g. 2000a, 2000b, 2004) argues that *portfolio-based* analyses, which optimize cost and risk, should be preferred to *stand-alone* project analyses. This implies that the value of the project would depend on the existing generating asset portfolio of the investor. The question arises, however, if this is too restrictive: e.g. Gustafsson (2004) explores valuation of projects in an environment, where the investor can invest both in financial securities and in a portfolio of private projects.

[3] See e.g. Laurikka and Koljonen (2005) for review.

3 Model

The model used in this paper makes a Monte Carlo simulation of selected stochastic variables in order to compare the dynamic performance of the three technologies *simultaneously* in different scenarios for emissions trading. It is based on the assumption that all the investment alternatives share the same *systematic* risk. This is a common practice in power plant valuations (see e.g. IEA/NEA 2005; IEA 2003). I thereby explore the total risk of the technologies, excluding technical and construction-related risks (e.g. IEA 2003). The hypothesis is that business-specific risks discussed above differ between technologies.

The total risk is explored through the volatility of *long-term* returns of power plant investments. This implies that I consider a simplified case, where an investor makes an irreversible investment at time t_0, and obtains the return on the investment gradually during the investment lifetime $[t_0, t_1]$. For simplicity, I exclude the case that the asset can be traded and/or closed down during $[t_0, t_1]$. This implies that the investor is *not* interested in short- to mid-term fluctuations in the asset value. The expected return on the initial investment, I, becomes:

$$E(ROI) = \frac{E(\sum DCF) - I}{I} = \sum \frac{E(CF_i)}{IR^i} - 1 \tag{1}$$

where R is the risk-adjusted discount factor.

A standard discounted cash flow (DCF) analysis is extended to better reflect the value of the option to alter operating scale (O_{scale}) for the CCGT. The extended net present value of an investment NPV_{ext} thus becomes[4]:

$$NPV_{ext} = NPV + O_{scale} \tag{2}$$

with NPV being the simple Net Present Value of the investment based on the expected cash flow. If O_{scale} is much larger than zero, the simple NPV analysis fails to valuate the investment correctly.

The value of *real options* is ideally estimated in a risk-neutral valuation framework (see e.g. Dixit and Pindyck 1994, p 120-121). I approach the value of the options through a *dynamic discounted cash flow analysis*[5] in a normal risk-adjusted valuation framework, which is applicable in incomplete markets. The starting point is a manager, who applies a *subjective* experience-based discount rate or the Weighted Average Cost of Capital (WACC) for the valuation problem.

Further, the following assumptions have been made in the model:

1. The investment decision needs to be made in 2005;
2. There are five stochastic variables with a constant correlation matrix ρ:
   - the price of electricity without emissions trading ($p_{e,base}$)
   - the price of an emission allowance (p_{CO2});
   - the price of natural gas (p_g);

[4] For more on "extended NPV", see Trigeorgis (1995).
[5] See Teisberg (1995)

- the full-load hours of hydro power (x_h); and
- the full-load hours of wind power (x_w);

3. The stochastic variables follow discrete-time continuous-state processes;
4. $p_{e,base}$, p_{CO2}, and p_g are lognormally distributed so that the expected value is given by the user and the volatility (σ_t) is given as:

$$\sigma_t^2 = \frac{\sigma^2}{2\kappa}(1 - e^{-2\kappa t}) \tag{3}$$

where κ is the rate of mean reversion, and σ the volatility at present. The time series thus resembles that of an Ornstein-Uhlenbeck process (Dixit and Pindyck, 1994, p. 74-75). The time period in the model is a year.

5. x_w and x_h are normally distributed. There is a small positive probability that this causes negative values, but with the data applied this has negligible practical implications. The volatility of x_w and x_h is simply σ.
6. Deterministic variables include the number of free allowances (N); and the tax subsidy for wind power in Finland (φ). Different scenarios with varying probabilities can be applied to the deterministic variables. The number of free allowances is considered independent from the operating strategy of the gas plant (there is no updating procedure);
7. p_{CO2} and p_g are constant within a year.
8. There are no switching costs (start-up or shut-down costs)[6];
9. The price of electricity directly depends on the allowance price (See e.g. ECON 2004; Electrowatt-Ekono 2003, Koljonen et al. 2004). As in Laurikka and Koljonen (2005), the market price of electricity, p_e, is separated into two parts, the "baseline" (business-as-usual) part ($p_{e,base}$) and the "CO_2-driven" part ($\gamma \cdot p_{CO2}$):

$$p_e = p_{e,base} + \gamma \cdot p_{CO2} \tag{4}$$

where γ is the estimated transformation factor. This is equal to the emission factor of the marginal plant, which results from the merit order in the power system. The transformation factor γ thus depends on the fluctuation in electricity supply and demand. Equation 4 allows the explicit modeling of γ. A further advantage is that there is historical data on pe, base, whereas a little is known about pe. The electricity supply in the Nordic countries - and thereby the price of electricity - significantly varies with hydrological conditions. However, the form of the price duration curve varies much less. Therefore, I add two more simplifying assumptions:

10. The marginal plant (type) in the power system and thus the transformation factor γ is a function of $p_{e,base}$ and the expected value for the emission allowance price, $E(p_{CO2})$, so that[7]:

[6] See Tseng and Barz (2002) for the importance of switching costs.

[7] This equation is derived from Laurikka (2005), who applies a simple non-linear regression to the results of ECON (2004). ECON (2004) show that the increase in the Nordic market

$$\begin{cases} \gamma(E(p_{CO2}), p_{e,base}) = Max\left[0,\ Min\left\{0.77,\ Ap_{e,base}{}^2 + Bp_{e,base} + C\right\}\right],\ so\ that: \\ A = -0.00012302 \cdot E(p_{CO2}) + 0.00223075 \\ B = 0.00205598 \cdot E(p_{CO2}) - 0.04110245 \\ C = 0.44116282 \end{cases} \tag{5}$$

11. The *form* of the duration curve of $p_{e,base}$ within any single year is constant, i.e. the proportions of peak and bottom prices vs. the average level are constant.

From Equation 4 we thus obtain for the spark spread of the gas plant:

$$S_g = p_{e,base} - \frac{p_g}{\eta} + (\gamma(p_{e,base}, E(p_{CO2})) - \frac{e_g}{\eta}) p_{CO2} - \psi \tag{6}$$

where η is the thermal efficiency, eg the emission factor and ψ the operation and maintenance cost. The annual cash flow (CFG) before income tax becomes:

$$CF_G = P_{\max} \int \max\left[S_g, 0\right] dt + Np_{CO2} - C_f - T \tag{7}$$

where Cf is the fixed cost; and T represents a potential additional tax for power generation. The annual cash flow of the hydro power plant (CFH) is calculated as:

$$CF_H = P_{\max} \int_0^{x_h} \left[p_{e,base} + \gamma(p_{e,base}, E(p_{CO2})) p_{CO2}\right] dt - C_f - T \tag{8}$$

where the integral is taken over the best hours of the year. It is thus simplistically assumed that hydro-power producers can perfectly predict when to produce. The annual cash flow of the wind power plant (CFW) is:

$$CF_W = P_{\max} x_w \left[\alpha p_{e,base} + \alpha\gamma(p_{e,base}, E(p_{CO2})) p_{CO2} + \varphi\right] - C_f - T \tag{9}$$

where α is the estimated profile factor reflecting the timing[8] of wind power production in the power system, and φ is the tax subsidy for production. Thus, CFW is not considered risk-free due to its exposure to electricity market price and emission allowance price risk.

price of electricity is a function of precipitation and of the expected value for emission allowances. If the latter is high, investments in new capacity will reduce the marginal emission factor, γ. The maximum value for γ (0.77) represents a coal-fired condensing power plant on the margin. γ must always be non-negative.

[8] If the profile factor > 1 then the timing is beneficial in terms of spot power prices, and vice versa.

The model applies an optimal input correlation matrix for the state variables. As the correlation matrix is given by the user and is potentially based on heterogenic data, it can contain inconsistent information, i.e. it is not necessarily positively semi-definite. The matrix is thus checked and corrected before simulation with the spectral decomposition procedure of Rebonato and Jäckel (1999). Before simulation the rows and columns of the matrix are also organized so that the computational error in the expected result correlation matrix is minimized[9].

4 Data

4.1 Constant parameters

The results are based on a simultaneous simulation of all three technologies with 1,000 runs in each scenario. Constant parameters are based on literature and press releases (Table 2). The investment cost and production estimates of the *off-shore wind power farm* are very much site-dependent. If the plant is situated near the coast, it produces more electricity, but the investment and O&M-costs are in all probability higher (Smekens et al. 2003; VTT 2001), which is not considered here in detail. For this reason, the values quoted here should be seen as indicative only. The profile factor (α) used in the simulation is 1.0. Monthly production and spot price data from 1996-2004 assuming perfect prediction for wind power give a profile factor of 1.02. Similar Figures have been obtained from simulations for the Nordic countries (1.02) and hourly data (0.98-1.02) for Finland and Sweden in 2001-2002 assuming perfect prediction and geographically dispersed production (Holttinen 2004).

Table 2. Technology parameters

Constants	Symbol	Unit	Gas plant	Wind farm	Hydro power plant
Output capacity	P_{max}	MW_e	250	150	325[3]
Operating lifetime	T_p	a	25[2]	25[4,5]	15[3]
Thermal efficiency	η	%	55[4]	-	-
Investment cost	I	€/kW_e	570[2]	1,450[5,6]	810[3]
Fixed cost	C_f	€/MW_e	11,000[2]	44,000[4,5]	25,000[2,4]
O&M costs and fees[1]	ψ	€/MWh_e	1.7[2,4]	-	-
Tax for power production	T	%	0	0	27% of taxable cashflow
CO_2 emission factor	e_f	gCO_2/kWh	201	0	0
Full load hours on the average	x	h	max. 7,500	2,400 nearshore[5] 3,000 offshore[6]	4,000[3]

[1]includes a precautionary stock fee,[2]Ryden 2003, [3]Kymppivoima 2004, EPV 2004
[4]Smekens et al. 2003,[5]based on PVO Engineering 2001,[6]VTT 2001

[9] See also Laurikka (2005).

Hydro power data are based on a recent trade between Etelä-Pohjanmaan Voima (EPV) and the Norwegian Statkraft within the Nordic Market, where the former leased 325 MW_e of hydropower production capacity for 15 years (Kymppivoima 2004; EPV 2004). The price was €263 million (EPV 2004). The annual full-load hours are estimated at 4,000 h (Kymppivoima 2004). There is an additional tax (*T*) for income from power production in Norway ("Grunnrenteskatt"), in which the taxable cash flow depends on the book accounts; the allowed tax-free rate of return; the spot market price and production. This tax is modeled here only roughly.

4.2 Stochastic variables and scenarios

Historical data and various estimates about future prices are used as parameters of the stochastic processes (Table 3). A high rate of mean reversion and low volatility imply that the price is likely to be close to the expected value. There are two scenarios for the allowance price (Table 4). A constant correlation matrix (Table 5) based on historical data is applied. Similar to the allowance price scenarios, two scenarios for the correlation of the allowance price with other stochastic variables are tested (Table 6).

Table 3. Assumptions on the stochastic variables

Variable	Symbol	Unit	Stochastic process	Long-run average	Volatility (%)	Rate of mean reversion
Annual average price of electricity (without emissions trading)	$p_{e,base}$	€/MWh	Lognormally distributed	24.1	33[1]	0.5[1]
Allowance price				See Table 4		
Price of natural gas	p_g	€/MWh	Lognormally distributed	2010: 14.0[2] 2020: 16.1[2] 2030: 18.2[2]	13[1]	0.3[1]
Full-load hours of wind power	x_{wind}	h	Normally distributed	2,400 near shore[5] 3,000 offshore[6]	10	-
Full-load hours of hydro power	x_{hydro}	h	Normally distributed	4,000	10	-

[1]Based on data from 1996-Sep/Oct 2004 (Nordpool, 2004; Electrowatt-Ekono, 2004)
[2]Based on data from IEA(2004) vs. 2003 prices
[3]Based on Nordpool data from 1990-10/2004 using the average price during the period (10.4 €/MWh)
[4]PVO Engineering, 2001; [5]VTT, 2001

Feasibility of combined cycle gas turbines is largely dependent on the assumptions made on prices *and* initial allocation of emission allowances (e.g. Laurikka and Koljonen 2005). Consequently, two scenarios for allocation of allowances are tested. In the first one, the free initial allocation is continued forever with tightening caps (from 6,000 reference hours before 2008 to 3,000 reference hours in 2020). In the "auction" scenario, the initial allocation is switched to auction after 2012. Both of these options can be considered realistic at this point from the point of view of an investor. It is the probabilities that matter. In the base case, I use a probability of 0.5 for both.

Table 4. Scenarios for the allowance price.

Scenario	Symbol	Unit	Stochastic process	Long-run average	Volatility (%)	Rate of mean reversion
"Low, well-predictable allowance price"	p_{CO2}	€/tCO_2	Lognormally distributed	10	20	0.2
"High, unpredictable allowance price"	p_{CO2}	€/tCO_2	Lognormally distributed	10 (-2007) 20 (2008-)	30	0.2

Table 5. User's input correlation matrix

Stochastic variable	Annual average price of electricity (without emissions trading)	Price of natural gas	Full-load hours of wind power	Full-load hours of hydro power
Annual average price of electricity (without emissions trading)	1	0.5[2]	0.1[1]	-0.7[1]
Price of natural gas		1	0.1[1]	0[3]
Full-load hours of wind power			1	0.2[1]
Full-load hours of hydro power				1

[1]based on annual average (gas on a monthly basis, electricity on a weekly basis) data in Finland 1996-2003
[2]based on annual average (gas on a monthly basis, electricity on a weekly basis) data in Finland 1996-2004
[3]based on annual average data in Finland 1990-2003

Wind power currently obtains a tax subsidy in Finland of 6.9€/MWh. The subsidies are under consideration at the moment, and the long-term position of the subsidy is uncertain. I consider a scenario where the subsidy is removed after 2012 due to the increased competitiveness and set the probability to 0.5 in the base case.

I further assume that the subsidy is reduced anyway by 20%. In addition to the tax subsidy, I assume an investment subsidy of 20% in the base case. The annual full-load hours are assumed to be 2,400 h in the "base scenario".

Table 6. Correlation scenarios for the allowance price.

Scenario	Annual average price of electricity (without emissions trading)	Price of natural gas	Full-load hours of wind power	Full-load hours of hydro power
"No correlations" scenario	0	0	0	0
"Correlations" scenario	0.3	0.7	0	-0.3

5 Results

The model runs show that emissions trading increases the expected return of all three power plant technologies (Table 7) with the function γ assumed for the marginal emission factor. The increase in risk is significant only for the CCGT: emissions trading can almost triple the total risk of the CCGT. The absolute increase in the risk of the wind power plant is very small, and the hydro power plant seems profitable in spite of volatility within an emissions trading scheme.

Table 7. Expected return on investment (*E(ROI)*) and its standard deviation (in brackets) in the "base-scenarios" (based on 1,000 model runs)

Scenario	"No correlations"		"Correlations"	
No emissions trading	CCGT: -84% (5.4%) Wind: -72 % (4.3%) Hydro: -6% (2.7%)			
"Low, well-predictable allowance price"	CCGT: Wind: Hydro:	-36% (8.0 %) -57% (4.4 %) +19% (3.2 %)	CCGT: Wind: Hydro:	-47% (8.1%) -56% (4.4%) +21% (3.3%)
"High, unpredictable allowance price"	CCGT: Wind: Hydro:	-8% (11%) -45% (4.4 %) +37% (3.4 %)	CCGT: Wind: Hydro:	-2% (13 %) -42% (4.5%) +44% (4.2%)

In the base-scenarios, the investment in the CCGT seems non-viable, but emissions trading decreases the expected loss. The investment becomes viable in the "correlations" scenario with a high allowance price, if the free of charge allocation is certain (Table 8): *E(ROI)* = +6% (σ = 8.8%). On the other hand, certainty about an auction scheme increases the expected loss to -11% (σ = 9.3%).

The off-shore wind power farm seems viable only in the most optimistic case (Table 8). Certainty in tax subsidy for production, a higher number of full-load hours (3,000) and a higher investment subsidy of 30% in the best emissions trading

scenario (high allowance price, correlations) gives modest positive numbers for the project. Emissions trading alone is not enough if the subsidies are removed.

The investment in the hydro power plant seems to become profitable in an emissions trading environment. The expected return can grow up to 44% with the allowance price scenarios tested without a significant impact on risk.

From the risk management perspective, it is interesting to note that the correlations of the project returns are fairly low (0.15-0.61) in scenarios, where the regulatory uncertainty (allocation, subsidies) is not resolved, but high (0.70-0.84) in the scenario, where no regulatory uncertainty exists (Table 9). A higher value for emission allowance somewhat increases the correlation of the wind power plant and hydro power plant returns. The impact on other correlations depends on the scenario.

Table 8. Sensitivity analysis in the "High, unpredictable allowance price"-scenario with "Correlations"

Technology	Pessimistic[1]	Base-case	Optimistic[2]
CCGT	-11% (9.3%)	-2% (13 %)	+6% (8.8%)
Wind	-57% (1.4%)	-42% (4.5%)	+3% (2.6%)

[1]CCGT: auction after 2012, Wind: certainty about subsidy removal, no investment sub sidy

[2]CCGT: free allocation forever, Wind: full-load hours: 3,000 hours, investment subsidy 30%, subsidy maintained

Table 9. Correlations of project returns in different scenarios

Correlation of project returns	No emissions trading	"Low well-predictable allowance price"	"High unpredictable allowance price"	"High unpredictable allowance price", Optimistic[1]
CCGT-Wind	0.16-0.18	0.17-0.19	0.15-0.24	0.79-0.83
Wind-Hydro	0.18-0.23	0.24-0.28	0.26-0.28	0.75-0.79
CCGT-Hydro	0.56	0.52-0.61	0.44-0.59	0.70-0.84

[1]See Table 8

The average error in the result correlations was about ±0.14 in the "Correlations" -scenario, and ±0.02 in the "No correlations"- scenario.

6 Conclusions

This article has explored the impact of emissions trading on the risk and return of three power generation technologies through hypothetical case-studies in Finland. The model runs suggest that the EU ETS increases the expected return of all three power plant technologies due to the higher market price of electricity and the free

allowances. The increase in risk compared to the expected return is significant only in the case of the CCGT.

With the data used here, the EU ETS can increase the expected return of CCGT and off-shore wind power investment enough to make them economically viable, but only in the most favorable scenario. This is in contrast to Laurikka and Koljonen (2005), who studied viability of a CCGT with a stochastic model using a constant fuel price. The positive correlation applied here changed the outcome.

Investment in an existing hydropower plant can be portrayed as a "high-profit, low-risk" investment within the EU ETS with the data used. Such opportunities can obviously be expected to be rare in competitive markets, particularly as opportunities for green-field hydropower in Europe are small. The prices are therefore likely to adapt. Combined cycle gas turbines seem to be "negative-to-low-profit, high-risk" investments, and off-shore wind power a "negative-to-low-profit, low-risk" investment. Off-shore wind power is viable only in good wind conditions with subsidies.

Regulatory certainty concerning allocation of allowances increases (free allocation) or decreases (auction) expectations on profit for CCGT, and somewhat decreases the total risk. The total risk of a CCGT grows within an emissions trading scheme also through higher volatility of market prices of electricity, gas and emission allowances. Similarly, regulatory certainty concerning wind power tax subsidy decreases or increases profit expectations. It is, however, not significant for the total risk.

Opportunities for portfolio diversification with the technologies studied are low, since the low correlations in Table 9 are caused by the regulatory uncertainty. Unless the regulatory uncertainty is resolved positively, the expected returns of CCGT and off-shore wind power fall below zero, and the technologies cannot belong to an efficient portfolio. The high correlation is caused by the market prices of electricity and emission allowance that affect all the technologies.

I have assumed that electricity producers are not penalized for potential windfall profits, i.e. there is no increase in the additional tax, T, for wind and hydro power due to emissions trading. Such a tax would obviously reduce the expected return on investment. I further assumed that hydro power and CCGT investments were idealized assuming perfect prediction and no start-up or shut-down costs. Taxation was not analyzed in detail, and technical risks were ignored. All three technologies were assumed to share the same systematic risk. It was also presumed that the systematic risk is not significantly affected through the introduction of emissions trading. For a power capacity investment, the correlation of the value of the asset with the market portfolio is difficult to determine, since traded twin securities are hard to find. More careful attention should be paid to the validity of this last assumption, particularly in situations where the price of allowances becomes very high.

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Investment decisions and emissions trading

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Abstract

The presented model offers a general approach to valuating investments with special regard to tradable emissions permits and uncertainty. By deriving the payments required for a financial valuation from production theory and production planning and by applying duality theory, it is possible to identify the determinants of the price ceiling for an investment. Certain discrete option pricing models can be derived as special cases. Sensitivity analysis shows that tradable permits have several effects on an investment and do not always encourage environmentally beneficial investments – in particular cases they even may be counterproductive.

Keywords: Emissions trading, investment decisions, price ceiling, (corrected) net present value, sensitivity analysis

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1 Introduction

As a result of the Kyoto Conference in 1997 and the European emissions trading directive[1], Germany is currently implementing a system of emissions trading which will commence in the beginning of 2005. In order to meet the Kyoto targets, Germany must reduce 17 million metric tons of carbon dioxide (CO_2) emissions by 2012. The industrial and energy sectors are particularly affected: According to the German National Allocation Plan – which is the core element of the emissions trading system and a result of the European directive – these two sectors together have to reduce 10 million metric tons; transport, the trade/commerce/service sectors, and private households have to contribute to the remaining share. The necessary laws and binding regulations were published in the summer of 2004,[2] and the allowances will be issued in November. In this context this paper examines, from a corporate point of view, how an emissions trading system can provide an incentive for investing in environmental protection technology. Since many environmental impacts of pollution have not yet been explored to their full extent, and because of changes in environmental policy and ecological awareness (especially after severe ecological accidents), this analysis will consider uncertainty.

Hence, after a short explanation of methodology, this article derives the required payments and constraints from production theory and production planning with special regard to tradable permits and joint production. On this basis, it will be possible to develop a valuation model and to examine the determinants of the price ceiling for an investment in environmental protection technology. We will see that results of environmental economics are confirmed for a single investment. However, in particular cases, systems of emissions allowances may be even *counterproductive* for environmentally beneficial investments. A conclusion will summarize the main results.

[1] Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC, Official Journal of the European Union L 275/32.

[2] Compare Gesetz über den Handel mit Berechtigungen zur Emission von Treibhausgasen of 8 Juli 2004 (BGBl. I p. 1578), Gesetz über den nationalen Zuteilungsplan für Treibhausgas-Emissionsberechtigungen in der Zuteilungsperiode 2005 bis 2007 of 26 August 2004 (BGBl. I p. 2211), Verordnung über die Zuteilung von Treibhausgas-Emissionsberechtigungen in der Zuteilungsperiode 2005 bis 2007 of 31 August 2004 (BGBl. I p. 2255), Kostenverordnung zum Treibhausgas-Emissionshandelsgesetz und zum Zuteilungsgesetz 2007 of 31 August 2004 (BGBl. I p. 2273).

2 Methodology – the theoretical framework for valuation under uncertainty

According to *Matschke* and *Jaensch* a financial valuation consists of two steps:[3]

The **basic program** calculates the value of the present investment program, which does not contain the investment to be valuated. Using the approach of *Hax* and *Weingartner*, adapted to uncertainty, it calculates the maximum utility (here: the maximum sum of weighted withdrawals) under constraints.[4]

The second step (the **valuation program**) refers to the situation *after* realizing the investment.[5] Provided that the utility of the new investment program, including the investment to be valuated, is not less than before (= in the optimal solution of the basic program), it computes the price ceiling or, in other words, the maximum payable price for the investment.

Uncertainty, for instance as a result of either reiterative changes in environmental policy, changes in the ecological awareness, or conditions of liberalized energy markets, can be taken into account by using decision trees.[6] With an adequate numeration of states, it is possible to adjust the approach of *Hax* and *Weingartner* to uncertainty. Then, under special assumptions regarding the tree structure and the development of payments, certain discrete option pricing models, such as the binomial model of *Cox/Ross/Rubinstein* and *Rendleman/Bartter*, can be derived as special cases.[7] As in these option pricing models, the valuation considers payments in *all* possible states. Information on probabilities, means or variances is not necessary. We therefore have dominance considerations and do not need the principle of *Bernoulli*; in fact, we gain valuable information regardless of the required axioms for this principle.

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[3] Compare Jaensch 1966a, pp. 138-139, Jaensch 1966b, pp. 664-665, and Matschke 1969, pp. 58-66, Matschke 1972, pp. 153-155, Matschke 1975, pp. 253-257, 387-390, and Hering 1999, pp. 54-55.

[4] For the case of certainty cp. Weingartner 1963, pp. 171-172, Hax 1964, pp. 439-441, Baumol/Quandt 1965, pp. 323-328, Franke/Laux 1968, pp. 743-744; for the adaption to uncertainty cp. Klingelhöfer 2003a, pp. 290-291 and Hering 2003, pp. 262-264.

[5] This way, the model treats the indivisibility of the investment to be valuated (0-1 decision).

[6] For the use of decision trees cp. Magee 1964a, Magee 1964b, Mao 1969 and in the context of investment planning cp. Laux 1969, pp. 730-742, Laux 1971, pp. 19-22, 39-44, and Klingelhöfer 2003a, pp. 284-288.

[7] Compare Cox/Ross/Rubinstein 1979 and Rendleman/Bartter 1979.

3 Derivation of the payments from production theory and production planning

In order to obtain the necessary information for computing the effects of emissions trading, the required payments and constraints have to be derived from production theory and production planning.

Every production – especially with regard to the environment – is characterized as joint production: Using activity analysis of production,[8] the one-time realization of the production process β (for example, one hour) – the so-called basic activity B,β – will lead to the following vector $\underline{\varphi}^{B,\beta}$ of input and output commodities φ_ε:[9]

$$\underline{\varphi}^{B,\beta} = (\varphi_1, \ldots, \varphi_{m+n})' = (\underline{r}'; \underline{x}')' = (r_1, \ldots, r_m; x_1, \ldots, x_n)' \tag{3.1}$$

with m inputs r_μ (e.g. material, fuel, labor, etc.) and n outputs x_ν (like products, electricity, heat, CO_2, SO_x, NO_x).

Then, every possible production of a technology $\boldsymbol{T}$ is a linear combination of the q basic activities with nonnegative coefficients λ^β (which represent the levels of the activities β):

$$\forall \underline{\varphi} = (\underline{r}'; \underline{x}')' \in \boldsymbol{T}: \qquad \underline{\varphi} = \sum_{\beta=1}^{q} \underline{\varphi}^{B,\beta} \cdot \lambda^\beta \ . \tag{3.2}$$

Introducing a price system with positive prices for the input of waste and the output of products, prices equal zero for neutral inputs and outputs (for example, air and water in certain cases) and negative prices for the input of (traditional) factors of production (primary commodities such as labor or fuel) and the output of waste leads to the contribution margin CM:

$$CM(\underline{\varphi}) = \underline{p}' \cdot \underline{\varphi} = \underline{p}' \cdot \sum_{\beta=1}^{q} \underline{\varphi}^{B,\beta} \cdot \lambda^\beta = CM(\underline{\lambda}) \ . \tag{3.3}$$

Under the conditions of joint production, this contribution margin CM is process specific. To integrate the consequences of tradable permits to the production program, the objective function and the restrictions have to be modified:[10] Each

[8] Compare Koopmans 1957, pp. 71-83, Koopmans 1959, Debreu 1959, pp. 37-49, Wittmann 1968, pp. 1-20, 102-113, Nikaido 1968, pp. 180-185, Kistner 1993, pp. 54-64, 239-245, Dyckhoff 1994, pp. 48-58, 73-87, 155-173, Steven 1994, pp. 82-86, and Klingelhöfer 2000, pp. 222-252, 417-442.

[9] Here and in the following the underlining of a variable denotes a vector and " ′ " the transposition of a vector.

[10] For the modelling of tradable permits in production planning cp. Klingelhöfer 2003b, pp. 106-112 and Klingelhöfer 2000, pp. 497-503.

tradable permit (TP) allows emission of the quantity b^{TP} of the restricted outputs (e.g. CO_2 equivalents). This may be a joint regulation of several substances x_ν at the same time (with the coefficients a_ν^{TP} according to their environmental hazardousness).[11] If a producer needs to cover more emissions than allowed by his initial endowment of tradable permits (quantity TP^{IE}), he has to buy tradable permits (TP^+); otherwise he can sell parts of his stock (TP^-):

$$\sum_{\beta=1}^{q}\sum_{\nu=1}^{n} a_\nu^{TP}\cdot x_\nu^{B,\beta}\cdot\lambda^\beta \;\le\; b^{TP}\cdot\left(TP^{IE}-TP^-+TP^+\right). \tag{3.4}$$

Adding terms for sales (prices p^{TP-}) and purchases (prices p^{TP+}) of tradable permits to Eq. (3.3) leads to the following consequences for the contribution margin CM:

$$CM(\underline{\lambda},TP^+,TP^-)=\underline{p}'\cdot\sum_{\beta=1}^{q}\underline{\varphi}^{B,\beta}\cdot\lambda^\beta+p^{TP-}\cdot TP^--p^{TP+}\cdot TP^+ \tag{3.5}$$

Considering that the prices of the tradable permits are discrete functions of supply (price intervals h1) and demand (price intervals h2), we receive a modified formulation:[12]

$$CM(\underline{\lambda})=\underline{p}'\cdot\sum_{\beta=1}^{q}\underline{\varphi}^{B,\beta}\cdot\lambda^\beta+\sum_{h1}p_{h1}^{TP-}\cdot TP_{h1}^-\;-\sum_{h2}p_{h2}^{TP+}\cdot TP_{h2}^+ \tag{3.6}$$

and for the emissions restriction by tradable permits:

$$\sum_{\beta=1}^{q}\sum_{\nu=1}^{n} a_\nu^{TP}\cdot x_\nu^{B,\beta}\cdot\lambda^\beta \;\le\; b^{TP}\cdot\left(TP^{IE}-\sum_{h1}TP_{h1}^-+\sum_{h2}TP_{h2}^+\right) \tag{3.7}$$

with the partial amounts of tradable permits in accordance with the discrete price functions:[13]

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[11] For example, the carbon equivalents of non-CO_2 greenhouse gases like methane (CH_4) or di-nitrous oxide (N_2O) "are calculated from the CO_2-equivalents, using the 100-year global warming potentials (GWPs): CH_4 = 21, N_2O = 310" (Intergovernmental Panel on Climate Change 1996, p. 11).

[12] This is obvious, if the tradable permits are indivisible. But even in the theoretical case of divisibility, emissions allowances usually will be sold in lots referring to certain price intervals.

[13] The producer cannot sell more tradable permits than his initial endowment TP^{IE}; he is only able to buy the difference between tradable permits issued by the government TP^{issued} and his initial endowment TP^{IE}. Special order conditions are not necessary since prices increase with the demand for tradable permits and decline with the supply.

$$0 \le TP_{h1}^{-} \le TP_{h1}^{-,max} \quad \forall h1 \qquad (3.8)$$
$$\left(\Rightarrow 0 \le TP^{-} = \sum_{h1} TP_{h1}^{-} \le \sum_{h1} TP_{h1}^{-,max} = TP^{IE} \right)$$

$$0 \le TP_{h2}^{+} \le TP_{h2}^{+,max} \quad \forall h2 \qquad (3.9)$$
$$\left(\Rightarrow 0 \le TP^{+} = \sum_{h2} TP_{h2}^{+} \le \sum_{h2} TP_{h2}^{+,max} = TP^{issued} - TP^{IE} \right).$$

Having derived the consequences (3.6)-(3.9) of tradable permits to the payments and the constraint system from production theory and production planning, we can use this information in the basic program and in the valuation program.

4 Valuation of investments in environmental protection technology with regard to tradable permits

According to section 2, the basic program calculates the value of the present investment program without realization of the investment to be valuated. This means that we have to maximize the utility U of the present and future withdrawals W_s, where $s \in \{0; 1; 2; \ldots; S\}$ denotes the present and the S future states.

$$U = U(W_0, W_1, \ldots, W_S) \rightarrow \max. \qquad (4.1)$$

Normally, in financial valuation, there are two possibilities for making this objective function operational: Maximize the value at distinct states (e.g. today or at the time horizon), or maximize the stream of withdrawals (e.g. the annuity). However, in case of uncertainty, only the first one is economically wise.[14] Hence, assuming that the optimal pattern of consumption between the states is determined and known, the **basic program** maximizes the sum SWW of weighted withdrawals $w_s \cdot W_s$ subject to the constraints of investment and production.[15] The liquidity constraints have to be adjusted, because – besides the payments z_{js} from the other

[14] In the case of uncertainty, maximizing the stream of withdrawals leads to a "bottleneck" optimization: the branch with the lowest maximum stream of withdrawals is restricting the rest of the tree. Therefore, there may be payments at the horizon states without positive values with respect to the objective function – an economically nonsensical situation. Compare Klingelhöfer 2003a, p. 286.

[15] Compare footnote 4.

projects inv_j (e.g. other investments and financial transactions)[16] and the withdrawals W_s – they also have to contain

- the contribution margins of the production processes β and the payments from emissions trading according to Eq. (3.6), and, furthermore,
- the payments uz_s that are independent from production quantities and from the investment program (e.g. additional individual deposits, fixed rents, taxes or fees determined in former periods, determined payments resulting from objects realized in former periods). Thus, these payments uz_s are (positive or negative) right-hand-side constants of the problem.

$$\textbf{max. SWW}, \quad SWW := \sum_{s=0}^{S} w_s \cdot W_s \tag{4.2}$$

subject to:

Liquidity constraints (capital budget constraints) for the S+1 states s:

$$-\sum_{j=1}^{J} z_{js} \cdot inv_j - \sum_{\beta=1}^{q} \sum_{\varepsilon=1}^{m+n} p_{\varepsilon s} \cdot \varphi_{\varepsilon}^{B,\beta} \cdot \lambda_s^{\beta} - \sum_{h1} p_{h1,s}^{TP-} \cdot TP_{h1,s}^{-} + \sum_{h2} p_{h2,s}^{TP+} \cdot TP_{h2,s}^{+} + W_s \le uz_s \qquad \forall\, s \in \{0; 1; \ldots; S\}$$

Production constraints by tradable permits for the S+1 states s (cp. (3.4)):

$$\sum_{\beta=1}^{q} \sum_{\nu=1}^{n} a_{\nu s}^{TP} \cdot x_{\nu}^{B,\beta} \cdot \lambda_s^{\beta} + b_s^{TP} \cdot \left(\sum_{h1} TP_{h1,s}^{-} - \sum_{h2} TP_{h2,s}^{+} \right) \le b_s^{TP} \cdot TP_s^{IE} \qquad \forall\, s \in \{0; 1; \ldots; S\}$$

Γ_s other production constraints γ for the S+1 states s:

$$\sum_{\beta=1}^{q} \sum_{\varepsilon=1}^{m+n} a_{\varepsilon\gamma s} \cdot \varphi_{\varepsilon}^{B,\beta} \cdot \lambda_s^{\beta} \le b_{\gamma s} \qquad \forall\, \gamma \in \{1; 2; \ldots; \Gamma_s\} \qquad \forall\, s \in \{0; 1; \ldots; S\}$$

Limits of emissions trading for the S+1 states s:

$$TP_{h1,s}^{-} \le TP_{h1,s}^{-,max} \qquad \forall\, h1 \qquad \forall\, s \in \{0; 1; \ldots; S\}$$

[16] These other projects characterize alternative uses of capital. Since they are also decision relevant, a problem of simultaneous investment and production planning has to be solved. For example, depending on production and emissions trading, there may result other lending and borrowing opportunities – and therefore other endogeneous interest rates.

$$TP^{+}_{h2,s} \le TP^{+,max}_{h2,s} \qquad \forall\, h2 \qquad \forall\, s \in \{0; 1; \ldots; S\}$$

Restrictions of quantity of J other investment objects and financial transactions:

$$inv_j \le inv_j^{max} \qquad \forall\, j \in \{1; 2; \ldots; J\}$$

q activity level constraints for the S+1 states s:

$$\lambda_s^{\beta} \le \lambda_s^{\beta,max} \qquad \forall\, \beta \in \{1; 2; \ldots; q\} \qquad \forall\, s \in \{0; 1; \ldots; S\}$$

Non-negativity conditions:

$$inv_j, \lambda_s^{\beta}, TP^{-}_{h1,s}, TP^{+}_{h2,s}, W_s \ge 0 \qquad \forall\, j \in \{1; 2; \ldots; J\} \qquad \forall\, \beta \in \{1; 2; \ldots; q\}$$
$$\forall\, h1 \qquad \forall\, h2 \qquad \forall\, s \in \{0; 1; \ldots; S\}$$

The **valuation program** has nearly the same structure, but a different objective function VAL – the maximization of the payable price p_{IEP} of the investment in environmental protection technology (index IEP). In addition, the constraints have to include the effects of this environmentally beneficial investment; the minimum withdrawal constraint also has to be respected, since it ensures that the utility (= sum of weighted withdrawals) is not less than before (= in the optimal solution of the basic program).

max. VAL; $\quad VAL := p_{IEP}$ (4.3)

subject to:

Liquidity constraints (capital budget constraints) for the S+1 states s (including the price p_{IEP}):

$$-\sum_{j=1}^{J} z_{j0} \cdot inv_j - \sum_{\beta=1}^{q} \sum_{\varepsilon=1}^{m+n} p_{\varepsilon 0} \cdot \varphi_{\varepsilon}^{B,\beta} \cdot \lambda_0^{\beta} - \sum_{h1} p_{h1,0}^{TP-} \cdot TP^{-}_{h1,0} + \sum_{h2} p_{h2,0}^{TP+} \cdot TP^{+}_{h2,0}$$
$$+ W_0 + p_{IEP} \le uz_0 + z_{IEP,0} + \sum_{\varepsilon=1}^{m+n} p_{\varepsilon 0} \cdot \varphi_{\varepsilon}^{B,IEP} \cdot \lambda_0^{IEP}$$

$$-\sum_{j=1}^{J} z_{js} \cdot inv_j - \sum_{\beta=1}^{q} \sum_{\varepsilon=1}^{m+n} p_{\varepsilon s} \cdot \varphi_{\varepsilon}^{B,\beta} \cdot \lambda_s^{\beta} - \sum_{h1} p_{h1,s}^{TP-} \cdot TP^{-}_{h1,s} + \sum_{h2} p_{h2,s}^{TP+} \cdot TP^{+}_{h2,s}$$
$$+ W_s \le uz_s + z_{IEP,s} + \sum_{\varepsilon=1}^{m+n} p_{\varepsilon s} \cdot \varphi_{\varepsilon}^{B,IEP} \cdot \lambda_s^{IEP} \qquad \forall\, s \in \{1; 2; \ldots; S\}$$

Production constraints by tradable permits for the S+1 states s (cp. (3.4)):

$$\sum_{\beta=1}^{q} \sum_{\nu=1}^{n} a_{\nu s}^{TP} \cdot x_{\nu}^{B,\beta} \cdot \lambda_s^{\beta} + \sum_{\nu=1}^{n} a_{\nu s}^{TP} \cdot x_{\nu}^{B,IEP} \cdot \lambda_s^{IEP} + b_s^{TP} \cdot \left(\sum_{h1} TP^{-}_{h1,s} - \sum_{h2} TP^{+}_{h2,s} \right)$$

$$\leq b_s^{TP} \cdot TP_s^{IE} \qquad \forall s \in \{0; 1; \ldots; S\}$$

Γ_s other production constraints γ for the S+1 states s:

$$\sum_{\beta=1}^{q} \sum_{\varepsilon=1}^{m+n} a_{\varepsilon\gamma s} \cdot \varphi_\varepsilon^{B,\beta} \cdot \lambda_s^\beta + \sum_{\varepsilon=1}^{m+n} a_{\varepsilon\gamma s} \cdot \varphi_\varepsilon^{B,IEP} \cdot \lambda_s^{IEP} \leq b_{\gamma s}$$

$$\forall \gamma \in \{1; 2; \ldots; \Gamma_s\} \qquad \forall s \in \{0; 1; \ldots; S\}$$

Minimum withdrawal constraint (ensures that the utility is not less than before):

$$-\sum_{s=0}^{S} w_s \cdot W_s \leq -SWW^{opt}$$

Limits of emissions trading for the S+1 states s:

$$TP_{h1,s}^{-} \leq TP_{h1,s}^{-,max} \qquad \forall h1 \qquad \forall s \in \{0; 1; \ldots; S\}$$

$$TP_{h2,s}^{+} \leq TP_{h2,s}^{+,max} \qquad \forall h2 \qquad \forall s \in \{0; 1; \ldots; S\}$$

q + 1 activity level constraints:

$$\lambda_s^\beta \leq \lambda_s^{\beta,max} \qquad \forall \beta \in \{1; 2; \ldots; q; IEP\} \qquad \forall s \in \{0; 1; \ldots; S\}$$

Restrictions of quantity of other investment objects and financial transactions:

$$inv_j \leq inv_j^{max} \qquad \forall j \in \{1; 2; \ldots; J\}$$

Non-negativity conditions:

$$inv_j, \lambda_s^\beta, TP_{h1,s}^{-}, TP_{h2,s}^{+}, W_s, p_{IEP} \geq 0 \qquad \forall j \in \{1; 2; \ldots; J\}$$

$$\forall \beta \in \{1; 2; \ldots; q; IEP\} \quad \forall h1 \quad \forall h2 \quad \forall s \in \{0; 1; \ldots; S\}$$

In the event of the existence of a finite positive solution, according to duality theory of linear programming, we obtain information about the determinants of the maximum payable price by inserting the optimal solution of the dual. Using complementary slackness conditions allows interpretation of the mathematical formula in an economic manner:

By introducing the dual variables

- l_s for the liquidity constraints,
- π_s^{TP} for the production constraints by tradable permits,
- $\pi_{s\gamma}$ for the other production constraints,
- ξ_j for the quantity restrictions of the other investment objects and financial transactions,
- $\zeta_{h1,s}^{TP-}$ and $\zeta_{h2,s}^{TP+}$ for the limits of emissions trading,

– ζ_s^{β} for the activity level constraints,

and dividing the dual constraints of the decision variables by l_0, we obtain the (corrected) net present values $NPV^{(corr)}$ of:[17]

- using the processes β (including IEP) in the states s:

$$NPV^{corr}\left(\lambda_s^{\beta}\right) := \underbrace{\sum_{\varepsilon=1}^{m+n} p_{\varepsilon s} \cdot \varphi_{\varepsilon}^{B,\beta} \cdot \frac{l_s}{l_0}}_{NPV\left(\lambda_s^{\beta}\right)} - \underbrace{\left(\sum_{\nu=1}^{n} a_{\nu s}^{TP} \cdot x_{\nu}^{B,\beta} \cdot \frac{\pi_s^{TP}}{l_0} + \sum_{\gamma=1}^{\Gamma_s} \sum_{\varepsilon=1}^{m+n} a_{\varepsilon\gamma s} \cdot \varphi_{\varepsilon}^{B,\beta} \cdot \frac{\pi_{\gamma s}}{l_0} \right)}_{\text{Correction}} \leq \frac{\zeta_s^{\beta}}{l_0} \tag{4.4}$$

$NPV^{corr}\left(\lambda_s^{\beta}\right) :=$ discounted process contribution margin

– (discounted monetary equivalent of the required emissions contingent restricted by tradable permits

+ discounted monetary equivalent of the required capacity of the other production constraints)

- realization of other investment objects and financial transactions j:

$$NPV\left(inv_j\right) := \sum_{s=0}^{S} z_{js} \cdot \frac{l_s}{l_0} = \sum_{s=0}^{S} z_{js} \cdot \rho_{s,0} \leq \frac{\xi_j}{l_0} \tag{4.5}$$

$NPV\left(inv_j\right) :=$ discounted payments

[17] All the following (corrected) net present values NPV can be derived from the basic program (4.2) as well as from the valuation program (4.3). However, the dual variables – and consequently the endogenous discount factors $\rho_{s,0} = l_s/l_0$ to discount payments in state s to state 0 – normally differ between the two programs. Especially, $l_0 = 1$ and therefore $\rho_{s,0} = l_s$ for all the (corrected) NPVs derived from the valuation program: For the case of an existing finite positive solution $p_{IEP} > 0$ of the primal and dual valuation program, we can deduce $l_0 = 1$ from the complementary slackness condition $p_{IEP}(1 - l_0) = 0$.

- sales of tradable permits in price interval h1, state s:

$$NPV^{corr}\left(TP^{-}_{h1,s}\right) := \underbrace{p^{TP-}_{h1,s} \cdot \frac{l_s}{l_0}}_{NPV\left(TP^{-}_{h1,s}\right)} \underbrace{- b^{TP}_{s} \cdot \frac{\pi^{TP}_{s}}{l_0}}_{\text{Correction}} \leq \frac{\zeta^{TP-}_{h1,s}}{l_0} \tag{4.6}$$

$NPV^{corr}\left(TP^{-}_{h1,s}\right) :=$ discounted price

– discounted monetary equivalent of allowed emissions

- purchases of tradable permits in price interval h2, state s:

$$NPV^{corr}\left(TP^{+}_{h2,s}\right) := \underbrace{-p^{TP+}_{h2,s} \cdot \frac{l_s}{l_0}}_{NPV\left(TP^{+}_{h2,s}\right)} \underbrace{+ b^{TP}_{s} \cdot \frac{\pi^{TP}_{s}}{l_0}}_{\text{Correction}} \leq \frac{\zeta^{TP+}_{h2,s}}{l_0} \tag{4.7}$$

$NPV^{corr}\left(TP^{+}_{h2,s}\right) :=$ – discounted price

+ discounted monetary equivalent of allowed emissions

It is remarkable that, on the one hand, the tradability of emissions allowances – without changes in the basis variables – does not have any direct influence on the NPV^{corr} of the investment or of the other processes (4.4).[18] However, on the other hand, it leads to **additional NPV^{corr}** (4.6) and (4.7) for the *trade* of emissions allowances.

If we use the (corrected) net present values (4.4)-(4.7) to substitute the dual variables of the valuation (VP) and the basic program (BP) in the equation for the dual equation for the maximum payable price, we obtain with the dual variable δ of the withdrawal constraint:[19,20]

[18] Since the corrected NPVs refer to the optimal solution of a simultaneous planning problem, indirect influences result from the dual variables.

[19] Due to the minimum withdrawal constraint, the valuation program takes into account the optimal solution SWW^{opt} of the basic program. According to duality theory of linear programming in the event of the existence of a finite positive solution, the optimal solution of the primal and the dual problem are equal. Ergo, it is possible to insert the optimal solution of the dual basic program for SWW^{opt} in the withdrawal constraint of the valuation program. Then the equation of the price ceiling, which results from equating the optimal solutions of the primal and the dual valuation program, contains variables of the valuation program and the corresponding ones of the basic program.

[20] δ calculates the value of a marginal increase in SWW^{opt} referring to the objective function of the valuation program (the price ceiling p^{opt}_{IEP}).

$$
\begin{aligned}
p_{IEP}^{opt} = & \underbrace{\sum_{s=0}^{S} z_{IEP,s} \cdot \rho_{s,0}^{VP}}_{(1)} + \underbrace{\sum_{NPV^{corr}\left(\lambda_s^{IEP}\right)>0} \lambda_s^{IEP,max} \cdot NPV^{corr}\left(\lambda_s^{IEP}\right)}_{(2)} \\
& + \underbrace{\begin{aligned} & \sum_{NPV^{corr,VP}\left(\lambda_s^{\beta}\right)>0} \lambda_s^{\beta,max} \cdot NPV^{corr,VP}\left(\lambda_s^{\beta}\right) \\ & - \delta \cdot \sum_{NPV^{corr,BP}\left(\lambda_s^{\beta}\right)>0} \lambda_s^{\beta,max} \cdot l_0^{BP} \cdot NPV^{corr,BP}\left(\lambda_s^{\beta}\right) \end{aligned}}_{(3)} \\
& + \underbrace{\begin{aligned} & \sum_{NPV^{VP}\left(inv_j\right)>0} inv_j^{max} \cdot NPV^{VP}\left(inv_j\right) \\ & - \delta \cdot \sum_{NPV^{BP}\left(inv_j\right)>0} inv_j^{max} \cdot l_0^{BP} \cdot NPV^{BP}\left(inv_j\right) \end{aligned}}_{(4)} \\
& + \underbrace{\begin{aligned} & \sum_{s=0}^{S} \left[uz_s \cdot \left(\rho_{s,0}^{VP} - \delta \cdot l_s^{BP} \right) + \sum_{\gamma=1}^{\Gamma_s^{VP}} b_{\gamma s}^{VP} \cdot \pi_{\gamma s}^{VP} - \delta \cdot \sum_{\gamma=1}^{\Gamma_s^{BP}} b_{\gamma s}^{BP} \cdot \pi_{\gamma s}^{BP} \right. \\ & \left. + b_s^{TP} \cdot TP_s^{IE,VP} \cdot \pi_s^{TP,VP} - \delta \cdot b_s^{TP} \cdot TP_s^{IE,BP} \cdot \pi_s^{TP,BP} \right] \end{aligned}}_{(5)-(7)} \\
& + \underbrace{\begin{aligned} & \sum_{NPV^{corr,VP}\left(TP_{h1,s}^{-}\right)>0} TP_{h1,s}^{-,max,VP} \cdot NPV^{corr,VP}\left(TP_{h1,s}^{-}\right) \\ & - \delta \cdot \sum_{NPV^{corr,BP}\left(TP_{h1,s}^{-}\right)>0} TP_{h1,s}^{-,max,BP} \cdot l_0^{BP} \cdot NPV^{corr,BP}\left(TP_{h1,s}^{-}\right) \\ & + \sum_{NPV^{corr,VP}\left(TP_{h2,s}^{+}\right)>0} TP_{h2,s}^{+,max,VP} \cdot NPV^{corr,VP}\left(TP_{h2,s}^{+}\right) \\ & - \delta \cdot \sum_{NPV^{corr,BP}\left(TP_{h2,s}^{+}\right)>0} TP_{h2,s}^{+,max,BP} \cdot l_0^{BP} \cdot NPV^{corr,BP}\left(TP_{h2,s}^{+}\right) \end{aligned}}_{(8)}
\end{aligned}
\tag{4.8}
$$

p_{IEP}^{opt} = NPV of all activity level independent payments of the new environmental protection technology (without p_{IEP}^{opt}) (1)

+ NPV^{corr} of using the profitable new processes at their maximum activity levels $\lambda_s^{IEP,max}$ (2)

+ NPV^{corr} of the changes between VP and BP regarding the use of the other production processes β (3)

+ NPV of the changes between VP and BP regarding the realized other investment objects and financial transactions (4)

+ NPV of the changes between VP and BP regarding the valuation of the payments which are independent from production quantities and from the investment program (5)

+ NPV of the changes between VP and BP regarding the monetary equivalents of the other production constraints (6)

+ NPV of the changes between VP and BP regarding the monetary equivalents of the constraints constituted by initial endowment of tradable permits (7)

+ NPV of the changes between VP and BP regarding the actual *trade* of tradable permits (8)

The maximum payable price for an investment in environmental protection technology depends on the (corrected) NPV of its payments and of the interdependencies occurring because of changes in the optimal investment program. Under uncertainty it includes the *discounted payments of all states* – even those, which, in fact, will not occur. As we can see, there are several effects of tradable permits on an investment in environmental protection technology:

1. The initial endowment restricts production like any other constraint. It may be unexpected, but tradability is *not* important for this *quantity effect*.[21] Using sensitivity analysis, right-hand-side ranging can assess the impact of changes in the initial endowment on the maximum payable price in the same way as the impact of other production constraints.[22]

[21] Term (7) of Eq. (4.8) only contains the emissions covered by the initial endowment of tradable permits in the basic and the valuation program; the term is independent from tradability effects. However, tradability leads to additional corrected net present values NPV^{CORR} (cp. Eq. (4.6) and (4.7)), and the realized trades affect the price ceiling.

[22] Compare Eq. (4.8), terms (6) and (7).

2. Tradability directly affects the *price ceiling*.[23] For every price interval h1 and h2 we have to compare the opportunity cost of a marginal reduction of emissions with the price of the next marginal emissions allowance to be bought or to be sold – the known results of environmental economics (e.g. the analogue effect of *Pigou* taxes) are confirmed for a single investment. However, sensitivity analysis of the left-hand-side coefficients of the basic and the valuation program (4.2) and (4.3) shows that a system of emissions allowances, in particular cases, may be *counterproductive even for environmentally beneficial investments*. The maximum payable price may increase, decline or remain constant, if prices of tradable permits rise. This has several reasons:

   - The decision variable for the particular trade is a basic or non-basic variable. This may differ between the basic and the valuation program.
   - The minimum withdrawal constraint connects the basic and the valuation program.
   - Negative (corrected) NPVs are not part of the optimal solution – neither in the basic nor in the valuation program.

   Therefore, (over-)compensation of the effects of price changes of tradable permits between the two programs is possible. For example, rising prices of tradable permits at first may ameliorate the conditions of environmentally beneficial processes in comparison to the older ones of the basic program (with the consequence that investments in environmental protection technology will be encouraged). However, if the prices of tradable permits continue to rise, parts of the optimal solution of the basic program may lose their profitability faster than in the valuation program. Since processes, trades and other objects with (corrected) NPVs that are becoming negative will not be chosen in the optimal solution any longer, they will no more diminish SWW^{opt} either. The optimal solution of the dual valuation program (and consequently the maximum payable price) may then decline.[24]

   In an economic interpretation, all the possible reactions – positive as well as negative – of the price ceiling on the changes of the prices of tradable permits are comprehensible:

   - On the one hand, rising prices for tradable permits may over-compensate the cost of additional emissions reduction, and falling prices may allow increased production.
   - On the other hand, rising prices for tradable permits may restrict production, while falling prices may reduce sales revenue.

   These effects may differ between the two programs.

[23] Additional indirect effects result from interdependencies by the terms (2) and (3), because the corrected net present values of the processes (4.4) may be affected via the dual variables as well.

[24] Compare footnote 19.

3. A third effect, which is perhaps less obvious, is of monetary nature as well: Profits of possible sales depend on the initial endowment. But: A higher initial endowment – as well as a smaller amount issued by the government – restricts the possibility of further purchases. This may lead to the following results:

   - Other intervals of the price function become decision relevant.
   - The price function may change.

5 Conclusion

The presented model offers a general approach to evaluate investments with special regard to tradable emissions permits. Since these investments affect production, the payments required for a financial valuation have to be derived from production theory and production planning: With special regard to the environment, production processes are characterized by joint production. Tradable permits modify the contribution margins and the constraints as well; their prices change with the quantity to buy or to sell. Nevertheless, a linear formulation of the problem is reasonable. It considers activity-level-dependent and activity-level-independent payments and handles the indivisibility of the investment to be valuated in two steps.

Applying duality theory, the model allows the identification of the determinants of the price ceiling for the investment to be valuated with regard to tradable permits and uncertainty. Certain discrete option pricing models can be derived as special cases. However, the main problems of practicability occur from simultaneous planning: To solve practical optimization problems, we often need large quantities of data; information on possible states may be incomplete. Nevertheless, the model provides *exact* information on the determinants of the maximum payable price. Information on probabilities, means and variances is not required.

Using sensitivity analysis we can show that tradable permits have several effects on an investment. They do not always encourage environmentally beneficial investments – in particular cases they may even be counterproductive.

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Part C

Corporate strategies

Emissions trading and Corporate Sustainability Management

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Abstract

The introduction of Emissions Trading (ET) on 1.1.2005 in Europe represents an institutional innovation and a significant change in the existing framework for many microeconomic activities. Likewise Corporate Sustainability Management proves to be a new challenge and a necessity for future-oriented companies to ensure profitability and competitiveness as well as legitimisation and public reputation. This paper outlines the main characteristics of Corporate Sustainability Management and investigates the impact of ET as a market-based instrument for environmental policy regarding the possibilities for sustainability-oriented management. Potentials for intersection management with the identification of success factors and triple-win situations are pointed out as well as prospects for structural policy and norm-setting activities. Stating the limits of market-based instruments and monetary regulation, it becomes obvious that additional non-economic incentives and ethical behaviour in the form of accepting 'sustainability responsibility' are necessary for meeting the demands of sustainability.

Keywords: Emissions trading, market-based instruments, institutional theory, sustainability, Corporate Sustainability Management, intersection management, structural policy, norm-setting, sustainability responsibility

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1 Introduction

The discussion about sustainable development arose from the observation of increasing ecological, economic, and social problems – most of them resulting from today's economic system with the constitutional paradigms of scarcity, efficiency, quantitative growth, and money as the universal measure for value (Zabel 2004a, 2001). The nowadays existing economic system perpetually creates external effects that lead not only to economic, but also to 'new' social and ecological scarcities with inherent self-destructive tendencies. The concept of so called 'new scarcities' (Zabel 2001, p. 31) states that the economic focus on material needs and monetary signals is not appropriate for measuring the value of nature and social structures. Ecosystem services are becoming increasingly scarce, which causes severe deficits in the satisfaction of people's needs. Therefore, new ecological scarcities emerge. Moreover, with regard to human needs, newly upcoming social scarcities such as deficits in the satisfaction of important social needs such as understanding, social embedding, and participation cause problems on any scale.

The existing economic principles oppose sustainability, and this implies the necessity for redirecting economic mechanism and activities towards a more sustainable development, while considering ecological and social requirements. The main characteristics of a 'Sustainability Economics' and the tasks of Corporate Sustainability Management deduced thereby are described in detail in chapter 2.

Emissions Trading – as a market-based instrument of environmental policy – is regarded as an institutional innovation with potential to influence expectations and corporate behaviour. Economic activities are embedded in an institutional regime or arrangement (Antes 2006 2002). Institutional theories, e.g. New-Institutional-Economics, define institutions as a 'system of formal and informal rules including measures for enforcement' (Richter and Furubotn 1996) or as the 'rules of the game' of human society (North 1992). Generally, institutions legitimate, orientate, and regulate human behaviour (Prittwitz 2000). Institutional theories identify different drivers towards institutional change: efficiency in the New-Institutional-Theory, common wealth in Institutionalism (Reuter 1996), or legitimacy in Neo-Institutionalism. To initiate an institutional change towards sustainability as the ultimate end, this knowledge can be used to create new environmental policy instruments and (economic) institutions that in a similar way ensure good conditions for both: economic efficiency on the one hand and ecological and social goal-attainment on the other.

The introduction of the EU-ET-System on 1.1.2005 means a change of the 'rules of the game' for microeconomic activities. Emissions Trading is characterized by a (partial) internalisation of former external effects and quantity restrictions as an absolute limit of emissions (Bonus and Niebaum 1998). As a typical characteristic of market-based instruments this parameter has to be determined by a political authority (Bonus and Niebaum 1998; Luks 2000). In the case of the European ET-System the overall cap is derived from the UNFCCC (Rio de Janeiro 1992) and the Kyoto Protocol (1997), in which the Annex-I-Countries oblige themselves to reduce Greenhouse Gas Emissions collectively by 5.2 per cent be-

low 1990 levels by the period 2008-2012. The EU is treated as a 'bubble', which means that there is a reduction target for the Union as a whole. In the EU's internal 'burden sharing agreement' the member states reduction targets vary – Germany will reduce its GHG emissions by 21 per cent between 2008-2012 compared to the emissions level of 1990. Because of the absolute limitation of emissions – expressed in assigned amounts units (AAUs) – and the use of the market mechanism, a price is forming for tradeable permits. It is expected that Emissions Trading activates the self-interest in profit making for the purpose of environmental protection and gives impulses to direct human behaviour within the economic system towards a more sustainable way of doing business. Therefore, the paper investigates the impact of ET on Corporate Sustainability Management and tries to identify possible limits of market-based instruments for a sustainability oriented management.

2 Sustainability and Corporate Sustainability Management

2.1 Sustainability and 'Sustainable Economics'

Sustainability is understood as a vision and humanitarian path to solve the global challenges and can be defined as 'targeting human survival in a good, fulfilling and free manner for an appropriate number of generations' (Zabel 2001). It is an interactive and holistic concept based on dialogue and deliberation and aspires to re-integrate human needs – the 'normativity of humanity' (Zabel 2001) – and ecological requirements into business, science, and society.

Sustainability corresponds to ecological stability, economic viability, and social criteria such as justice, quality of life, and human needs. The three dimensions of Sustainability are shown in Figure 1.

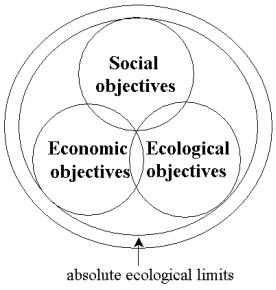

Fig. 1. Dimensions of Sustainability

Doing business in a sustainable way means to follow the triple bottom line pursuing social, economic, and ecological objectives. But this does not imply formal equity of the three dimensions. The weighting varies over time, and in the long run the sole limiting factor will be the ecological dimension (Meadows 1998).

It is a challenge for the scientific society to outline the characteristics of a modern economic approach called 'Sustainable Economics'(Zabel 2004b) that gives consideration to economic, ecological, and social requirements. The elements of this modified paradigm are in many cases contrary to traditional neoclassical assumptions. A focus on human needs – material and immaterial ones –, the acceptance of absolute limits of growth, the coexistence of economic and non-economic incentives, and the cognition that eco-social markets and prices are needed as well as altruism and genetic-based ethics. Constituting components of this 'Sustainable Economics' are:

- closed loop recycling management triggered by solar energy,
- supporting individual behaviour towards sustainability by activating genetic predisposition,
- sustainability oriented institutions and institutional arrangements.

Enterprises prove to be important actors in the process towards a more sustainable society. Therefore, it is necessary to make the overall concept of 'Sustainable Economics' practicable on a corporate level. The outlines and tasks of Corporate Sustainability Management are described in the following chapter.

2.2 Three tasks of Corporate Sustainability Management

Corporate Sustainability Management is defined as a management subsystem of a company with the task to ensure the sustainability of all products, processes, structures, and corporate behaviour, and furthermore, to render contributions to ensure and increase the sustainability orientation of the stakeholders and the society. Corporate Sustainability Management is based on the theoretical concept of 'Sustainability economics' mentioned above. This approach provides the theoretical basics for the explanation and design of sustainability oriented economic systems.

For analytical purposes three tasks of corporate sustainability management are distinguished (Figure 2).

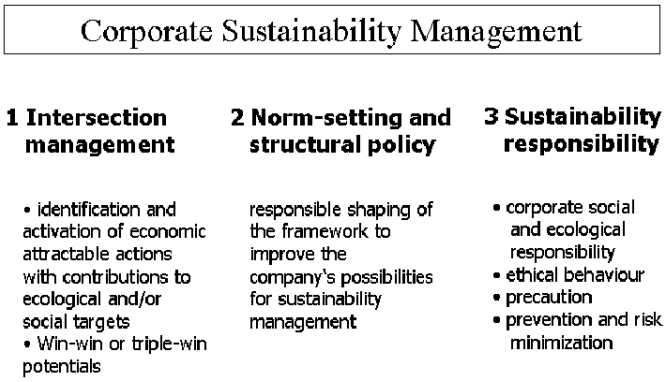

Fig. 2. Tasks of Corporate Sustainability Management
Source: Zabel 2004b, p. 76

Each of the three tasks corresponds with different dimensions of responsibility and renders various contributions to Corporate Sustainability Management, as is shown in Figure 3 and elaborated in the following chapter. First, 'intersection management' requires the identification and use of measures that generate triple-win potentials and simultaneously contribute to economic, ecological, and social objectives. Because of various trade-offs between the different dimensions the possibilities for intersection management prove to be very limited. This is why corporations are requested to contribute to 'norm-setting' and 'structural policy' in order to expand the intersection in a dynamic way. The third task 'Sustainability responsibility' arises because of time lags, limited resources, and unintended consequences of structural policy that always require a certain amount of responsibility for sustainable behaviour within the enterprises.

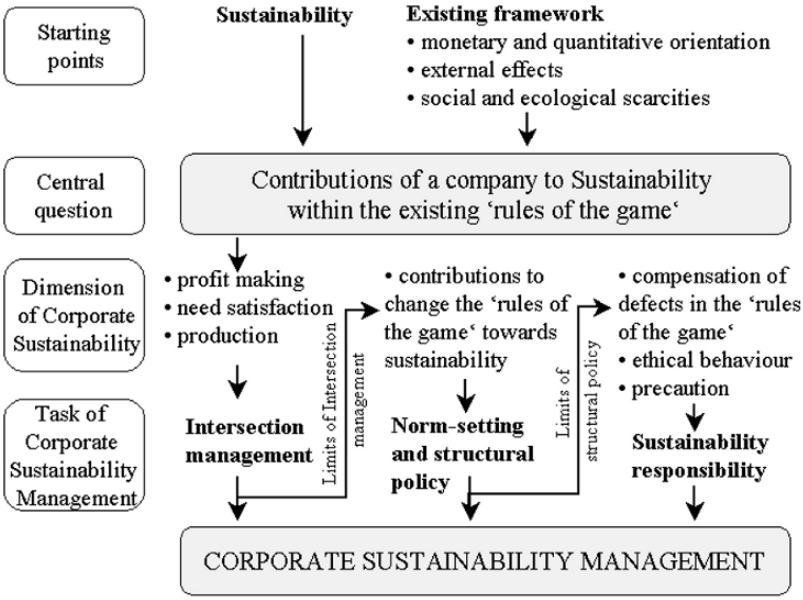

Fig. 3. Reconstruction of the three tasks of Corporate Sustainability Management
Source: Zabel 2004b, p. 75

3 Impact of emissions trading on Corporate Sustainability Management

3.1 Intersection management

First, the part of the company as a profit making organization and the contribution of ET to 'Intersection management' is regarded. Intersection management consists of the identification and resolute use of those actions, which correspond on the one

hand with economic rationality and on the other hand with ecological and/or social requirements (see Figure 1).

The model of Intersection management was first developed at the end of the 1980s to explain that despite existing tensions between economic and ecological systems, there are intersections with goal harmonies and potentials for win-win situations (Pfriem 1996; Freimann 1996). The search for intersections and the resulting success factors are traditional challenges for environmental management: Environmental protection was forced to legitimate itself by contributing to formal goals such as profitability and competitiveness (Steger 1992; Meffert and Kirchgeorg 1993).

The internalisation of external effects[1] – as carried out by the idea of trading permits – is a transmission mechanism that significantly expands the existing intersection and reduces the paradox between economic and ecological survival (Sahlberg 1996).

Identification of the intersection

In the following, the contributions of ET to 'intersection identification' are regarded: Generally, the range of economic rational measures is not fully exhausted, and a lot of 'triple-win potentials' can be identified. Examples for such unidentified and unused potentials are no-regret measures.[2] These are measures with negative marginal abatement costs, already being part of the intersection, but which were not realized because of structural barriers, organizational deficits, missing knowledge of opportunities, or/and informational imperfection.

Because of the direct correlation between CO_2-emissions and energy input, ET represents a transmission of ecological facts into economic ones ('hard facts') by generating a price for GHG emissions. The result is the 'translation' of non-monetary information (energy and material data) into the binary code of the economic sector (Luhmann 1984). According to systems theory every system develops a specific code for communication in order to reduce complexity. Information that is coded in another way is filtered and therefore out of perception and irrelevant for decision making processes. The fundamental code of the economic sector is the price – that means monetary quantified information like payment/non payment or costs/earnings.[3]

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[1] The theory of external effects interprets environmental pollution as negative external effects that are transferred from the causer to society. This theory corresponds to assumption about the 'Homo Oeconomicus': an egoistic, opportunistic, and individual benefit maximizing behaviour (Siebenhüner 2001).

[2] Various studies confirm the enormous cost-saving potential of ET to achieve GHG reduction goals, e.g. Öko-Institut/DIW/ECOFYS (2002) expects 500 million € per annum with an assumed certificate price of 10€/ton CO_2 and 90 million tons CO_2 reduction potential for Germany by 2010, of which almost 45% are no-regret measures.

[3] Analogies to resource flow based cost accounting occur: This environmental cost accounting method provides process and causer-oriented ecological information and tries to transmit them into the monetary code. Significant contributions to eco-efficiency and cost-savings can be noticed. See e.g. Antes 2000.

According to the EU-Monitoring Guidelines (KOM 2004/156/EG) and § 5 TEHG[4] companies in the EU-ET-System are obliged to install a systematic emissions control and monitoring system and to deliver annual emissions reports to the national entity. The systematic flow of information thereby increases the reflection of consequences of corporative activities and provides continual and transparent energy and emissions data that are inter-temporal comparable.

The monetary market signal can be much easier recognized by decision makers and increases the probability of an adequate consideration of environmental aspects in investment decisions and strategic planning. As a consequence there is a strong and perceptible incentive for a systematic search involving either an increase in energy efficiency, a fuel switch, or innovations. This is supported more by the characteristics of GHG-management as a cross management task: this management also requires an increase in cooperation, communication, and participation by, specifically, installing either cross-functional teams or competence groups for ET.

Use of the Intersection

The use of the intersection with economically attractive and simultaneously ecological and/or socially advantageous actions corresponds to the traditional responsibility of business to produce goods and services to satisfy needs and meet the rational-economic target of making profit to ensure economic survival (Friedmann 1970). According to some traditional economists, this is and should be the only responsibility companies have to accept.[5] As explained below, economic efficiency, profit, and viability are essential, but not sufficient, conditions for sustainability management.

The main characteristic of market-based instruments is economic efficiency: They enable the attainment of the ecological goal with the lowest marginal costs. Each company has the flexibility to choose between different strategic options: internal emission reduction measures, investment in projects, or buying emission rights on the market. Especially, the project mechanisms of the Kyoto Protocol – JI and CDM – provide a huge potential of cost efficient measures for fulfilling reduction targets. Furthermore, the projects – if they accomplish the strict criteria – can contribute to technology transfer, capacity building, and sustainable development in the host countries (Pohlmann 2004).

Various benefits, triple-win potentials, and success factors can be activated with ET and a successful corporate sustainable management, e.g.:

- Cost reduction: reduced material and energy input: i.e. cogeneration of power and heat, increased degree of efficiency, heat recovery (Metz et al.

[4] TEHG (Treibhausgasemissionshandelsgesetz) is the German national law to regulate ET, implementing the European directive 2003/87/EG.

[5] The traditional mainstream economics is inward-looking and aims at human need satisfaction under scarcities following the economic principle. Profit-making is accepted as the only corporate responsibility; ethical norms or motives are not regarded.

2001; Scheelhaase 1994; Landgrebe et al. 2003), and/or increased operational efficiency,
- possibilities for risk management and risk minimization: reduced ecological risks through the reduction of emissions (Schaltegger et al. 2003), reduction of uncertainty of economic consequences, new instruments of risk management, e.g. derivates, hedging, insurance (Janssen 2001),
- increased turnover and shareholder value (Schaltegger et al. 2003),
- advantages by 'Sustainopreneurship' (Petersen 2003): pioneering and offering innovative technologies in 'Lead-markets',
- emerging markets: monitoring technologies, consultant services, information brokerage, new financial products (UNEP FI 2005), and
- increased competitiveness by sustainable management and stakeholder-satisfaction because of reputation, motivation, customer satisfaction, image, and societal legitimisation (Dyllick 2004).

Using the opportunities of the intersection and the market as a mechanism that brings up innovations and high performance, results in the intended reduced environmental impacts, in contributions to social criteria such as safety, intra- and intergenerational justice (e.g. decentralized and clean energy supply in developing countries), or minimized health risks, and in a more efficient management and contribution to the formal objective of the company. This efficiency in doing business proves to be an essential, but not sufficient, requirement for sustainability management. Despite a partial internalisation of external effects and some positive contributions to economic, ecological, and social targets, a complete fulfilment of sustainable goals with a pure intersection management is found to be impossible. Using the existing 'rules of the game' nevertheless causes some social and ecological scarcities. Based on this fact, norm-setting and structural policy are regarded as the second task of Corporate Sustainable Management.

3.2 Norm-setting responsibility and structural policy

The role of companies can not be reduced to passive adaptors determined by the existing general framework; furthermore, they have capacity to influence their environment. Therefore, corporations are regarded as structural policy actors striking and thereby expanding the intersection in a dynamic way and contributing to the creation of new 'rules of the game'. The British sociologist Anthony Giddens describes the phenomena of structure creation and alteration in the 'Theory of Structuration', which can also be transferred and applied to corporations. Structural policy in a sustainability context demands norm-setting by the responsible shaping of the institutional framework in order to improve the company's possibilities for sustainability management (Schneidewind 1998; Antes 2006).

Giddens 'Theory of Structuration'

Giddens hypothesized a 'duality' of structure in his 'Structuration theory'. According to Giddens, structure exists outside 'time and space' only as memory traces and can be defined as "… sets of rules and resources, implicated in the production of social systems" (Giddens 1997, p. 377). The central idea of the 'duality of structure' overrides dualism and dichotomy: In structuration theory structure is recursively involved in the reproduction of social systems. This means that structure is both medium and outcome of interaction, action-enabling as well as action-restraining (see Figure 4). Because of existing unknown consequences and unacknowledged conditions of action, structure is never reproduced identically.

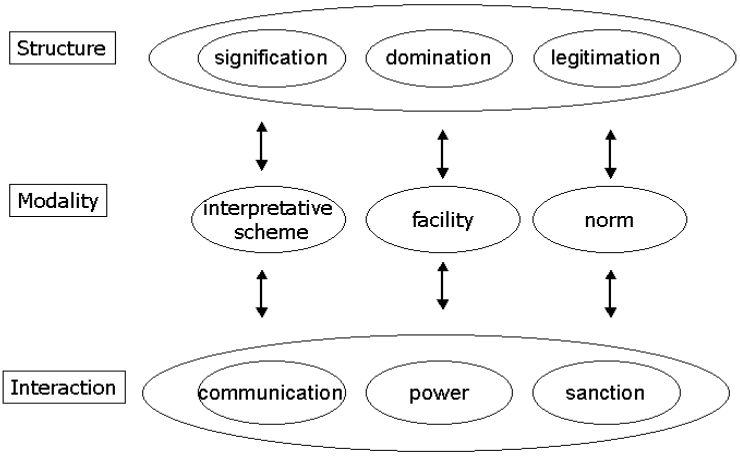

Fig. 4. Dimensions of the duality of structure
Source: Giddens 1997, p. 27

Social actors draw upon so-called modalities in interaction, and the continual reproduction of these dimensions reconstitutes the structure recursively. Modalities are divided into rules – interpretative schemes and norms – and facilities containing allocative and authoritative resources. Rules of signification emerge by drawing upon interpretative schemes (e.g. rules of communication) and build symbolic systems. Rules of legitimisation are constituted by reference to norms (e.g. formalized rules and laws). Resources, in the terminology of Giddens called facilities, are divided into authoritative and allocative ones. Allocative resources emerge from disposability about technology or monetary budgets. Authoritative resources result from power over human beings, e.g. by organizational structure, administration, charisma, or high reputation (Ortmann 1995).

Corporate structural policy in an ET-System

While transferring this theoretical background to corporations and regarding them as structural policy-making actors with norm-setting capacity, various starting points for structural policy in an ET can be regarded (Schneidewind 1998):

- structural policy modalities,
- sets of actors,
- functional mechanisms, and
- different arenas of structural policy.

Some selected starting points of structural policy that arise in an ET-System are regarded more detailed as follows. It is obvious that the starting points are extremely connected and interdependent.

1. Rules of signification and legitimisation (Modalities)
Emission trading was opposed for a long time by large sections of German industry (i.e. VCI and BDI[6]) as well as environmental NGOs and interpreted as 'selling of indulgence', 'selling of nature', or 'trading with pollution rights'. The dominating cognitive pattern of interpretation and perception considered ET as impractical, immoral, and cost-intensive for both companies and authority administration. Recently, a changed interpretation has become more and more widely accepted: ET as a 'cost effective instrument for achieving reduction targets' and an 'efficient and operative instrument of environmental policy'.

Communication and interpretative schemes prove to be important sources of power; especially in market economies with the fundamental profit-making principle as the paramount maxim. Economic formulations and expressions such as 'efficient', 'innovative', 'cost-saving', and 'flexible' unfold an immense normative power.

A special code and technical language has developed: abbreviations and termini such as JI, CDM, QEELRO, AAU, Marginal abatement costs and CER are commonly used among the members of the 'ET community'. This sophisticated expert language with specialized knowledge (Giddens 1997; Minsch et al. 1998) is partly transferred to society. By stressing the connection of ET with cost efficiency, flexibility, and climate protection, norms and interpretative schemes are reproduced and stabilised. Public-orientated cooperations, in particular, such as environmental or social organizations (e.g. WWF, Greenpeace, or ILO) or scientific circles (e.g. universities, research institutes) reveal a particular structural policy power, because they are able to combine different resources in a symbiotic way. Environmental organizations or scientific institutions bring in a high amount of authoritative resources in the form of expert knowledge, independency, public credibility, and reputation. The participating corporations contribute allocative and authoritative resources.

[6] VCI: Verband der chemischen Industrie (Organization of chemical industry in Germany); BDI: Bundesverband deutscher Industrie (Federation of German industries).

2. Resources (Modalities)
Resources are the typical modality corporations refer to in markets. Beside allocative resources (e.g. financial resources for R&D, new energy-efficient technologies, technical infrastructure, emission measurement methods) authoritative resources can be used for structural policy. Sources for the generation of authoritative resources in an ET-System are pilot projects, internal markets, and privat-public partnerships, with federal authorities (in Germany, for example, 'Hessen-Tender' or 'Emissionshandel Nord'). In addition to the attraction of gathering early experiences and making pioneer profits, the attainment of authoritative resources such as expert knowledge, legitimisation, reputation, and credibility are substantial motives for companies to act as early movers. The expertise obtained is brought into policy making processes (for example, into the AGE[7] in Germany) through expert reports, statements, and comments to influence both public opinion and policy making (Lafeld 2004). This influence can be increased by industrial federations and organizations with both a high level of organization and the capability to mobilize authoritative and allocative resources (Olson 1965).

3. Sets of actors in different arenas of structural policy
In co-evolution with the ET-System new markets and business segments are emerging, and new sets of actors occur in different arenas: market, policy, and public (Schneidewind 1998; Antes 2003). In the market arena institutions evolve which organize trading, such as: carbon exchanges (e.g. EEX Leipzig; European Climate Exchange Amsterdam), agents, brokers, and carbon funds (e.g. PCF; KfW Carbon Fund). Sustainability-orientated structural policy is exemplified by: participation in the formation of transaction-cost efficient market institutions (e.g. information platforms for JI and CDM-projects), engagement with gained expert knowledge, as well as transparent and frank information in public and policy agenda-setting-processes. More examples for structural policy in this context are initiatives to build up ambitious 'Golden standards' for CDM projects to establish the concept of 'sustainability' as mandatory in international law (Pohlmann 2004; Bode 2004) or to participate in sustainability-orientated networks like BSR[8] or SCR Europe[9] for defining 'codes of conduct'.

Because GHG management is an innovative and complex task with new administrative demands, this proves to be an interesting emerging market for consultants as well as legal and technical experts. Corporations – especially if they are engaged in structural policy – are embedded into a societal environment, have to legitimate their behaviour and are more and more in an exposed position as 'quasi-public institutions' (Ulrich 1977). This underlines the increased importance of the public as an arena for sustainability-orientated corporate structural policy. Using their authoritative and allocative resources for agenda-setting, communication,

[7] AGE: Arbeitsgruppe Emissionshandel (German task force Emissions Trading), see http://www.bmu.de/de/txt/sachthemen/emission/index_age.
[8] BSR: Business for responsibility, international network in the U.S.A., see http://www.bsr.org.
[9] CSR Europe: Social Corporate Responsibility in Europe, non-profit organization to support CSR, see http://www.csreurope.org.

public relation, and stakeholder-dialogues, corporations provide enormous potential to contribute to the sustainability orientation of the stakeholders and expand intersections in a dynamic way. If the concept of ET proves to be practicable, cost-efficient, and ecologically effective, and if the positive interpretation and perception of this environmental instrument can be established and stabilized, then it will be much less complicated to expand this concept to other companies, sectors, GHG (opt-in), countries, and applications in quite different subjects.

3.3 Sustainability responsibility

Although ET offers various starting points for structural policy and norm-setting towards a more sustainable behaviour, these possibilities are limited. The existing framework conditions can neither be changed arbitrarily nor without a time lag: Norm setting and the establishment of new 'rules of the game' are long-lasting processes with various persistent barriers, unpredictable developments, and huge time lags between causes and effects. Structural policy is never deterministic and monocausal. Due to reverse, long-range, and distorted effects as well as perception and knowledge barriers, there are always unintended consequences and unacknowledged conditions of action. Furthermore, the norm-setting capacity of corporations is based on resources and rules – that are scarce and limited in their accessibility, respectively.

Illustrating the limitations of intersection management (see chapter 3.1) and structural policy makes it clear that a certain amount of responsibility always remains within corporations in order to keep their activities within a responsible, sustainability-orientated limit and range of tolerances (Zabel 2004b).

Corporate Sustainability Management therefore demands as a third pillar the acceptance of social and ecological responsibility within the bounds of existing 'rules of the game'. In the concept of 'Corporate Social Responsibility' (CSR) corporations also have – besides economic and legal responsibility that are required by society – ethical and philantrophic responsibilities that are expected and desired by society and essential for a sustainable development (Caroll 1991; Matten and Crane 2004). These extended responsibilities include right, just, and fair corporate behaviour above and beyond legal requirements and positive contributions to society such as: sponsoring, building recreation facilities, or improving quality of working conditions for employees.

Towards the middle of the 1990s the newer concept of 'Corporate Citizenship' (CC) emerged which is understood as a normative idea of societal engagement for companies. CC implies positive contributions to the community and appropriate behaviour of a 'good corporate citizen' (Westebbe and Logan 1995; Schrader 2003).

Corresponding with the concepts CSR and CC the third task of Corporate Sustainability Management is called 'sustainability responsibility'. This implies compensation for possible defects in the existing rules and a renunciation of profitable measures if they are proved, or at least suspected, to have unintended and intolerable consequences for ecological and social systems. The relinquishment of un-

ethical behaviour such as corruption, fraud, and violence – even if it is attractive in an economic sense – has to be taken for granted. Furthermore, sustainability responsibility means to show solidarity through contributions for environmental protection, precaution, regeneration, and damage compensation. These contributions basically arise from ethical motivation and genetic-based altruism (Zabel 2001). Corporates generally have options open to act in a responsible way without endangering economic viability.

In the context of ET this means, for example, abstinence from doubtful JI/CDM projects that involve unknown risks and vague supplementary, and initiatives with significant positive effects, e.g. investment in renewable energies (even if less financially rewarding).

In an analysis of the impact of a market-based instrument such as ET, the general limitations of internalisation and monetary quantification have to be mentioned (Streißler 1993). Generating a price for emissions through an artificial scarcity (the cap) is only a rough approximation of 'true ecological prices' and in the best case a partial internalisation of external effects. This does not necessarily attain an ecological or social optimum, and often times does not even represent the bare minimum. The limits of market-based mechanisms become evident when a free, decentralised allocation generates unbearable, life-endangering effects: This demands categorical, cost- or profit-ignorant protection areas, respectively.

A pure monetary orientation hampers recognition of the value of nature, immaterial needs and the complex performance of ecological systems. In addition, some ecological and social phenomena such as a stroll in the forest, friendship, sociability, joy, or love cannot be adequately controlled on a monetary basis. Human behaviour will never be totally influenced by monetary signals. Furthermore, there are intrinsic, ethical, and genetic based motivations and non-economic incentives that are highly interdependent and connected (Zabel 2001). Besides the positive contributions ET can provide – especially to intersection management and structural policy – the limits of monetary regulation and market-based instruments underscore the necessity for additional non-economic incentives and ethical behaviour.

4 Conclusion and outlook

Emissions trading as a market based instrument has shown itself to be an institutional innovation that can provide several positive contributions to Corporate Sustainability Management. In addition to identification of success factors and triple-win potentials, emerging markets in the organizational field of ET open up multiple possibilities for corporate structural policy and norm-setting activities towards sustainability. While pointing out the limitations of market-based instruments, it becomes apparent that pure monetary regulation will not be sufficient for sustainable development and that additional non-economic incentives and ethical behaviour are necessary. Future-oriented companies are therefore requested to identify and exploit the economic benefits of ET, and in addition, to accept an extended

'sustainability responsibility' by avowing to adopt ethical behaviour in their efforts to meet the demands of sustainability.

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Links of corporate energy management strategies in Europe with the European Union emissions trading system and environmental management systems

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Abstract

This paper analyses the interaction of the novel emissions trading directive of the European Union with energy management strategies of European firms and the empirical determinants of corporate energy management activities related to these. After a brief introduction, three generic corporate energy management strategies to address climate change are introduced and discussed. This also takes into account the "embeddedness" of energy management in environmental management systems, which may lead to a policy interaction with the emissions trading directive. The determinants of specific energy management activities linked to the different corporate energy management strategies are subsequently analysed empirically. It is found that especially implementation of environmental management systems has a very positive effect on activities. The paper concludes by discussing the implications of this for the European Union's emissions trading directive and the interaction of the different empirical determinants for activities and strategies with climate policy initiatives on firms in Europe. In particular, the findings confirm that fostering environmental management systems which achieve emission reductions and the emissions trading directive lead to interaction that increases the allocative efficiency of a system using both environmental policy instruments over one which only uses one of them, i.e. that favourable policy interaction is possible.

JEL classification: L19, Q01, Q48

Keywords: Climate policy, emissions trading, energy management, environmental management systems, European Union

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1 Introduction

Due to its large emission levels and a long lifetime in the atmosphere, carbon dioxide still contributes most to the greenhouse effect. The main source of global greenhouse gas (GHG) emissions, and in particular carbon dioxide emissions is the combustion of fossil fuels to generate energy. Currently international cooperation to influence and stabilise global climate change is still on its way to being fully institutionalised within the Framework Convention for Climate Change. Whilst the main objective resulting from Conference of Parties (CoP) 7, the ratification of the Kyoto Protocol did seem unlikely for a long time, the change in position of Russia finally brought the Kyoto Protocol into force.[1] Global emission trading has become increasingly relevant in this context (see e.g. Antes et al. 2006) and is to become a major element under the Kyoto Protocol from 2008 onwards. The slow progress on the ratification of the Kyoto Protocol had led the European Union (EU) in March 2000 to propose a closed European emission trading (ET) system (EU ETS), also to form the basis for inter-country ET from 2008 onwards (EC 2003). This was detailed in a draft EU directive on GHG emissions trading between firms in October 2001 (EC 2003) which was ratified by the European Parliament in late summer 2003 after the second reading of the directive in the parliament. The system became active at the beginning of 2005 and enables trading between EU firms. This landmark event raises the issue of how emission trading interacts with corporate energy management strategies and activities of European firms, and what the relevant determinants for this are. Any analysis here needs to start with the broader strategic frame for energy management strategies and to take into account their embeddedness in environmental management systems (EMS), since this implies the possibility of an interaction with the EU ETS. The remainder of the paper is structured as follows: after deriving the different energy management strategies for business responses towards climate change, the paper introduces data and methods and subsequently provides empirical results on the drivers for energy management activities which reflect these strategies. It concludes by analysing the implications of the findings.

2 Corporate energy management strategies and links to EMS, the EU ETS and climate policy

There are three strategies for the corporate sector to address climate change by means of energy management whilst at the same time not jeopardizing economic performance.[2] These are: improvement of energy efficiency (e.g. through adoption

[1] However, Russian use of its bargaining power resulted in a weakening of the Protocol's targets (Böhringer and Vogt 2004).

[2] These three strategies are basically input-oriented. Emissions-oriented approaches are defined here as any end-of-pipe measures for the reduction of air pollutant emissions and are not included because they are thought to jeopardize central business objectives. The

of measures or activities to reduce energy use in production or energy use required for transport, whilst keeping production output constant), increased use of renewable energies or fuel switching in general (e.g. by means of measures for substituting non-renewable resources such as fossil fuels) and the use of flexible mechanisms (like Joint Implementation (JI), the Clean Development Mechanism (CDM) or ET). The first of these strategies, improvement of energy efficiency, has been on the corporate agenda for quite some time, initially triggered by the 1970s oil crises and recently predominantly because of increasing energy taxes and oil prices. Unfortunately, two factors limit the scope of this strategy. Firstly, because of its considerable history, energy efficiency improvements through direct measures (e.g. process integration, combined heat and power, heat and steam recovery) at plants or sites have often reached a level that leaves limited scope for cost-efficient improvement, since frequently the process-related limits are very close. Secondly, market imperfections such as lack of information hinder even cost-efficient investments in energy efficiency (Jaffe and Stavins 1994; Sanstad and Howarth 1994). Hence, the potential for energy management-based GHG reductions by means of increased energy efficiency seems to be most viable in countries with low efficiency levels in energy generation and utilisation such as India, the U.S. and the post-socialist economies of Central and Eastern Europe or China rather than in the EU. Despite this, new technologies bear some additional potential in the EU as well. For example, the specific energy consumption of thermal processes is expected to decrease by 30% due to novel membrane technology to replace thermal processes. Especially in the consumer market segment of the electricity industry, considerable potential also exists for demand-side based energy management strategies such as Demand Side Management or Least-Cost Planning, which were also found not to be attractive to energy suppliers in financial terms (Greening 1995). For the second strategy mentioned, namely the increased use of renewable energy technologies and sources, or more generally for fuel switching, the longer-term potential is high, since it leads to direct GHG emission reductions. Particular potential here exists in countries with a fossil-fuel intensive energy mix and for renewable energy technologies, one example with significant potential being photovoltaics (PV). For companies in the EU corporate sector, PV will however only be a viable energy or fuel source (and thus an element of their corporate energy management strategies), if they can compete on price with fossil fuel-based technologies. This would require prices to fall from currently around 3-4$/Wp to around 1.5$/Wp by 2010, which can only be achieved by means of significant innovation efforts, not only of solar cell and PV module technology, but also associated manufacturing processes. As a note of caution and a remainder that such radical innovation is not a ‘free lunch’, Grubb (1997) points out the relevance of early (government supported) PV innovation activities and associated induced innovation benefits, which may require more systematic market support in order for PV technologies to become a competitive energy source in the increasingly liberalized

empirical analysis however includes the reduction of air emissions for completeness. Flexible mechanisms are an input-oriented strategy where reductions in GHG emissions are achieved not directly on site, but indirectly.

and deregulated EU energy markets. Finally, a third general strategy for corporate energy management consistent with firms' economic objective of addressing climate change-induced demands is the use of flexible mechanisms such as JI, CDM and ET which are the mechanisms of the Kyoto Protocol, but which can also be used outside of a protocol, as long as regulated (as, for example, in the EU ETS). Whilst CDM and JI enable European industry to exploit marginal abatement cost differences between countries, incentives for early action are currently comparatively low.[3] Whilst the first two strategies together with end-of-pipe reductions of air emissions lead to lower GHG emissions and, therefore, to lower demand for certificates under, for example, the EU ETS, the third strategy of flexible mechanisms creates offsetting credits which may reduce further certificate demand because they may be counted towards the emissions remaining, after use of the other two strategies introduced above, plus the use of end-of-pipe emissions reductions. Corporate energy management strategies are frequently embedded in EMS and this may actually lead to favourable policy interactions between them and the EU ETS in the event that EMS implementation would have a positive effect on strategy adoption. The drivers of energy management strategies can empirically be analysed in terms of determinants for corporate energy management activities. This is possible because of the largely one-on-one linkage between the different energy management activities to be analysed and only one of the generic strategies. The activities included in the empirical analysis are the reduction of energy use in production (EUSE) and the reduction of energy use in transport (ENTR), which are directly linked to the first generic strategy of increasing energy efficiency. The substitution of non-renewable resources such as renewable energy for fossil fuels (RENS) is a direct proxy for the second generic strategy of fuel substitution, whilst the reduction of emission through air pollutants (EMAR) is closely linked to emissions-oriented end-of-pipe approaches. Whilst the activities do not directly correspond to the three generic strategies introduced earlier, there are very close links. Thus, by analyzing the drivers for the above energy management activities, determinants of higher or lower GHG emissions, and *ceteris paribus* higher or lower certificate demand, can be identified. Application of flexible mechanisms by a firm can then further reduce certificate demand. Unfortunately, at the time of the last EBEB survey, the EU ETS was not in force and empirical data on its effects in firms were not available. However, this is not considered a limitation since Kyoto and the EU ETS came into force only recently in 2005, it seems unlikely that firms would already use, to a larger degree, flexible mecha-

[3] There is, for example, uncertainty regarding the use of emission reduction units or emission credits from JI/CDM in the EU emissions trading system with the current status, being that such use would be possible from 2008 onwards in the scope of the Kyoto Protocol. Hence, whilst early JI/CDM projects may have positive reputation effects for firms, they run the risk of gaining only limited economic benefits. It seems that this would merit a cautious approach by firms towards integrating flexible mechanisms into their existing energy management strategies. For example, if firms carried out energy management activities in the context of an existing EMS, then they would continue to implement all cost effective activities as before (see also Hamschmidt and Dyllick (2002) on an evaluation of EMS with regards to profitability and an analysis of links to learning processes).

nisms as a strategy. In addition to this, it would seem that firms would change their energy management activities and strategies fundamentally because of Kyoto or the EU ETS. It rather seems that firms would do so gradually due to existing resource allocations and because flexible mechanisms will always only be a subset of energy management strategies and activities. Therefore, the dependent variables proposed earlier for an empirical analysis are the most important drivers for the level of GHG emissions by firms, and thus the number of emission certificates required, which also allows one to link them to emissions trading.

3 Data and research method

The empirical analysis for which results are presented in the following section is based on data collected during the European Business Environment Barometer (EBEB) survey. This is a (roughly) bi-annual survey on the state of environmental management in practice carried out in several European countries based on a mail questionnaire. The questionnaire asks firms about their main environmental effects and stakeholder demands, the main management and technological activities carried out, their degree of sophistication, and the extent of their corporate environmental strategy.[4] The results reported in the following are based on the last EBEB survey round in 2001 carried out in nine countries (Belgium, France, Germany, Hungary, Netherlands, Norway, Sweden, Switzerland, United Kingdom). Prior work provides descriptive results and some comparison between countries (Baumast and Dyllick 2001). In the 2001 EBEB round almost 2100 firms in manufacturing industries, surveyed Europe-wide, replied. For Germany, after having sent the first questionnaires to about 2000 companies, 334 usable questionnaires in total were returned, corresponding to an effective response rate of 16.7 percent. This response rate is inconsistent with the average response rate of other countries (e.g. Hungary 35.2%, Switzerland 14.9%, Sweden 36.3%, Netherlands 18.1% and United Kingdom 10.7%), for which data was collected during the 2001 EBEB survey round (Baumast and Dyllick 2001). Amongst the technical activities of environmental management surveyed in the EBEB questionnaire were four relating to energy management. For each of these (detailed at the end of Section 2 above), respondents had to state whether their firm had carried out the measure or not. Given this binary dependent variable, a binary Logit model (Greene, 2000) is applied. Since 30 independent variables were used in the regression analysis, data for all countries was pooled. The model was estimated using Maximum Likelihood (ML).

The embeddedness of energy management strategies and activities into EMS suggests inclusion of the latter as a determinant, since likely EMS implementation has a positive effect on the adoption of strategies/activities. This would result in reduced emission levels and a lower likelihood of ETS participation. Even though the levels of EMS implementation ("Not implemented", "Considering", "In process", "Implemented") could be seen as an ordinal variable, this would assume that there are equal changes in effect between levels.

[4] The full questionnaire can be accessed in English at www.agf.org.uk/pubs/pdfs/UK.pdf

To avoid this (restrictive) assumption, dummy variables were introduced instead (with no EMS existing as the reference group), to take into account the possibility of different changes between two adjacent levels.[5] Firm size was measured by the number of employees (in thousands), and country membership through dummy variables for each country with firm location in the Netherlands being the reference group omitted in the regression. Sector membership was also measured through dummy variables based on two-digit NACE codes with firms in the metal products sector being the reference group. Other control variables included were the logarithm of firm age in years, market growth (measured on a 5-point scale to assess whether the main market of a firm has increased or decreased over the last three years), firm legal status (in terms of a dummy variable taking unity value if the firm is solely owned), and overall profitability (measured on a 5-point scale to assess if a firm is profit- or loss-making). Based on these considerations, the Logit model for the analysis to follow is defined as:

odd of activity i = function (firm size, sector dummies, country dummies, market growth, firm age, legal form, overall profit, level of EMS implementation).

4 Estimation results

Table 1 provides the results of the estimation as well as several important statistics providing information about the quality of the estimation. These are the Likelihood Ratio (LR) test, Nagelkerke's R^2 and the Cox & Snell R^2, all of which provide some assessment of the overall quality of the model. In addition, the Hosmer-Lemeshow-Test provides an indication about the goodness-of-fit of the model.

The most important finding is that the strongest significant effect, positive across all variables, is that of environmental management system (EMS) implementation. Also, the strength of this effect is increasing across different implementation stages and is strongest for firms which have a fully implemented EMS: here the effect was significant, positive and economically relevant for all four dependent variables/energy management activities (proxying for strategies) analysed. Also for the variable of EMS implementation in progress, significant positive effects were found in the case of activities to reduce energy use in production and for the substitution of non-renewable resources. The positive effect of an incomplete EMS can potentially be explained by the fact that this implies that at least some elements of an EMS already exist. This (and even more so, full implementation) enables more systematic identification of attractive activities based on learning processes and better information quality.

Next to EMS, important findings are that for energy use in production (EUSE), all country dummies except for Belgium (which is also a Benelux state) have a significant and strong negative effect relative to the Netherlands as reference groups. This is less the case for the other energy-related dependent variables (where for only a few countries the negative effect is negative relative to the Netherlands), and is even turning to largely positive for energy use in transport

[5] The results of the estimation confirm that this cautionary approach was appropriate.

(ENTR). These observations may be explained by the leading role the Netherlands have in industrial energy efficiency. Apart from these findings, the country effect is generally very negative for France and, to a little lesser degree, for Norway.

As well, a number of sectoral dummy variables are significant relative to the dummy group. Again, the effect seems to be variable-dependent: exclusively positive for fuel substitution (RENS) and transport energy use, and more neutral for energy use in production and the reduction of air emissions (always relative to metal products).

Table 1. Results of Logit models for different dependent variables

Dependent variable	EUSE	RENS	EMAR	ENTR
Independent variable	Beta	Beta	Beta	Beta
Food	.386	.090	-.342	.933
Textiles	.304	-.107	-.798	.212
Leather	-.115	.421	.037	.583
Wood	.147	.551	.836	.662
Pulp/Paper	-.143	1.100	.059	.502
Print	-.399	.199	.155	.159
Energy	.857	-.633	.021	-.654
Chemical	-.175	.510	-.147	-.237
Rubber	.796	.048	-.143	.479
Nonferrous	.112	1.420	.759	.448
Machines	-.365	.076	-.168	.128
Electric	.141	.341	-.080	.040
Transport	-.042	.567	-.536	.606
Other	-.464	.370	.126	.176
Germany	-.591	-.357	.160	.357
Sweden	-.939	-.142	-.327	-.260
Switzerland	-.631	.210	.192	.846
United Kingdom	-.804	.231	-.419	.083
Hungary	-.635	-.391	.431	.910
France	-.911	-2.377	-.665	-.590
Belgium	-.039	.100	-.014	.098
Norway	-.826	.066	-.645	-.357
Market growth	-.093	.024	.065	-.227
Considering EMS implementation	.225	.428	.320	.247
EMS implementation in progress	.304	.559	.258	.086
EMS implemented	.964	1.036	.686	.471
Firm legal status	.033	.082	-.156	-.038
Overall profitability	-.078	-.011	.001	.063
Number of employees	.266	.003	.080	.010
Firm age	.046	.001	.021	.004
Constant	1.018	-2.081	-.002	-.696
Number of observations	1527	1109	1324	1333
Degrees of Freedom	30	30	30	30
Hosmer-Lemeshow test	14.277	4.961	3.442	4.649
Cox & Snell R-squared	0.100	0.071	0.068	0.079
Nagelkerkes R-squared	0.136	0.107	0.093	0.110
-2 Log-Likelihood	1857.1	1135.7	1654.1	1574.4
Chi-squared (LR test)	160.60	81.65	93.08	109.28

Bold and italicised Figures mean significance at the 1% level, bold Figures at 5% level, and italicised Figures significance at the 10% level; leading zeros for all Betas were surpressed.

In addition to the influences from the identified country, industry, and EMS, some firm size effects were positive and significant in the model.

However, these were not economically relevant, due to the small coefficients which have almost no effect on the odd ratios. Effects were only significant for activities to reduce energy consumption in production and for the reduction of air emissions, but not for the other variables. Finally, a strongly growing main market had a significant negative effect on activities for reducing energy use in transport.

This seems plausible, since firms which act in a strongly growing market likely have to expand their transportation activities over-proportionally in order to participate in market growth. This may lead to reduced attention to energy use in transportation, due to a strong managerial focus on achieving the expansion of transport activities.

Wagner (2002) found for the German EBEB sub-sample no significant differences in 2001 ratios of energy consumption per employee (data for which was not gathered in the other countries) between firms with and without EMS certification, as can be seen in Figure 1.

As well, Figure 1 shows no positive trend from 1991 to 2001, but the sample size is very small. Compared with the Figure 1, the results based on Table 1 indicate that the relevant aspect is likely implementation, not certification, supporting the research design used.

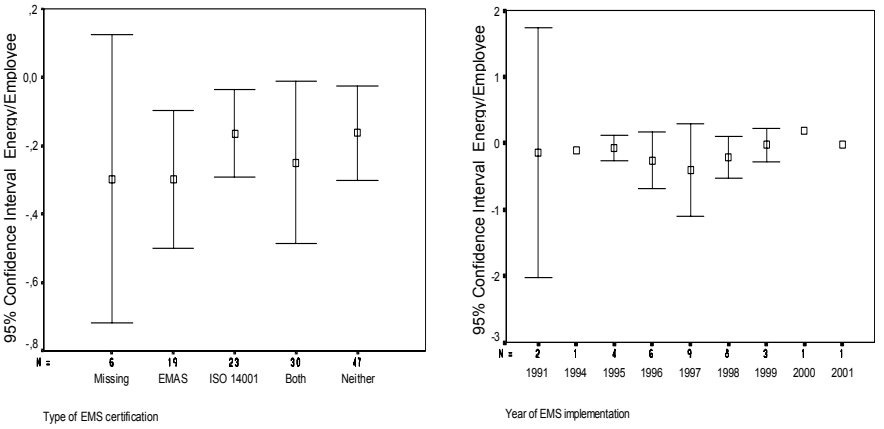

Fig. 1. Effect of EMS (proxy for voluntary agreements) on energy efficiency

5 Conclusions and implications

What are the implications of the empirical results for the interaction of the different determinants for energy management activities/ strategies with climate policy initiatives, especially the EU ETS? As noted earlier, the dependent variables of the empirical analysis can be understood as drivers for corporate emission levels as well as proxy measures for different generic strategies. Therefore, they are also linked to firms' demand for emission certificates. For example, if firms pursue many energy efficiency improvement or fuel substation activities (and the results of the regression analysis inform us that one main determinant for doing so is EMS implementation), then certificate demand is likely lower, all else being equal. In other words: positive (and significant) effects in Table 1 mean that the probability of firms to reduce their energy use is positively affected and thus the demand for certificates will be reduced. Conversely, a negative and significant coefficient would imply a lower probability for reducing corporate energy consumption and hence a higher demand for emission certificates. The significant positive effect of EMS implementation on energy management activities ensures that a mechanism links EMS and the EU ETS through the effect on certificate demand which ensures that the equilibrium market price for certificates is equal to the marginal abatement costs from carrying out energy management activities under an EMS: if the marginal cost of energy management activities are above the certificate price, then a firm would choose to carry out the activity. If the cost of the activity is above the certificate price, then the firm would opt to buy certificates. Hence social welfare in a system using both instruments will be higher than in one using only one, either EMS or ETS. The EMS hence plays a critical role here, because it is its implementation that enables the correct identification of marginal costs for the activities, based on learning processes and better information quality.

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The implementation of emissions trading in companies

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Abstract

This paper investigates what activities large companies have undertaken to utilize emissions trading and/or offset projects as part of a strategy for climate change. The main objective is to explore how the political conditions in home countries have affected corporate activity towards emissions trading. Based on an analysis of data of 218 companies derived from a questionnaire, this is examined by assessing to what extent emissions trading is becoming embedded in large companies. Looking at the pattern of actions of a cross-section of companies from different countries and industries, an evaluation is made of the path that companies take to move towards the implementation of emissions trading. Findings show that many companies have the intention to participate in the emission market, but are postponing implementation until government policy becomes more concrete.

Keywords: Emissions trading, corporate strategy, climate change

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1 Introduction

Over the past decade, an increasing number of companies has recognized the challenge to combat climate change (Kolk and Pinkse 2004, 2005). Business attention for this issue was spurred by adoption of the Kyoto Protocol in 1997, in part because it contained the introduction of three innovative market-based policy instruments – emissions trading, the Clean Development Mechanism (CDM), and Joint Implementation (JI) – which are collectively labeled as the flexible mechanisms (Grubb et al. 1999). Noticeably, there has been very little research on the response of companies to the introduction of these flexible mechanisms or their intention to implement them as part of a strategy for climate change (Pinkse 2007). Most predictions on the effectiveness of emissions trading have been based on outcomes of scenario analyses (which vary according to participating countries, projected economic indicators and estimated emissions growth) using economic models (see Springer (2003) for an overview). However, these models merely focus on cost-effectiveness of a range of policy options for different scenarios (Sandén and Azar 2005), but do not take into account that successful implementation of policy instruments depends to a great extent on the outcome of a political bargaining process between governments, companies and non-governmental organizations (Markussen and Svendsen 2005). As a consequence, emissions trading schemes that are put in practice differ considerably from their optimal economic design and cover a limited number of countries and industries (Boemare and Quirion 2002).

Moreover, individual companies may have incentives to engage in emissions trading and offset projects that are not directly cost-related. Studies that investigate business responses to environmental regulation from a management perspective, suggest that regulation stimulates companies to develop environmentally-induced competences (Porter and van der Linde 1995; Rugman and Verbeke 1998). This implies that firms may use emissions trading strategically to outmaneuver their competitors and not, in the first place, to control greenhouse gas (GHG) emissions. Alternatively, companies may also participate in emissions trading schemes for more symbolic purposes to maintain legitimacy (Meyer and Rowan 1977), because trading may be seen as 'good' management by external constituencies, such as governments, non-governmental organizations and the public.

In order to shed light on corporate responses to the flexible mechanisms, this paper investigates what activities large companies have undertaken to utilize emissions trading and/or offset projects as part of a strategy for climate change. It not only takes into account factors that motivate companies to participate in the emission market, but also what prevents them from doing so. In view of the difficulties in identifying incentives and/or barriers for firms to participate in emissions trading schemes, this paper takes a process view by investigating the pattern of actions of firms to implement the flexible mechanisms (Mintzberg and Waters 1985; Winn and Angell 2000). To assess the degree of implementation and reflect on the reasons to participate in an emissions trading scheme, empirical data from a ques-

tionnaire sent out to the 500 largest companies according to the Financial Times will be analyzed. First, however, the next section will start with a discussion of the literature on the politics surrounding the introduction of the flexible mechanisms with the aim of shedding light on the institutional context in which companies operate.

2 The politics of implementing emissions trading

The implementation of an emissions trading scheme is essentially a political process. As a result of political bargaining and the fact that many interest groups try to influence the implementation process, the final design of trading schemes deviates considerably from the optimal design economic theory suggests (Boemare and Quirion 2002; Markussen and Svendsen 2005). The influence of politics on the implementation of an emissions trading scheme for climate change mitigation centers around two closely connected policy issues: support for the Kyoto Protocol and use of the flexible mechanisms. For both issues the interaction between politics on an international and a domestic level has been crucial (Busby and Ochs 2004; Sprinz and Weiss 2001). Since emissions trading for climate change mitigation is a direct result of the negotiations of the Kyoto Protocol (Grubb et al. 1999), whether or not to implement it as a policy instrument first depends on the political will of a country to take on a commitment to reduce GHG emissions. Historically, climate change was an issue dominated by nongovernmental actors (mainly scientists), but with the inception of the Intergovernmental Panel on Climate Change (IPCC) and the United Nations General Assembly resolution on climate change in 1988, governments started to play a greater role (Bodansky 2001). It thus became an intergovernmental issue without a long history in domestic politics. Nevertheless, even though the political debate has been taking place on an international level, the position of countries depends to a great extent on the behavior of domestic political actors as well (Busby and Ochs 2004; Sprinz and Weiss 2001).

Several explanations have been proposed for the different political standpoints of countries, particularly the US and EU (and to a lesser extent Japan), on climate change and the use of emissions trading. In sum there are three types of interests – polluters, victims, and third parties – that have influence on the national positions on the Kyoto Protocol and the flexible mechanisms (Sprinz and Weiss 2001). The general public, government, business, and environmental NGOs all have a role to play with respect to each of these interests. Business is generally considered to represent the interests of polluters, particularly the energy-intensive industries, while the general public (represented by environmental NGOs) is considered as the chief victim. Third parties are those actors who are the main providers of abatement technologies and substitutes for polluting activities, including the emerging renewable energy industry, and business clearly has a role in this as well (Sprinz and Weiss 2001).

The position of the US has been characterized by the large influence of domestic constraints (Busby and Ochs 2004), and, despite well-organized environmental

NGOs, the dominance of business, particularly of polluters (Sprinz and Weiss 2001). As a consequence, abatement costs have been emphasized and the adverse effects on international competitiveness, which ultimately led to the rejection of the Kyoto Protocol in 2001. At the same time, however, the US has also been the main advocate of the flexible mechanisms. Out of fear that domestic action would not be sufficient to achieve the commitments of the Kyoto Protocol, the US (supported by Japan and Russia) negotiated as much flexibility as possible (Grubb et al. 1999). The cost-effectiveness of emissions trading and experience with similar trading schemes for sulphur and nitrogen oxides (Kruger and Pizer 2004; Schreurs 2003) are probably other motives for this favorable view of emissions trading. Yet, the federal government of the US has not implemented, to date, a large-scale trading scheme for GHG emissions.

The view of the EU on the Kyoto Protocol and emissions trading has been the complete opposite of the US position. Unlike the US, it has not primarily been domestic constraints that determine the position of the EU, but instead credibility in international negotiations to live up to the role of frontrunner on climate change (Sprinz and Weiss 2001). The EU has always supported a protocol with strict targets for emission reductions, but was not in favor of the flexible mechanisms, at first. The EU first gave in to the US by allowing the flexible mechanisms into the Kyoto Protocol. After the rejection of the Protocol by the Bush government, the EU also made concessions to Japan, Canada, Australia, and Russia by allowing unlimited use of the flexible mechanisms and (limited) use of forests and farmlands as carbon sinks (Buchner 2005). The EU has thus made a remarkable shift (Christiansen and Wettestad 2003) by being the first to have introduced a large-scale emissions trading scheme in 2005, the European Union emissions trading scheme (EU ETS).

In the EU domestic actors have less influence on the governmental positions in international negotiations than in the US (Busby and Ochs 2004). Moreover, the interests of victims are more highly valued (in part because environmental NGOs are relatively strong), and third party interests are stronger because European companies are ahead in developing energy-efficient technologies and renewable energy (Sprinz and Weiss 2001). However, in the process of implementing climate policy instruments in each member country, business has had a much greater role (Busby and Ochs 2004; Sprinz and Weiss 2001). This has partly been due to the fact that some EU countries have a longer history in regulating climate change (Sorrell and Sijm 2003). For instance, countries such as Germany and the Netherlands negotiated voluntary agreements with industries to reduce GHG emissions, and the UK and Denmark launched emissions trading schemes ahead of the EU. Because of such vested interests of business in climate change regulation, companies have used their bargaining position to influence the design of the EU ETS (Christiansen and Wettestad 2003) and the allocation of allowances (Butzengeiger and Michaelowa 2004).

Finally, the Japanese stance lies in between that of the EU and US. It has been the international community that particularly influenced Japan in developing its environmental policy. Since Japanese environmental NGOs are not yet mature (Schreurs 2003) and relations with business used to be based on consensus

(Hamilton et al. 2003), the Japanese government has not been pressurized much by domestic actors. Traditionally, Japan used to lag behind other industrial countries with regard to environmental policy (Schreurs 2003). The Japanese government only excelled in environmental policies that are appropriate for the private sector in cutting costs, which has resulted in considerable improvements in energy efficiency over the last decades. However, as a result of international pressure, Japan has followed a different approach to environmental policy since the late 1980s; it introduced new environmental laws and became more prominent at international negotiations of global environmental problems. In the climate negotiations, this new approach first resulted in Japan's support for the US proposal of the flexible mechanisms in 1997, but also led to the decision to move forward with the Kyoto Protocol after the withdrawal of the US. Japan also started to take more responsibility for environmental problems in East Asian countries, such as China with which it has strong connections (Schreurs 2003).

Nonetheless, there is much uncertainty regarding the position of Japan in coming years, because of resentment of the major energy-intensive industries with the outcome of negotiating the Kyoto Protocol (Hamilton et al. 2003). These industries feel cheated by the binding character of the Japanese emission reduction target of the Kyoto Protocol (traditionally environmental targets are non-binding in Japan), and the fact that it does not take into account past achievements in energy-efficiency. This is likely to lead to political tension between industry members and the government, because it is unclear who is responsible for the emission reductions to reach the binding target: government or business. So far, Japan has not introduced an emissions trading scheme, but the gap between current emissions and the target of the Kyoto Protocol (Hamilton et al. 2003) will probably compel the government to do so in the near future.

To summarize, then, historically the three largest economies (US, EU, and Japan) have clearly developed divergent political standpoints on the Kyoto Protocol and emissions trading, which expected to have have implications for companies. Business in the US clearly made use of the opportunity to influence the political process to their advantage, which led to the rejection of the Kyoto Protocol by the federal government. EU companies have more heavily influenced the design of the EU ETS (launched in 2005) and used their strong bargaining positions in their national economies. Japanese companies have not been able to have a similar decisive effect on their government, but will have to anticipate the difficulty to meet the Kyoto commitment. The remainder of this paper will analyze how these internationally divergent political standpoints on climate change have affected companies in taking steps to implement emissions trading within their organizations.

3 Methodology and data

A first question that guides the research is to what extent are companies taking action to use the flexible mechanisms as part of their climate change strategy. Do companies from the same country or industry have a tendency to follow similar

paths? Then, if a company takes concrete measures, how can it be characterized, and, what appears to be the underlying motive? Alternatively, what reasons do companies have for not using the flexible mechanisms? These issues will be examined by assessing to what extent emissions trading is becoming embedded in large companies, furthermore, to what extent can it develop into a vital aspect of corporate climate strategies? Looking at the pattern of actions of a cross-section of companies from different countries and industries, an evaluation is made of the path that companies take to move towards the implementation of emissions trading (Mintzberg and Waters 1985; Winn and Angell 2000).

The data used for this study have come available through the second cycle of the Carbon Disclosure Project (CDP 2004); a joint initiative of 95 institutional investors to assess the risks of climate change for companies. As part of this survey the 500 largest companies worldwide (according to the 2003 Financial Times Global 500 list) were asked to provide information on their strategy for emissions trading. The fact that it was institutional investors who sent the questionnaire resulted in a very high response rate: 59% of the companies answered the questionnaire, 19% did not respond, 15% declined to participate, and 6% provided only limited information (in most cases from their sustainability reports). Of the 288 companies that answered the questionnaire, the responses of 218 companies, used for the analysis, were made available through the Internet.

The qualitative data were analyzed using an inductive coding technique. First, the data were scanned to obtain a long list of concepts. Next, these concepts were grouped to obtain higher-order, more abstract concepts. These high-order concepts were translated into codes and filed under several categories, which helped to build the argumentation. Finally, all the responses were analyzed in a more detailed way for all sectors separately with the aid of the codes, and the resulting patterns were examined (Strauss and Corbin 1998). This subsequently led to the topics that will be discussed in the following four subsections: corporate participation in different types of existing emissions trading schemes; the effect of country of origin and industry membership; the degree of implementation; and incentives and barriers. While the first two subsections portray the general trends, the latter two look more closely into companies' motives for actually implementing emissions trading in their organization.

4 The advancement of emissions trading in companies

4.1 Corporate participation in different emissions trading schemes

Findings reveal that companies which take emissions trading into consideration generally single out one particular emission market. It is not surprising, then, that the largest part of the sample focuses on the EU ETS because it certainly affects the greatest number of companies. About 16 per cent of the sample is definite about taking part in this scheme, while 19 per cent is considering participation or monitoring the current developments (see Figure 1). Nevertheless, 65 per cent of

the companies do not express any interest in the EU ETS, or state that they will not participate at all. The EU scheme is not the only emission market that currently exists in Europe and some companies have already traded in a small-scale market, such as the UK ETS or the Danish scheme. However, participation in a national emission market is not a guarantee for trading in the EU ETS. For instance, the British bank Barclays was a leading participant in the UK scheme, but states that it cannot join the EU scheme, because it is designed differently with a much stronger focus on large consumers of energy.

Relatively small emission markets have been established in the US and Australia, even though these countries did not ratify the Kyoto Protocol. In the US a number of companies together with NGOs founded the Chicago Climate Exchange, a scheme in which participants commit themselves to a voluntary reduction target. Trading is one of the options participants have for realizing these reduction targets. In contrast, the most important scheme in Australia – the New South Wales State Government's Greenhouse Gas Abatement Scheme – is government-induced instead of private, but locally organized on a state-level. These non-Kyoto markets only include a few companies compared to the EU scheme, which may be due to their voluntary nature. On the whole, participants in these schemes are frontrunners in emissions trading and also active in the EU scheme. Altogether, only 5 per cent is active in one of these non-Kyoto schemes and 3 per cent is considering participation, while the remainder (92 per cent) shows no interest. To illustrate, the reason FPL Group, a US utility, gives for not participating in a voluntary scheme is that it does not reflect the design of a regulatory driven GHG market.

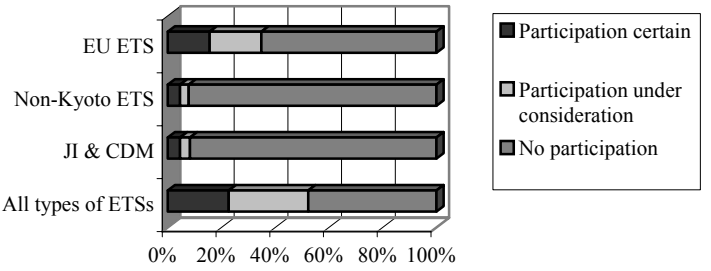

Fig. 1. Participation in emissions trading schemes and offset projects based on responses to CDP 2004 (N = 218)

Apart from emissions trading, a few companies have also started to develop carbon-offset projects. Credits earned with these projects can be used for compliance in the EU ETS (under the so-called 'linking directive') in the first commitment period (2008-2012), but not in the preliminary trading period (2005-2008). Only 5 per cent is currently in the process of developing projects that are eligible

for CDM or JI, while 4 per cent is considering this option. Nevertheless, some companies stress the importance of these projects because this enables them to exploit their international presence (e.g. Suez). Uncertainty about the role of these mechanisms in emissions trading schemes is probably the reason why only a few have taken some first steps to realize carbon-offset projects. Some companies see the use of CDM and JI as complementary to emissions trading (e.g. Astrazeneca), but others consider it a substitute and prefer these projects because they lead to actual GHG reductions of their own company (e.g. Ricoh). Apart from developing carbon-offset projects on their own, some companies (e.g. ENI) also explore the option to become involved in projects through a carbon fund, such as the World Bank's Prototype Carbon Fund.

Not all companies relate their business interest in emissions trading to an existing market. Particularly companies from Japan and Canada give a broad opinion on the issue, but do not give details about their engagement in one specific market. This appears to be the consequence of the fact that their governments have ratified the Kyoto Protocol, but currently still refrain from introducing an emissions trading scheme linked to the EU ETS. For example, Suncor, a Canadian oil company, emphasizes the uncertainty that prevails due to the lack of initiative taken by their government:

> "The lack of a clear direction from the Canadian government, with respect to Kyoto obligations and standards to ensure emission reductions are standardized across an international market, limits our involvement in any emissions trading regimes at this time."

This does not always mean that companies from these countries fail to act altogether. Figure 1 shows that with regard to emissions trading in general, whether the trading scheme is specified or not, a total of 23 per cent of companies in the sample is certain to participate, while 30 per cent is considering this. Nevertheless, 48 per cent of the companies in the sample is without a strategy to anticipate the introduction of the flexible mechanisms.

4.2 Trends by country and industry

The political divergence on climate change clearly affects large corporations in forming strategies for emissions trading. As Table 1 shows, companies from the EU are ahead of their American and Japanese counterparts. However, companies from the US and Australia do not seem to lag behind Japanese and Canadian companies. This suggests that whether or not a country ratified the Kyoto Protocol does not appear to be decisive for a company to become involved in emissions trading; more important is the extent to which regulation is being implemented. This is also reflected in the response of EU companies to regulation in their respective countries. At the climate negotiations the European Union acted as one party, but implementation of the Protocol and allocation of the allowances has been left to the individual countries (conditional on approval of the European Commission). Moreover, the individual EU members have different histories in

regulating GHG emissions (Sorrell and Sijm 2003). As a result, British companies currently hold a leadership role with regard to emissions trading because of the early launch of a national emissions trading scheme by the UK government. Similarly, initiatives of the German government to introduce climate change regulation in an early stage have also led to more activity by German companies.

National differences are somewhat different with regard to corporate participation in carbon-offset projects. Ratification of the Kyoto Protocol plays a much greater role, because governments of ratifying countries are more likely to acknowledge credits earned with JI and CDM projects because these mechanisms are an intrinsic part of the Protocol. Japanese companies in particular are developing projects that may apply for CDM. Nippon Steel, for instance, is currently investing in energy saving projects in China and India. Moreover, it can be expected that the Japanese and Canadian governments will strive for harmonization with the EU ETS, and as a consequence also accept JI and CDM credits. Petro-Canada, however, is still hesitating to invest in projects for CDM because of the uncertainty about the way Canadian climate regulation will unfold.

Table 1. National patterns in corporate action on emissions trading based on responses to CDP 2004 (N = 218)

		EU ETS (%)			Non-Kyoto (%)			JI & CDM (%)			All Types of ETS (%)		
Region	N	1	2	3	1	2	3	1	2	3	1	2	3
EU	88	24	23	53	5	0	95	8	3	89	32	28	40
US	79	13	15	72	6	4	90	1	1	97	18	25	59
Japan	26	4	19	77	0	0	100	8	8	85	15	38	46
Australia	3	0	33	67	33	67	0	0	0	100	33	67	0
Canada	8	0	38	63	0	25	75	0	13	88	0	75	25
UK	26	31	31	38	12	0	88	4	0	96	46	42	12
Germany	13	38	31	31	0	0	100	0	15	85	38	38	23
France	18	6	33	61	0	0	100	6	0	94	6	33	61

[1] Participation certain; [2] Participation under consideration; [3] No participation

There are also clear differences in the impact of emissions trading on the various industries (see Table 2). On the whole, large consumers of fossil fuels are the most active participants in the emission market, but there are clear differences between energy-intensive industries. A first distinction is between producers of fossil fuels and producers of electricity. While 65 percent of companies that operate in oil, gas and mining will definitely trade emission allowances in one of the existing markets, and 29 per cent is considering this, participation is certain for only 26 per cent of electric utilities. This pattern is also seen with regard to the EU ETS, which is remarkable because utilities are included in this scheme. A second distinction is between chemicals and pharmaceuticals. Both types of industries are related in terms of the production process, but pharmaceutical companies are more willing to start with emissions trading than chemical companies. For other energy-intensive industries, such as general manufacturing and metals, progress is moderate

with about one third of the companies expecting to trade in the near future. Finally, the design of the EU ETS with its focus on large fossil fuel installations perhaps explains the difference between two other related industries: automotives and transport. Fuel consumption in the transportation sector is dispersed over a large transportation fleet and not concentrated in industrial installations, while such concentration is precisely the case in the manufacturing process of automobiles.

The emerging emission market does not affect service-related sectors in the same way as energy-intensive industries. On average, the share of service companies that are participating in emissions trading schemes is therefore much lower (see Table 2). However, financials and insurance companies, particularly, are in the process of developing services related to emissions trading. Some financial companies, for example Fortis, assist their clients in trading emission allowances, while insurance companies are currently developing products for risk coverage of emissions trading. Since companies from both sectors are also large investors, some (e.g. Westpac, Royal Bank of Canada, Ace Limited, Munich RE) also assess the influence of emissions trading schemes on the risk profile of their clients.

Table 2. Sectoral patterns in corporate action on emissions trading based on responses to CDP 2004 (N = 218)

		EU ETS (%)			Non-Kyoto (%)			JI & CDM (%)			All Types of ETS (%)		
Sector	N	1	2	3	1	2	3	1	2	3	1	2	3
Automotive	10	40	50	10	10	0	90	10	0	90	40	50	10
Chemicals	14	14	36	50	0	0	100	0	7	93	14	43	43
Comm/media	21	5	19	76	0	10	90	0	5	95	5	33	62
Electronics	21	10	14	76	5	0	95	5	0	95	19	38	43
Financials	34	0	12	88	3	6	91	6	0	94	12	21	68
Insurance	11	0	9	91	0	0	100	0	0	100	0	45	55
Manufacturing	13	15	27	58	4	4	92	8	4	88	31	27	50
Oil/gas/Mining	17	53	18	29	18	6	76	12	6	82	65	29	6
Other services	13	8	4	88	8	0	92	0	0	100	17	17	67
Pharmaceuticals	14	43	29	29	0	0	100	0	14	86	50	21	29
Transport	7	0	29	86	0	14	86	0	0	100	0	57	43
Utilities	19	21	16	63	5	0	95	11	11	79	26	21	53

[1] Participation certain; [2] Participation under consideration; [3] No participation

4.3 Implementation of emissions trading

These general trends give an indication of the intention of companies to engage in emissions trading. However, to assess to what extent emissions trading is actually becoming embedded in companies, a more detailed examination of the implementation process is needed. Most activities to this end are currently aimed at making preparations for engagement in a government-induced scheme. Since emissions trading schemes have only recently been launched, not many companies have traded allowances on a large scale yet.

There are several stages in the process of preparing for emissions trading schemes. A first step for companies is to study how the flexible mechanisms work (mentioned by 8% of the sample). A fair amount of companies (8%) have also taken the next step to engage in pilot projects to gain experience with emissions trading. These pilot projects have not only been conducted within organizations (e.g. Matsushita), but also in cooperation with governmental bodies on a state or national level. In Germany several pilot projects have been carried out, such as the 'Hesse Tender' in which Deutsche Telekom participated. However, it has mainly been Japanese companies (e.g. Hitachi, Sony, Fuji Photo Film, Mitsubishi Estate) that take part in pilot projects, because the Japanese Ministry of Environment and Ministry of Economy, Trade and Industry have initiated pilot schemes before launching a national scheme.

To prepare for compliance with a large-scale scheme such as the EU ETS, companies have started to collect data on GHG emissions and to identify which installations will fall under the scheme. To this end, reporting systems are being developed and several companies that will participate in the EU ETS have already reported their data to governmental bodies responsible for the allocation of allowances. In total, 31 companies (14%) in the sample have collected data to be able to engage in emissions trading, but so far only 8 companies (4%) have also verified and/or reported the data to the government.

A final step in making preparations is the allocation of responsibility for emissions trading within a company. While some companies consider emissions trading as a task for the environmental department (BMW), others have set up special climate change teams (Dow Chemical, Alcoa), and a few companies have also become aware of the fact that trading may require cooperation between departments (ChevronTexaco). For example, Bayer, a German chemical company, set up a task force, while Norsk Hydro, Statoil, and Royal Dutch/Shell are all establishing separate departments to deal with emissions trading.

In concordance with the overall trend that companies in oil, gas and mining and the automotive industry are most likely to trade emission allowances; it is these industries that are also ahead with making preparations (see Figure 2). General manufacturing and metals as well as the utilities are also making an effort to be able to start trading soon. It appears that when companies in these two industries have the intention to participate, they also act on it, which is probably a result of the large impact of the EU ETS on these industries. However, the pharmaceuticals, which showed evidence of having the intention to trade, have not made much progress yet in the implementation process. It must be noted that the chemical

industry draws much nearer to the pharmaceuticals when implementation is considered. A comparison between intention and implementation for the full sample suggests that companies that have the intention to participate (53%) do not always follow this up with initiatives to implement the practice of trading in the organization (32%).

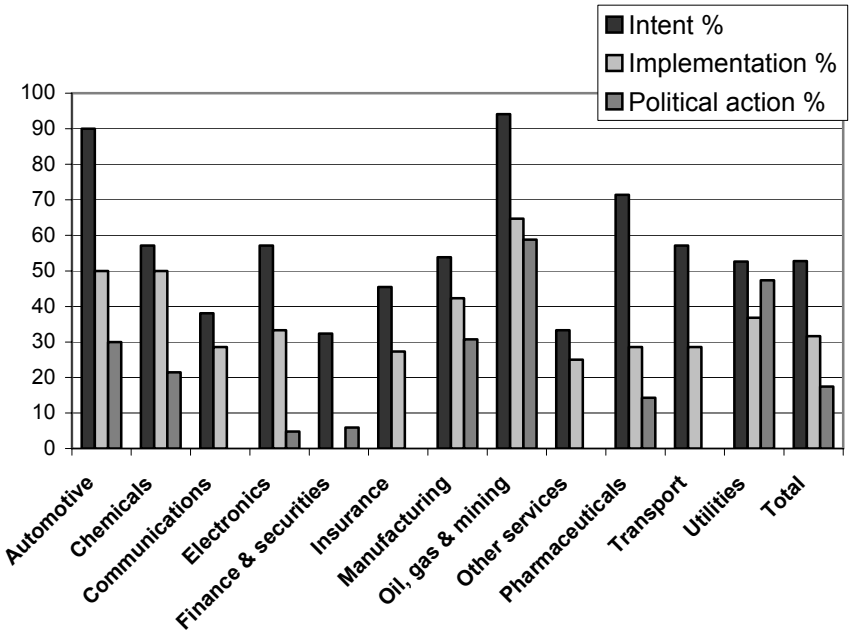

Fig. 2. Intent, implementation, and political action compared across industries based on responses to CDP 2004 (N = 218)

4.4 Incentives and barriers

It is apparent that companies have different opinions regarding the function of emissions trading as part of a strategy for climate change. The pattern of actions across companies suggests that industry membership and country of origin exert considerable influence on the decision to participate in an emissions trading scheme, but the question remains what the underlying incentives are that cause certain companies to take on a leadership role in implementing emissions trading. Besides, what reasons do companies have for taking almost no concrete measures (which is applicable to nearly two-thirds of the sample)?

For many companies emissions trading is predominantly a mechanism for compliance and will be used to reach the target for GHG reduction imposed upon them by the government. Most companies do not explore the option of emissions trading until the government launches a fairly large scheme. About 14 per cent of the companies that will participate in the emission market explicitly states that

compliance with legislation is an important incentive. Additionally, of those companies that will not participate in the near future, 16 per cent reasons that they are not affected by any trading scheme, 11 per cent highlights a low level of GHG emissions, and 6 per cent states that their presence in the EU is limited. The significance of compliance is also reflected in the way emissions trading is organized in many multinational corporations. Since emissions trading is the result of emerging regulation, many multinationals manage it on a country-by-country basis (e.g. Unilever, CRH). This is even the case for trading within the EU, because the allocation process is different in each member state (depending on the National Allocation Plan). However, International Paper and Novartis both point at the opportunity to leverage the overall position in emission allowances by trading internally, and ChevronTexaco is currently developing a corporate level 'carbon markets strategy'.

As Figure 2 shows, business involvement in the political debate on emissions trading also functions as an incentive to actually participate in trading schemes. The sectoral pattern of corporate political activities suggests that those industries that expect to be affected by regulation (oil, gas & mining; automotives; manufacturing and metals; utilities; and chemicals) are also the ones that have tried to shape public policy as much as possible. Royal Dutch/Shell states that the development of trading schemes by governments gives companies the opportunity to influence the design, and therefore Shell has set up an internal information network to influence governments through different channels. Companies have tried to influence governments directly (10%) and indirectly through industry associations (8%). At the outset, political activities are aimed at involvement in the design of emissions trading schemes, but when a scheme has actually been implemented, such as the EU ETS, involvement focuses more strongly on the allocation of allowances (through lobbying and negotiating).

Additional incentives mentioned are first the cost-effectiveness of emissions trading in comparison to alternative policy instruments. For example, for American Electric Power the main objective of involvement in the Chicago Climate Exchange was to demonstrate that emissions trading is a cost-effective solution to climate change mitigation. In this case early action is used to influence policymakers and avoid more restrictive regulation on climate change. A second reason for active participation in the development of the emission market is to gain experience with trading (mentioned by 5%). It is notable that even though the majority of US utilities are not active in the GHG emission market yet, they are not too concerned about regulatory developments in this direction because they already have significant experience with emissions trading of other gases, such as SO_2 and NOx (Kruger and Pizer 2004). Finally, only a few companies consider trading as an opportunity to create value or maintain credibility towards stakeholders.

The fact that the trading periods of the EU ETS (2005-2007 and 2008-2012) have quite a short timespan may explain the gap between intention and implementation. Some companies (6%) are simply waiting for the outcome of the next allocation process before they take any concrete measures. In addition, design of the EU ETS is still severely criticized, particularly the lack of transparency on the role

of carbon-offset projects in the scheme. Daimler-Chrysler, for example, states the following:

> "However we haven't engaged into active trading yet, because a number of important boundary conditions, especially the ones with respect to project based instruments still need political clarification at the EU/international level."

Other barriers that are mentioned are high transaction costs (in particular of carbon-offset projects), exemption from trading because of early involvement in voluntary agreements with the government, and a preference for internal reduction initiatives.

5 Conclusion

The purpose of this study was to shed light on the response of companies to the launch of emissions trading schemes. It focused on the activities of large companies from the Global 500, and assessed to what extent they are in the process of preparing for emissions trading. Currently, on a global level the emission market is still in a developing stage, but already half of the companies in the sample are considering participation in one of the schemes recently implemented. As expected most companies focus on the EU ETS, since it covers the broadest range of industries of all schemes introduced to date. The effect of international political disagreement on climate change and emissions trading is evident and the general trend shows that European companies are more engaged in emissions trading than companies from other parts of the world, thus, reflecting the frontrunner position of the EU in the international negotiations on climate change. However, a country's ratification of the Kyoto Protocol does not automatically warrant a leadership role of national industries as well. Findings suggest that only when ratification is followed up with a concrete proposal for the launch of an emissions trading scheme, companies consider trading or engagement in carbon-offset projects an option to combat climate change. Uncertainty about the position of the government thus leads to a wait-and-see attitude of business, which is currently seen in Japan and Canada.

Not surprisingly, compliance with legislation is the primary incentive for business to participate in a trading scheme. As a consequence, many multinationals follow an approach where they deal with emissions trading on a country-by-country basis. For companies that are forced by regulation to take part in a trading scheme, design of the scheme is critical. To make sure that the boundary conditions of participation are favorable, many companies, particularly from energy-intensive industries, have therefore tried to influence the political process on the design and evaluation of proposed schemes. In the EU, companies are also engaged in the process of lobbying for allowances, when the allocation plans of member states are being drawn up. As a rule, companies that take part in the political process are farther ahead in implementing emissions trading in their organi-

zations, which suggests that they have been successful in shaping the institutional context to their advantage.

Nevertheless, there is still a clear gap between, on the one hand, business interest in emissions trading and, on the other hand, concrete action to implement the necessary structures to collect and report data on the level of GHG emissions and allocate responsibility for trading within the organization. In coming years, further research is needed to clarify whether those companies that expressed the intention to participate in an emissions trading scheme have also become active traders. It remains to be seen if emissions trading is not only a mechanism to comply with regulation, but also incites companies to go beyond compliance and use it to increase the value of their company. It may be worthwhile to examine how the position of Japanese and Canadian companies will change when their governments launch trading schemes. Finally, it will also be interesting to find out whether companies from ratifying and non-ratifying countries will further diverge when the US and Australia fail to set up trading schemes with a national coverage, and what consequences divergence will have for the international effort to combat climate change.

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Corporate strategy and the Kyoto mechanisms – institutional and transaction cost perspectives

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Abstract

This chapter examines the relative attractiveness of Kyoto project mechanisms as an option in corporate strategy to meet greenhouse gas emission targets. The analysis employs a transaction cost theory approach in combination with perspectives of institutional theory in organisational analysis. Empirical evidence is given from a study of climate strategies of Swedish companies. The analysis indicates that participation in the Kyoto project mechanisms is less attractive than other options. These mechanisms do not provide companies with the legitimacy they need to obtain other resources, and they are associated with transaction-specific costs that are too high to be viable alternatives.

Keywords: Corporate strategy, climate policy, greenhouse gas management, clean development mechanism, joint implementation, emissions trading, transaction cost, institutional theory

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1 Introduction

With calls for new approaches in environmental policy, emissions trading is introduced as a key instrument in policy and management for climate change mitigation (Hasselknippe 2003; Hansjürgens 2005; Stowell 2005; von Malmborg and Strachan 2005). Besides the international mechanisms related to the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol, emissions trading schemes (ETS) are introduced in national (e.g. United Kingdom, UK) and regional (e.g. the European Union, EU, California) climate change policy programmes. The aim is to increase flexibility and cost-effectiveness in strategies to meet national/regional emission reduction targets. Whilst the UNFCCC system focuses trading of greenhouse gas (GHG) emission allowances between nation-states, national and regional ETSs such as the UK ETS and EU ETS, focus trading between companies. With the UK ETS and EU ETS, flexibility is introduced also in corporate strategies for reducing GHG emissions. Recently adopted, the so-called 'linking directive' (2004/101/ EC) amends the emissions trading directive (2003/87/EC) to further increase the flexibility in corporate climate change strategies of European companies, and to reduce the costs of complying with binding targets. The 'linking directive' allows companies participating in EU ETS to top-up their emission allowance accounts with emission credits from the project based mechanisms of the Kyoto Protocol in order to comply with their obligations under EU ETS. The Kyoto project mechanisms refer to joint implementation (JI) and the clean development mechanism (CDM).[1] It is hard to estimate the precise magnitude of economic impacts, but it has been claimed that the 'linking directive' may halve the market price for allowances in the EU ETS (Criqui and Kitous 2003).

The high hope among climate policy-makers for emissions trading as an effective and efficient policy instrument rests on the assumption that companies are technically rational actors. According to neo-classical economics, backing up the current belief in emissions trading, corporate behaviour is guided by informed comparisons of internal marginal costs of mitigation and emission allowance market prices (e.g. Tietenberg 1985; Nordhaus 1998; Sorrell and Skea 1999). A company with mitigation costs above the market price would buy emission allowances instead of reducing emissions in-house. Since mitigation marginal costs are generally lower in economies in transitional and developing countries, many companies in the EU are also expected to invest in JI and CDM projects rather than reducing their own emissions. However, it is common knowledge to contemporary organisational analysts that companies, as well as individuals, act with a more or less

[1] Whilst JI projects are to be undertaken in developed countries or countries with economies in transition (so-called 'Annex I' parties to UNFCCC), involving at least two countries that have agreed to an emission target, CDM projects are to be hosted by developing countries (so-called 'non-Annex I' parties to the UNFCCC) that do not have quantitative emission reduction targets. JI projects render emission credits in terms of 'Emission Reduction Units' (ERUs), whilst CDM projects render 'Certified Emission Reductions' (CERs).

bounded rationality. Market solutions are not always appreciated by companies, and transactions are often withdrawn from the market while resources are integrated hierarchically (Williamson 1975). Thus, we are likely to find deviations from economic theory in the practical applications of GHG emissions trading.

Given the recent adoption of the EU 'linking directive' and government calls for more private investment in national JI- and CDM-programmes, putting the project based mechanisms of the Kyoto Protocol in focus of European companies, this chapter aims at examining the 'likelihood' that companies with GHG emission targets would enroll in the project based mechanisms. A guiding question for the chapter is: *How attracted are companies to investing and participating in JI and/or CDM projects?*

From a public policy point of view, the chapter will thus shed light on, among other things, the potential contribution of the 'linking directive' in providing flexibility to European climate change policy and the EU ETS. As such, it complements previous analyses of the proclaimed cost-effectiveness of the project-based Kyoto mechanisms (Jackson 1995; Fichtner et al. 2003; Michaelowa et al. 2003). More importantly, the chapter provides valuable knowledge on corporate strategic behaviour in emissions trading and climate change mitigation. There are several studies of corporate strategies for climate change in general (Levy 1997; Kolk and Levy 2001; Levy and Kolk 2002; van den Hove et al. 2002; Dunn 2003; Pulver 2003; Pinkse 2006), but fewer that analyse corporate behaviour in emissions trading in particular (Engels 2001; Paulsson and von Malmborg 2004; von Malmborg and Strachan 2005, Antes et al. 2006). Such knowledge would help to improve future governmental policy as well as facilitate corporate learning in emissions trading.

The next section outlines the theoretical framework employed in the chapter. Then, empirical evidence is presented for the case of corporate participation in JI, drawing from a qualitative study of corporate climate change strategies in Swedish companies. In the fourth section, the theoretical and empirical perspectives are synthesised. With regard to the specific structure of the project based Kyoto mechanisms, no specific information is given in this chapter.[2]

2 Theoretical perspectives on corporate behaviour

There are many 'schools' and theories of strategic and operative behaviour of companies and other organisations. I share the general position of contemporary organisation theory that organisational behaviour, in terms of attitudes and actions of the individuals and collectives that constitute organisations, is dependent on the interplay of external and internal factors. Among the internal factors, we find formal ones such as goals and structures in terms of distribution of work and control

[2] Jackson et al. (2001) and Haites and Yamin (2004) provide good overviews of the project based mechanisms. The mechanisms and their linking to the EU ETS are also described in a working paper of the European Commission on impacts of the 'linking directive' (CEC 2003).

and coordination of work. Besides the formal factors, informal factors, personal and social conditions, such as culture and internal power relations, are also influencing corporate behaviour. Despite the influence of internal factors on corporate behaviour, I agree with Perrow (1986) and Scott (2001) that internal factors are heavily influenced by external factors rather than vice versa. Organisations are open sub-systems integrated in a social context (Parsons 1956), symmetrically or asymmetrically dependent on external actors and influenced by their environments via external uncertainties (complexity and change) and external pressure in terms of values, culture, politics and technologies, etc. In order to survive and prosper, an organisation must adapt to the changing general and specific environments – acknowledging not technical environments, but also different institutional environments (Scott 1991, 2001). The technical environments, accounting for technological, economic and demographic conditions, determine what is perceived as efficient and how things are done in an organisation. The institutional environment(s), accounting for political and socio-cultural conditions, determine what is perceived as organisational objectives and what counts as legitimate behaviour. Generally neglected in economic theories of market and organisational behaviour, any organisation must be perceived as legitimate by central actors in the social context in order to get the support necessary to sustain (Selznick 1957; DiMaggio and Powell 1991a; Scott 1991, 2001).

From this, it follows that an institutional perspective is important for a proper understanding of corporate behaviour in relation to JI and CDM, and in climate policy more generally. Such an approach has also been employed in previous studies of corporate strategy in relation to emissions trading (Paulsson and von Malmborg 2004; Antes 2006). To give a richer understanding, accounting for both technical and institutional factors, this chapter, however, combines the perspectives of institutional theory in organisational analysis with an economic perspective on organisational behaviour, namely transaction cost theory. Common fundaments in both theories employed, making them compatible despite the different perspectives, are the focus on the organisation's dependence on and relation to other actors in the environment, and the acknowledgement of bounded rationality of any actor. In contrast to several studies analysing corporate behaviour in GHG emissions trading, from an economic perspective (e.g. Laurikka 2006; Letmathe and Wagner 2006; Spangardt et al. 2006; Stronzik 2006) this study does not, however, take on a computational modelling approach.

2.1 Companies seek to reduce uncertainty in the technical environment

If we consider a company with restrictions to meet a specific GHG emissions target, assuming also a flexibility to choose between in-house measures to reduce emissions and buying emission allowances on a market or through investment in a JI/CDM project, the strategic question of corporate climate policy and management would be (cf. Antes 2006): *Should we reduce our own emissions or should we buy emission reductions produced by someone else?* This is analogous to the

basic problem that transaction cost theory sets out to solve (Williamson 1975, 1981, 1994): Why do companies sometimes choose to produce a good or service themselves, instead of buying it on a market? Or stated from the perspective of corporate strategy: Should we produce the resource ourselves, or should we buy it? Emission allowances would be regarded as input factors (resources) necessary for production.

Similar to resource dependence theory (Thompson 1967; Pfeffer and Salancik 1978), transaction cost theory ascribes successful management of relations to actors in the environment holding resources and the acquisition of resources necessary for performing the business as a main goal of the organisation. Special attention is given to strategies for reducing uncertainties and dependencies in relations to other actors in the relational network in which the organisation is embedded.

According to Williamson (1981), three factors determine why an organisation buys some goods and services and integrates others into their own production: (i) the degree of uncertainty/complexity of the transaction, (ii) the transaction density (i.e. how often a transaction is to be made), and (iii) the amount of transaction specific investments (i.e. investments arising from initiating and completing a transaction, with little value external to the specific transaction – e.g. finding partners, holding negotiations, consulting with lawyers or other experts). If a transaction is considered complex and carries the stamp of uncertainty, which all transactions do according to Williamson, it is mainly the two remaining factors that determine whether a company should choose the market solution and buy a product or a hierarchical solution and produce what it needs itself (Williamson 1981, 1994). Table 1 presents a simplified typology of structural solutions for managing transactions with external actors, as suggested by transaction cost theory.

When low transaction specific investments are made and the transaction density is low, organisations can choose market solutions, even in uncertain conditions. If specific costs are low but transaction density is high, it may be more attractive to arrive at a bilateral agreement with a specific contractor. If the transaction density is low and transaction specific costs are high, the partners face the risk of strong inter-dependencies. In such cases, they should look for a third party solution. If transaction density as well as transaction specific costs are high it is most reasonable to integrate production hierarchically in the organisation and take care of it internally. Hence, uncertainties are reduced and transaction costs can be kept low (Williamson 1975).

Table 1. Typology of structural solutions to managing transactions

	Degree of transaction specific costs	
Transaction density	Low	High
High	Bilateral solutions	Hierarchical solutions
Low	Market solutions	Third party solutions

Turning to the case of corporate strategy in climate change mitigation, the transaction in focus is the attempt of a company to obtain emission allowances (or reduce emissions). Hence, the transaction cost analysis would focus on (i) the degree of uncertainty/complexity of different options to meet a corporate GHG

emission target (for instance given by the initial allocation of emission allowances in the EU ETS), (ii) how often the company will need extra room for emitting GHGs, and (iii) the amount of transaction specific investments related to the different options. With regard to the typology of structural solutions, buying extra allowances in the European carbon market would be considered a market solution, while investing and participating in JI or CDM projects to receive emission credits for subsequent exchange into EU allowances would be considered a bilateral solution. In-house emission reductions count as a hierarchical solution, while, finally, private investment in a fund (e.g. the World Bank Prototype Carbon Fund, PCF) may be considered as a third party solution. To what extent bilateral solutions would be attractive to companies, particularly those forced to participate in the EU ETS, is the focus of the final discussion.

2.2 Companies seek legitimacy in their organisational fields

As indicated, an organisation must not only produce and provide goods or services in a technically efficient way to survive. It must also adapt to norms, values and beliefs in its general and specific institutional environments (the latter also called organisational fields) to be legitimate (Selznick 1957; DiMaggio and Powell 1991a, 1991b; Scott 1991, 2001). The shared cognitive systems of an institutional environment determine what an organisation can do. According to DiMaggio and Powell (1991b), organisations are rewarded for being similar to other organisations in their fields because it makes it easier to conduct exchanges, to attract personnel, to maintain good reputation, and to be eligible for contracts and grants. Early adopters of organisational innovations change goals and develop new procedural structures and practices, aiming at improved performance. But in the long run, they construct an environment that constrains their ability to change in the future. As new practices spread, a certain point appears in the structural development of the field at which they become taken for granted and infused with value beyond the technical requirements of the task, and adoption provides legitimacy rather than improves performance (Meyer and Rowan 1977). “Strategies that are rational for individual organisations may not be rational if adopted in large numbers. Yet the very fact that they are normatively sanctioned increases the likelihood of their adoption” (DiMaggio and Powell 1991b, p. 65).

The ‘isomorphic’ behaviour of organisations occurs through mechanisms such as (i) coercive isomorphism, resulting from formal and informal political pressures exerted on an organisation by other organisations upon which they are dependent and by cultural expectations in the society; (ii) mimetic isomorphism, resulting from standard responses to uncertainties where organisations model themselves on other organisations that are perceived of as successful, and (iii) normative isomorphism, stemming from professionalisation, interpreted as a collective struggle of members of an occupation to define the conditions and methods of their work (DiMaggio and Powell 1991b). Elaborating upon the influence of institutional environments on organisations, Scott (1991) presents seven mechanisms regarding how certain structures ‘enter’ organisations. They can be (i) imposed, (ii) author-

ised, (iii) induced, (iv) acquired, (v) imprinted, (vi) incorporated or (vii) bypassed. In the latter four, it seems that the organisation itself plays a more active role. Nevertheless, Scott refers to the nation-state and the professions as the great rationalisers of the late twentieth century. Scott argues that the nation-state will more likely influence the creation of rationalised structural frameworks, while the professions are more likely to influence the creation of rationalised cultural systems.

A complicating premise for acquiring legitimacy is the existence of different and competing institutional environments. It is not only government policies and legislation that influences corporate behaviour. Thus, organisations cannot be passive actors being imprinted by cultural templates, but may be expected to make some 'strategic choice' in relating to their institutional environments (Oliver 1991; Scott 1991). Choices range from deciding upon new goals or introducing new structural elements, to selecting the type of institutional environment with which to connect. The conflicting nature of external demands may lead to organisations introducing symbolic goals and/or structural procedures or elements adhering to rationalised norms in the environment, but these do not relate and, thus, do not influence the core structures and cultures of the organisation. Acting (proactively) on a symbolic issue may help companies make up for past, or hide present, illegitimate behaviour on other issues (Brunsson 2002). Sometimes, it is also rendering legitimacy just to discuss or decide on an issue. An organisation must not necessarily perform to show commitment. Moreover, people tend to be rationalising rather than rational (Aronson 1973), as to why goals and preferences are sometimes the result of action. Instead of guiding decision-making and action, goals and preferences are shaped to justify our actions. As a consequence, problems and solutions are typically decoupled, and decisions are decoupled from action (March and Olsen 1976; Brunsson 2002). Besides decoupling of formal structure and actual behaviour, organisations can also try to influence future legislation and other institutions in directions that would make the present behaviour legitimate in the future. Organisations frequently attempt to resist or alter external demands that are placed upon them (Pfeffer and Salancik 1978). Overall, this clearly indicates that organisations are not passive receivers of institutional demands. The company itself participates in shaping the rationalising norms of its own organisational field(s). Organisations located in a specific organisational field react to an environment composed of other organisations reacting to their environment, which means that the organisational field is composed of organisations reacting to an environment of reactions of organisations (DiMaggio and Powell 1991b).

Despite strong isomorphic forces, there are variations in internal responses to institutional influence. Powell (1991) outlines several reasons for the variations. First of all, institutionalisation is a history-dependent process. Moreover, resource environments vary greatly, even within tight organisational fields; there are key differences in the structures of industries and how organisations relate to the nation-state; government requirements are not always felt by organisations as direct coercion; occupation and professional projects vary; and sources of constraints vary in direct relation to the capability of organisations to shape or influence the nature of institutional environments.'

In order to understand and explain corporate strategy in relation to the Kyoto project mechanisms, it is thus important to analyse the values, beliefs and rationalising norms related to JI and CDM that companies (have to) relate to – i.e. are influenced by and try to influence.

3 Corporate views on the project mechanisms

3.1 Outline of the empirical study

As the primary empirical basis for the analysis of corporate strategy related to the Kyoto project mechanisms serves data provided from a study in Sweden of corporate views on JI (and to some extent CDM) (von Malmborg et al. 2002). The main purpose of the empirical study was to provide qualitative business perspectives on the prerequisites for implementing JI and CDM policies in Sweden, and the main question addressed was: What would make Swedish companies invest and participate in JI and CDM projects?

Since detailed knowledge of the Kyoto project mechanisms was not widespread in the Swedish business community at the time of the study (and still is not), data was mainly collected in full-day workshops with different groups of companies, employing focus group interviews (Morgan 1997) as the main data collection technique. Each workshop was opened with presentations of JI and CDM in general and the status of Swedish institutions for flexible mechanisms. The company representatives were given the opportunity to pose questions about JI, CDM and emissions trading directly to officials from the Swedish Government, The Swedish Energy Agency (being responsible for administration of the Swedish JI and CDM programmes), and two governmental commissions related to the flexible mechanisms. The presentations were followed by a short discussion on corporate strategy in climate policy, providing information on strategies and measures at the companies represented. Finally, the respondents took part in a target-modelling exercise, determining and discussing opportunities and obstacles for participation of companies in the Kyoto project mechanisms as well as concrete measures for enabling such participation. Notes were taken throughout the presentations and discussions, and the results and discussions of each target modelling were recorded. To prepare the respondents for the workshops, information material describing and explaining the structure and process cycles of JI, and a short interview guide, were sent to all participants in advance.

In all, three workshops were held with representatives of 15 Swedish companies from different industry sectors. The study covered companies with very large GHG emissions (e.g. utilities such as powergen and district heating, chemical industry, refineries and metals industry) as well as companies with hardly any GHG emissions but mainly providing technology/knowledge to reduce GHG emissions (e.g. energy engineering industry and consultants). It is worth noting that the minerals industry and pulp and paper industry were not represented. Each company was represented with one senior energy market strategist or vice president (tech-

nology/production), the latter serving as the environmental manager. Reflecting upon the low number of participants, it should be mentioned that it nevertheless adequately represents the total number of Swedish companies interested in Kyoto project mechanisms. A follow-up by telephone asking why the rest of the 140 companies initially invited did not want to participate revealed that climate change was very often less prioritised than other environmental issues in corporate environmental management. Some companies even claimed that climate change was too long-term an issue to fit their corporate policy and strategy. Lack of explicit corporate climate strategies was evident also in the 15 companies taking part in the study. Only one of them, a refinery, had a well developed climate strategy. One should bear in mind, though, that the workshops were arranged almost a year before the EU ETS Directive was agreed upon, and that the last years has seen a dramatic increase in media coverage of climate change. While this is being written, in the autumn of 2007, climate change has a higher priority in corporate strategy in Sweden. If not for other reasons, the EU ETS launched on January 1, 2005 has forced them to address the topic.

It should be noted that the primary data used is some years old, and this may be considered too old, given that there is rapid development in the climate policy area. However, this author still considers the data on corporate positions related to project-based mechanisms to be representative and valid. A seminar on the theme "How companies can use the Kyoto project mechanisms", organised by the Swedish Energy Agency in late November 2004, was attended by only five per cent of the Swedish companies with installations in the EU ETS, and they corresponded to only ten per cent of the seminar attendees. The majority of attendees were representing governmental authorities, universities, business organisations and consultancies. Apparently, the interest in JI and CDM in Swedish companies with mandatory GHG emission targets is still limited. This is also confirmed by Point Carbon, a leading carbon market analyst (J. Buen, pers. comm.). Point Carbon has a large number of Swedish companies as subscribers to their free-of-charge newsletter and cheap services, but hardly any as subscriber to the more expensive services focusing in particular on JI and CDM. In addition, a recent survey on corporate climate strategy in Sweden (Sandoff et al. 2007) shows that less than two per cent of Swedish companies taking part in EU ETS have plans to invest in JI or CDM. Only half of the companies did actually know of the project-based mechanisms.

3.2 Swedish companies' views on the Kyoto project mechanisms

From the empirical study it was found that Swedish companies are presently playing a waiting game, if not directly opposed, regarding investments and participation in specific JI and CDM projects. According to the data, companies would invest and participate in JI and CDM projects if and only if it is found to be the most competitive of various alternatives for the company to meet its carbon dioxide (CO_2) emission restrictions (targets), or if it represents a profitable project. The former condition applies to companies with considerable CO_2 emissions, the latter

to companies with low or no such emissions that would be participating primarily to sell technology or knowledge. However, JI and CDM is perceived as a risky project associated with large uncertainties, and no company really did think of investing and participating in a JI project.

Little knowledge of the Kyoto project mechanisms

The perceived uncertainties associated with participation in the Kyoto project mechanisms are partly related to the low level of knowledge about JI and CDM among the companies. Representatives of the energy companies and environmental and energy technology and management consultants taking part in the study claimed that some people in their organisations (but not the senior management) know of JI and CDM in detail – but only theoretically. The remaining participants have little knowledge of JI and CDM. None of the companies had practical experience with JI or CDM, nor with their prototype, AIJ (activities implemented jointly).[3] According to the respondents, the widespread lack of knowledge is related to indistinct and ambiguous messages in the current Swedish national climate policy, which, among other things, indicates to us that flexible mechanisms both should and should not be used to achieve the national climate policy targets. In addition, the ambiguities could be mentioned as to whether the Swedish state is interested in JI and CDM from a climate policy perspective or rather from technology-export and development-aid perspectives. Overall, hardly any actor (governmental, private or civic) urges that companies would participate in JI or CDM. It is mainly the Swedish Energy Agency that works with JI and CDM. The recent seminar referred to above is perhaps a turning point – but few companies attended. Uncertainties regarding the future of climate policy strategy, nationally and internationally, are other significant factors influencing the companies.

High uncertainties in the Kyoto project mechanisms

The obvious hesitance about JI and CDM is also related to uncertainties regarding proceeds of JI and CDM projects as well as the true costs for undertaking a JI or CDM project. On the cost side, it is primarily high costs for planning, administrating and controlling a JI or CDM project that make companies hesitate. A number of uncertainties were also revealed in relation to the practical organisation of a JI/CDM project: What will be required from the private JI/CDM actor and what will this require from the internal organisation? As mentioned, the level of knowledge about JI and CDM is relatively low in most companies today, and there is limited preparedness internally in most companies as for how to manage a JI or CDM project. There are also uncertainties concerning the external organisation of a JI/CDM project. What kinds of contacts and agreements with actors in the coun-

[3] In 1995, the UNFCCC agreed to institute a pilot phase of the project based mechanisms, labelled ”activities implemented jointly” (AIJ). In 1997, when the Kyoto protocol was agreed upon, AIJ was developed into JI and CDM as two separate mechanisms.

try where the project will be carried out will be required? Or as one of the respondents did express it: "You come to Bucharest, enter a taxi, and ask yourself – Where will I go next?" As an implication, companies fear that costs for raising the internal competence and for creating and maintaining necessary external contacts may show to be very high. This need for assistance to navigate in foreign countries and markets seems to be a major obstacle hampering particularly smaller Swedish companies selling climate technologies to engage in export and foreign investments (Henryson 2007; Swedish Energy Agency 2007).

Narrow scope of the project mechanisms

In addition, it should be stressed that some companies see a problem in JI and CDM projects being exclusively focused upon climate issues when it comes to crediting. They asked for broader crediting, taking into account for instance reduction of other pollutants. Companies live in a pragmatic world and cannot- as authorities, ministries and governments can- discriminate different environmental issues. They must handle all issues at the same time. This counts not only for environmental issues, but in general. In order to survive, a company has to meet requirements on economic profitability, different environmental standards, quality standards, equity standards, requirements on social accountability and much more, all at the same time. The Kyoto project mechanism institutions and the Swedish authorities' view and behaviour regarding JI and CDM, seem not to conform to the views and behaviour of most companies. As a consequence, the attractiveness of JI and CDM is limited.

Invest in their own facilities

Finally, an interesting result of the study is that companies with CO_2 emissions, if they (against the odds) are to invest directly in JI or CDM projects, would only consider investments in projects meeting certain criteria regarding 'location'. First of all, all companies made it clear that they would only invest in projects in the same sector that they operate in. Secondly, they would only invest directly in JI or CDM projects in countries where they are already working.[4] Thirdly, and partly as a consequence of the other criteria, they would only invest in their own facilities in other countries. It was explicitly stated by companies (in the process/manufacturing industry acting on an international competitive market), that they are interested only in investing in JI or CDM projects in their own industrial plants in the host country – if they have any. They saw no reasons to invest in plants that are owned by other companies, and thus to subsidise their competitors.

[4] It is worthwhile to mention that countries that were initially prioritised in the effort to meet framework agreements between Sweden and potential host countries for Swedish JI projects are of low priority according to these companies. As a matter of fact, the Swedish Government's priority list of JI host countries changed due to this result. Romania was initially of low priority, but turned out to be the first country signing a framework agreement with Sweden.

A corresponding restriction on participating in JI or CDM projects only in their own facilities was not explicit in the energy companies, who act on more local/regional markets and are less subjected to international competition. However, the energy companies represented in this study are all expanding outside Sweden, and investing in a JI project in a power plant in Eastern Europe would be closely related to a take-over of the plant. Thus, the investment is in fact made in what is about to become their own facility.

4 Corporate strategy related to Kyoto project mechanisms

According to the theories framing the analysis, a company would invest and participate in JI/CDM if it provided the lowest transaction costs related to getting hold of emission allowances, and if it would render legitimacy in the organisational field of the company. From the empirical study reported in the previous section, it was evident that few, if any, Swedish companies in need of GHG emission reductions considered investing in a JI or CDM project in the near future. In this section, we will combine the theoretical perspectives and the empirical evidence and try to explain how corporate strategy related to Kyoto project mechanisms work. Given the empirical hesitance to invest and participate in JI and CDM projects, the analysis will be directed towards explaining why companies are likely not to choose the JI/CDM tack if they are in need of (extra) margin for emitting GHGs. Some suggestions as to how to make companies more interested in the Kyoto project mechanisms are also provided.

4.1 Institutional perspectives on corporate climate strategy

In order for an organisation not to be questioned or perceived as deviant, it tries to adapt to external values and norms when formulating goals and organising the business. What then are the values and norms related to corporate investment and participation in JI and CDM?

Looking for rationalising norms related to corporate behaviour in GHG emissions trading, it must not be ignored that the EU ETS commenced operating in January 2005. As a consequence, any organisational field identified in this area would be characterised as an infant field, yet in very early stages of structural development. In fact, Antes (2006) notes that the topic of GHG management is so new, it is not yet possible to empirically identify any organisational fields. Organisational fields are analytical concepts and consist of organisations institutionally linked together by acting in the same market or region, and they can be observed as an increase in the extent to which certain organisations interact, an increase of the information load they share and the development of mutual awareness that they are involved in a common debate (DiMaggio 1983; DiMaggio and Powell 1991b).

In this particular case, we may also ask ourselves if there is one field, or a large number of fields. Of course, the EU ETS itself, linking a lot of companies and other organisations to each other, may be perceived of as an organisational field. However, EU ETS consists of thousands of companies with installations in ten different industries with little in common but the participation in EU ETS. In addition, the companies and their installations are located in 27 different countries. In all, analysing organisational fields related to the EU ETS and JI/CDM may be cumbersome. It also makes it difficult, or in fact unlikely, to find cognitive systems and rationalising norms for corporate behaviour common to all companies participating EU ETS. As there are or will be several organisational fields related to emissions trading, and given that institutionalisation or structural development of organisational fields is a history-dependent process (Powell 1991), we are also likely to find an array of diverse corporate behaviours in the EU ETS. It is, nevertheless, relevant to take a closer look at those institutional and related factors that already exist and influence what may become important rationalising norms and taken-for-granted solutions to corporate behaviour in climate change mitigation under EU ETS. It should be stressed here that the analysis mainly regards the Swedish situation, but reflections are made on potential differences in institutional pressures on companies in different countries.

International institutions of climate change mitigation

Starting with the highest level, the global/international climate change institutions, with UNFCCC as main proponent of flexible mechanisms, present no pressure on companies to invest in JI/CDM projects. The Kyoto Protocol and Marrakech Accords of UNFCCC, outlining the structures and rules of JI and CDM, are directed towards nation states. Accordingly, the institutions of Kyoto project mechanisms are adapted to nation states rather than companies. The World Bank PCF, aiming at raising knowledge of JI and CDM through collaborative learning, has seen some private investors, but it mainly *allows* companies to invest, which is different from forcing or encouraging. Besides, a company investing in PCF doesn't really participate in a JI or CDM project. Instead, it pays for other organisations (companies) to do all of the work: from identification to planning, performing and monitoring.

National institutions of climate change mitigation

At a lower policy level, governments of nation states have called for increasing private investment in JI and CDM. However, one may question whether they are truly interested in companies that are in need of extra emission credits/allowances to invest and participate in JI/CDM projects. In most nations, these companies would be competitors to the State with regard to the emission allowances generated in the project. Consider a company enrolled with the EU ETS and located in an EU member state that foresees extensive use of project-based emission allowances to meet its national target given by the EU burden-sharing agreement. From the 2004 national allocation plans of the EU-15 member states (all potential donor

countries with regard to JI/CDM, while the new EU-12, with one exception so far, have been regarded as suitable host countries of JI projects), it is obvious that Kyoto project mechanisms play a key role in the national climate change programmes, sometimes accounting for fifty per cent of the emission reductions necessary for the nation to meet its Kyoto target. A company under the EU ETS investing in and undertaking a JI/CDM project would gain credits that the nation cannot use for meeting its target. In such cases, the private investments called for would come from companies that want to sell emission reducing technology or knowledge (e.g. environmental and energy technology companies or consultants), rather than companies in need of emission allowances themselves. The latter will actually compete with nation states to find low cost projects.

In Sweden, the Government does not yet plan to make use of Kyoto project mechanisms to meet the Kyoto target – the reason this competition is less likely to occur. Nevertheless, measures taken so far to engage companies in JI/CDM are primarily directed towards companies selling emission reduction technology and know-how, as a means for boosting environmental and energy technology export (Swedish Energy Agency 2007). As presented, some companies covered by the empirical study sincerely questioned whether the Swedish JI/CDM programme was part of the national climate policy, or part of a technology export policy or development aid policy. Similarly, Swedish companies repeated several times the ambiguity of the Swedish national climate strategy, stating that the flexible mechanisms should not be used whilst simultaneously implementing the EU ETS as well as JI/CDM programmes. This sends contradictory signals to Swedish companies in terms of rationalising norms (cf. Paulsson and von Malmborg 2004). Whether other EU member states are more positive towards corporate use of JI/CDM is not known. It should be noted that the Dutch Government has launched two tender programmes (ERUPT and CERUPT) whereby companies get paid to undertake JI and CDM projects for delivering ERUs and CERs to the State. Similar programmes are emerging in other EU member states. Again, such policy measures help the State to get emission credits, as opposed to the companies in need of emission credits.

EU 'linking directive' provides an option only

The EU 'linking directive' is the first institutional signal to companies in need of emission allowances to really consider the Kyoto project mechanisms. However, like the EU ETS directive, it is not a coercive force as to corporate behaviour – and it should not be assumed that it aims at increasing the flexibility of corporate climate strategy in EU companies. At a meta-level, though, the EU ETS and 'linking' directives would be interpreted as codifications of political beliefs in market solutions as superior to direct regulation to curb environmental problems. EU policy-makers implicitly want companies to adhere to the market solution or JI/CDM. But due to its nature, the 'linking directive' will not provide signals to the market other than the fact that it is now legitimate, from a (supra)governmental perspective, for companies to invest in JI/CDM projects. From a perspective of corporate climate strategy, the 'linking directive' institutionally communicates little more

than the fact that it is not illegitimate for companies to make use of credits from JI/CDM projects in the EU ETS. In comparison to other policy instruments aiming at reducing emissions from industry, EU ETS and the Kyoto project mechanisms imply that emissions must no longer be reduced, energy carriers (fuels) must no longer be substituted or energy efficiency must no longer be increased, only in the installation (plant) subject to regulation. Such subtle 'requirements' are not necessarily perceived as rationalising norms by companies at large within a specific organisational field, and the corporate behaviour governments desire will not be imposed or authorised (Powell 1991).

Lack of public debate and critics of corporate behaviour

So far, business organisations, social movements like national or international environmental organisations (e.g. Swedish Society for Nature Conservation, Greenpeace, WWF), academic societies and media have played anonymous or silent roles in the shaping of norms for corporate behaviour in relation to JI and CDM. Some of the environmental organisations have made statements about the mechanisms, but they haven't been very active. At least, this is the situation in Sweden. In fact, some of the companies participating in this and a related study (see Paulsson and von Malmborg 2004) noted that there is a complete lack of (public) discussion and debate over the flexible mechanisms, the project based mechanisms in particular. In other words, the institutionalised solution to the problem, if it is perceived as a problem at all, is to wait and see.

In a situation like this facing Swedish companies, where no strong policy coalitions in the organisational fields of companies speak clearly in favour of or against JI or CDM, it appears that companies are adopting a wait-and-see strategy regarding the Kyoto project mechanisms. Evidently, Swedish companies are standing by and waiting for a clear signal to either go ahead or terminate any potential JI/CDM bid. As long as no one is criticising this behaviour to such an extent that it turns out to be illegitimate, this is a successful strategy and defensible behaviour from the perspective of institutional organisation theory.

Reflecting upon the reactive nature of Swedish companies, it is interesting to note that no company has invested in or intended to invest in JI or CDM as a (pro)active means to improve the image. This was touched upon by some respondents to the study, claiming that participation in JI and CDM potentially may give the company environmental goodwill. However, they thought that this alone was not enough reason to enter a JI or CDM project. Besides, the (then) lack of public or political debate on climate change and other environmental issues wouldn't increase the intangible returns of a JI/CDM project. Although the public awareness of climate change has increased significantly during the last years, partly due to increasing public debate and media coverage, the public knowledge of JI/CDM is limited and 'no one' would know what good comes out of a JI/CDM project. The wish for broader crediting of JI and CDM projects, put forward by some respondents in this study, should be interpreted against this background. It should be mentioned, though, that companies in other EU member states, particularly large multinational corporations, may be more exposed and criticised by the public or

environmental movement (cf. Levy and Kolk 2002). Consider for instance Shell/Royal Dutch with Brent Spar. As a consequence, they may find participation in JI/CDM more attractive, trying to make up for previous illegitimate behaviour.

More recently, a debate has emerged nationally and internationally on voluntary carbon neutralisation or carbon offsetting, where organisations or individuals that are not forced by law to take part in EU ETS or similar mandatory GHG markets compensate their GHG emissions by investing in emission reducing activities elsewhere. Credits from JI and CDM projects (i.e. emission reduction units, ERU, or certified emission reductions, CER) may be used for such offsetting, but usually other kinds of credits are used. However, the latter are often seen as less credible than ERUs or CERs due to less stringent procedures for verifying that emission reductions have really taken place, and environmental organisations promote the use of CER or ERU prior to other emission reduction credits for voluntary carbon offsetting. It is yet too early to say if this will pave the way for an increasing interest in JI and CDM among companies.

Companies expect command-and-control

Another reflection to be made on the reactive approach of Swedish companies is the low interest in really influencing the policies, legislation and other institutions of the flexible mechanisms. There is no difference between EU ETS and JI/CDM in this respect (cf. Paulsson and von Malmborg 2004). Answering a direct question, the respondents asserted that the State decides what is to be done regarding JI and the other flexible mechanisms. They also claimed that the companies entered the policy debate too late, and referred to lack of dialogue between the State and the companies. They criticised the government and authorities as well as the business organisations, which have a dialogue in which the companies do not participate. Paradoxically, the companies do not seem to be doing anything to change the present order – at least they couldn't present any evidence. Instead of trying to engage in a dialogue with the Government and authorities, the companies continue to rely on the knowledge and work of the business organisations in trying to influence public policies. One of the respondents to the study said, without being criticised by other company representatives, that: "Swedish companies generally start playing when the rules are set by the authorities". Knowledge of the policy process related to implementing the EU ETS in Sweden gives further evidence to this state of play. Very few companies have been active in the process leading to, for instance, the rules of allocating emission allowances. Most companies reacted just when the rules were decided, obviously too late to make a difference. With very few exceptions, the business organisations represent the 'industry' in the early lobbying of climate change and flexible mechanisms policies. However, this seemingly conspicuous state of play is no real surprise – it rather seems to be a tradition in the way companies behave in relation to the State. As a matter of fact, Dobers (1997) explains that Swedish industry companies are stuck in a command-and-control manner in environmental policy and management, expecting and waiting for the State to tell them what to do in new problem areas, despite earlier calls from industry to participate in and influence more the policy formulation.

Schwartz (1997) has also explained this path dependency or 'automorfism' in Swedish corporate environmental management and corporate relations towards the State and other actors in environmental policy.

4.2 Transaction cost perspectives on corporate climate strategy

Employing an institutional perspective in analysing corporate climate strategy indicates that corporate investment and participation in Kyoto project mechanisms don't seem to guarantee the legitimacy needed for survival. How, then, will the situation turn out when looked at through transaction cost theoretical spectacles?

Uncertainties

Considering the acquisition of emission allowances, it is needless to say that there are large risks and uncertainties associated with the flexible mechanisms and corporate climate strategy in general (Larson and Parks 1999). Some questions have been answered in recent years. For instance: (i) Russia has ratified the Kyoto Protocol, which entered into force in February 2005; (ii) there are international institutions in place for JI and CDM projects; (iii) many EU member states have signed framework agreements with a number of host countries, which are necessary for commencing a JI/CDM project; (iv) the 'linking directive' has entered into force, making it possible for companies to use ERUs or CERs in the EU ETS. However, there are still many uncertainties influencing companies considering how to manage GHG emissions. How large will the emissions be in future years? How will the demand for our products develop? What will the initial allocation be in the second trading period of EU ETS? What will international climate policy look like post-Kyoto? How will the price of emission allowances develop? What about the political stability in potential host countries for JI and CDM projects? What are the risks and thus the real costs of JI and CDM projects? According to transaction cost theory, the attractiveness of each structural solution will then, given the uncertainties, depend on the transaction density and the degree of transaction specific costs. Considering corporate direct investment and participation in a JI/CDM project as a bilateral solution, the theory would favour JI/CDM if transaction density is high and transaction costs are low. Below, the state of these factors is discussed. In comparison to the institutional analysis, it should be noted that this analysis is less dependent on the country of origin of the companies.

Transaction density

Regarding transaction density, i.e. how often a company needs emission allowances, it should be admitted that the border-line between 'high' and 'low' (cf. Table 1) is blurred and all but easy to delineate. It is a continuum rather than a distinct switch. Given that companies under the EU ETS are obliged to report annually, for several years ahead, a balance or surplus of emission allowances in relation to the actual emissions, it would be fair to assert that the transaction

density is moderate to high for these companies. Since emission levels of carbon dioxide from utility installations burning fossil fuels are highly dependent on weather, it may be impossible to predict annual emissions. In order to hedge risks, companies may want to obtain small amounts of emission allowances at several times, instead of obtaining everything in one transaction. This would increase the density. If a company has more than one installation under the EU ETS, the transaction density would also increase. Fichtner et al. (2003), who analysed the impact of private investor's transaction costs on the cost effectiveness of project-based Kyoto mechanisms, consider the corporate possession of a sufficient amount of emission allowances as a *major* input factor to production, thus supporting my assertion.

Transaction specific costs

Continuing with transaction specific costs, it is unfortunately very hard to get reliable data on emission abatement costs of individual companies or entire sectors, nor on transaction costs actually hitting companies. These are usually considered commercially sensitive. In addition, no JI or CDM projects were approved at the time of my empirical study. In fact, it was only in November 2004 that the first CDM project was approved by the CDM executive board. Moreover, none of the companies included in the study had participated in any of the Swedish and other AIJ projects that had been undertaken.[5] These projects were initially administered by the Swedish Business Development Agency, and finalised by the Swedish Energy Agency, the latter who is now administering the Swedish JI and CDM programmes. Hence, we have to rely on secondary data or even qualitative reasoning based on knowledge of the industries and companies participating in EU ETS.

Fortunately, the UNFCCC provides relatively good data on costs of the Swedish AIJ projects, which have been analysed in several studies recently (e.g. Jackson et al. 2001; Michaelowa et al. 2003). In addition, Fichtner et al. (2003) have estimated transaction costs of JI and CDM projects by analysing data of 60 other AIJ projects as well as indirect costs of investment in some new power plants realised as independent power producers. Despite limitations in data, and somewhat different approaches, these studies have found that transaction costs of international GHG mitigation projects have previously been underestimated, and that they are usually higher than expected. Swedish AIJ projects have seen transaction costs on average amounting to 25-37% of production costs (Jackson et al. 2001) or 14-21% of total costs (Michaelowa et al. 2003). The lower end refers to fuel conversion projects and the higher end to energy efficiency projects. Fichtner et al. (2003) report that 80% of 60 other AIJ projects evaluated have transaction costs hitting private investors amounting to 14-89% of production costs, or 12-47% of total costs. Accounting for more than 80% of transaction costs, expenditure for administration and technical assistance is said to be most influential. In addition, these studies provide some evidence to the influence of economies of scale on the share of transaction costs. Larger projects bear lower transaction specific cost per

[5] As mentioned, AIJ was the pilot phase of what is now JI and CDM.

unit of reduced emissions (e.g. tonnes of carbon dioxide). The finding that transaction costs are usually higher than expected gives quantitative evidence to the uncertainties and risks of increasing costs expressed by the respondents to the study – referring in particular to risks of increasing costs.

All companies covered by the study claimed that they didn't see business potentials in prioritised host countries of Swedish JI-projects, and they asserted that investment in JI-projects would render no or very little benefit except for the emission credits generated. Similar concerns over increasing transaction costs of the Kyoto project mechanisms have been raised by the World Business Council for Sustainable Development (WBCSD 2000). As a consequence, the level of transaction specific investments would be rather high if companies were to undertake a JI/CDM project. As mentioned, few companies have enough knowledge of JI/CDM, and they will have to initially invest quite an amount of time and money just to raise the internal competence. In addition, they may also have to invest to find potential partners in the host country, both public and private partners. If the potential host countries are of little interest to the company from more general business perspectives, then the efforts to make contacts will be a large JI/CDM specific cost. Seemingly to the surprise of some climate policy-makers, the attractiveness of a region or country as a supplier of emission credits will not only depend on its cost advantage. It will also depend on the business climate offered to carbon investors; factors like a well-functioning legal and regulatory system, economic and political stability and the capacity to process emission reduction projects efficiently. From a study of the carbon investment climate in the transition countries eligible for JI, Fankhauser and Lavric (2003) conclude that JI investors will face a clear trade-off between the scope for cheap JI on the one hand, and the quality of the business environment and JI institutions on the other. The countries with the highest potential for cheap emission reductions also tend to be the countries with the most difficult business climate and the least institutional capacity for JI. The same is most likely valid for CDM.

Comparing the Kyoto project mechanisms, Michaelowa et al. (2003) argue that CDM projects will have to bear higher transaction costs than most JI projects. Michaelowa and colleagues also report that transaction costs of JI/CDM projects would not exceed 25% of proceeds from permit sales for a project to be viable. This generally makes all but large or very large JI/CDM projects non-viable. Besides direct investment and participation in JI/CDM projects, a company could obtain emission credits by investing in funds that invest in JI/CDM projects. This would imply reduced transaction specific costs for the company. However, the emission credit price will be higher than the production price in direct investment.

In comparison to JI/CDM projects, in-house investments (i.e. hierarchical solutions) would have very low transaction specific costs. Regarding internal measures to reduce emissions (other than reducing production output), the companies included in this study considered primarily energy efficiency measures. Such measures would not only reduce emissions of GHG (mainly carbon dioxide), but also contribute to better economy of production and a general increase in performance and value of the facility. The same would be valid for other in-house measures too, due to the fact that all potential measures are related to production level or

production technology. There are presently no wholesale or retail end-of-pipe technologies for reducing GHG emissions. The investments made in-house do not only burden the item of emission reduction. It should be mentioned that costs for monitoring, reporting and verification of emissions are generally considered transactions costs, but they would not differ among the options in this case. The company will have to monitor and report emissions at similar costs no matter what measure is taken to comply with the emissions target.

As for market solutions, no comparative analyses have been made of in-house measures and buying of emission allowances at the EU market, but the latter would probably be associated with low transaction cost, at least within a few years from now when the European carbon market has been developed (cf. Fichtner et al. 2003; Michaelowa et al. 2003).

Looking more specifically into the transaction specific costs indicated by the Swedish companies, one item seems to be partly ignored in other studies of transaction costs related to Kyoto project mechanisms. As mentioned, none of the companies had enough knowledge of JI (and CDM), regarding why they would have to initially invest such a large amount of time and money just to raise the internal competence. Moreover, since they would largely have to work in new countries, they would also have to invest to find potential partners in the host country, both public and private partners. If the potential host countries were of little interest to the company from more general business perspectives, then the efforts to make contacts would be a large JI/CDM specific cost. These costs would, however, decrease in time, but they are high initially. Other transactions cost referred to by the companies are costs of developing baseline scenarios. However, these costs would not necessarily hit the private investors, but governments. As mentioned by Michaelowa et al. (2003) as well as Fichtner et al. (2003), one should distinguish between governments and private investors when discussing who will bear the transaction costs. To some extent, companies in this study fear that they have to bear the costs that normally would be born by governments. Nevertheless, the transaction specific costs they would have to bear, if they undertake a JI/CDM project, are high.

Hierarchical solutions are more attractive than bilateral solutions

In summary, I argue that corporate climate strategy in general is associated with high uncertainty. The transaction density for companies being short of emission allowances after the initial allocation would be moderate to high. As for the transaction specific costs, corporate investment and participation in project-based Kyoto mechanisms is associated with high transaction specific costs. With Williamsons typology of structural solutions to managing transactions with external actors (cf. Table 1), this would imply that (Swedish) companies in order to get sufficient emission allowances to meet a GHG emissions target would probably choose a hierarchical solution with integration, or a third party solution, instead of a bilateral solution. Put differently, employing a transaction-cost-theory perspective, this means that it would be more ‘effective’ for a company to invest in meas-

ures to reduce emissions internally than to invest and participate in a JI/CDM-project, the latter which in its basic form is a bilateral solution.

Third party solutions are more attractive than bilateral solutions

Dependent on the level of transaction density, it may also be more attractive to the company to look for a third party solution, which could be regarded as investing in a fund that in turn would finance other actors to undertake the actual project. According to transaction cost theory, a hierarchical or third party solution in corporate strategy for climate change mitigation would always be preferable compared to a bilateral solution, given the present situation with high transaction specific costs related to JI/CDM.

Hierarchical solutions reduce uncertainties when long-term perspective is needed

A general problem with all options, aside from the hierarchical solution, is that investments today have little value in the future. Climate change management needs a long-term perspective, and those companies that take climate change seriously and are currently developing corporate climate strategies that will help them survive in the long run may want to reduce the uncertainty about future international climate policy regimes by undertaking all measures in-house. Corporate investments in most industries take a longer perspective than the reach of the current climate policy regime, ending in 2012. In a short-term perspective, focussing on the first and second trading periods of EU ETS (2005-2007, and 2008-2012 respectively), it may be viable to buy emission allowances in the market if needed. However, climate strategists in large emitter companies would know that post-Kyoto climate policy regimes will require much more radical emission reductions, also in highly developed countries. Several analysts argue that global GHG emissions must be reduced by 60-70 per cent by 2050 compared to current levels, which requires emission reductions in industrialised countries up to 95 per cent in the next four to five decades (see e.g. Schellnhuber et al. 2006; Stern 2007). This cannot be met by using the flexible mechanisms only, but must render large in-house investments in new low-emitting production processes and products. Due to the economic dynamics, such investments must be made soon (cf. Stern 2007). Postponing investments in their own facilities may reduce competitiveness and thus be very expensive, especially if it is substituted by direct or indirect investment in increasing efficiency of their competitors. Some of the largest emitters of carbon dioxide included in the study have indicated, once the initial allocation of emission allowances for the first trading period of EU ETS was decided, that they will undertake all measures to reduce carbon dioxide emissions hierarchically. They want to develop new production processes to stay competitive. Reflecting upon such statements when discussing EU ETS and the option of also using emission credits from JI/CDM projects as currency, it is worth repeating that some of the companies participating in this study mentioned at the workshops that they

would only invest and participate in JI or CDM projects if they could invest in their own facilities in other countries.

This reasoning is based on the same logic that favours hierarchical solutions, but it pertains to JI and CDM. This would be a special case of JI/CDM since it is basically a hierarchical solution – the measure is taken in a facility owned and run by the company (but in another country), not just in 'any facility' that would make it a bilateral solution. This implies that perceptions of what is to be regarded as JI/CDM projects must be diversified. We may talk about bilateral as well as hierarchical JI/CDM projects. This may look trivial, but it can require changes of the existing institutions of JI/CDM. An analysis of which specific changes, however, lies outside the scope of this chapter. Whether changes are eventually to be made is also dependent on the future need of private investment in Kyoto project mechanisms – you should not forget that the Kyoto mechanisms are principally designated for trading between countries, not between companies. Nevertheless, a major topic would be the potential of hierarchical JI/CDM projects to meet the criteria of additionality (i.e. that emission reductions resulting from a specific project are additional to those that would anyway occur).[6]

5 Conclusions

The overall aim of chapter was to examine the 'likelihood' of companies with GHG emission targets in enrolling with the project-based Kyoto mechanisms. The main question addressed qualitatively is: "How attracted are companies to investing and participating in JI and/or CDM projects?" To examine this question, the chapter employed two different, but complementary, theoretical perspectives on organisational behaviour, and empirical evidence from a study of Swedish companies' views on the Kyoto project mechanisms.

Despite limited empirical material, focussing particularly on the situation in Sweden, it is concluded that the Kyoto project mechanisms, linked to the EU ETS through the entry into force of the 'linking directive', would hardly be the first choice solution in European companies' strategies for climate change mitigation, focussing on reducing GHG emissions. The institutional perspective revealed that the organisational fields related to JI/CDM are in their infancy and there is a lack of regulative, normative or cultural pressure on companies to use JI/CDM as options in climate change mitigation. Thus, participation in JI/CDM would not guarantee or increase the legitimacy in the organisational field needed by companies to get necessary support. Accordingly, they show little interest in undertaking JI/CDM projects. The transaction cost theoretical perspective indicated that bilateral solutions such as traditional JI/ CDM-projects are less attractive than other solutions for companies that currently emit more greenhouse gases than is covered

[6] For a project to be approved as JI/CDM, it must add extra emission reductions than what would be expected in a baseline scenario taking into account all other requirements (regulations etc.) to reduce emissions.

by initial allocations of emission allowances. However, the corporate interest for participation in JI/CDM may increase if the JI/CDM regulative framework allows corporate investment in their own facilities in other countries, resulting in 'hierarchical' JI/CDM-projects (in comparison to the traditional 'bilateral' JI/CDM-projects). This indicates that multinational corporations, particularly those with facilities in developing countries and economies in transition, would be more likely to participate in JI/CDM projects than companies operating in one or a few (industrialised) countries only. According to Point Carbon (J. Buen, pers. comm.), a leading GHG market analyst, Japanese multinationals are currently the most active private actors in the JI and CDM markets. Third party solutions, e.g. through investment funds where the companies do not really participate in the project, may also increase the private investments in international climate change mitigation projects.

As a consequence, it is found to be unlikely that emission credits (ERUs or CERs) eventually entering the European carbon market are gained to a large extent from projects undertaken by companies obliged to take part in EU ETS. There are few multinational companies in the EU ETS that operate in countries suitable as host countries to JI/CDM projects. The entering of ERUs/CERs in EU ETS would rather depend on successful set-up and operation of carbon funds. To what extent this will influence the effectiveness of the 'linking directive' – it is too early to draw conclusions.

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Understanding business participation in UK emissions trading: dimensions of choice and influences on market development

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Abstract

This research explores resource and capacity-based linkages between the choice to become involved in emissions trading and the development of an emissions market. The analysis is based on semi-structured interviews with key corporate participants in the UK emissions trading scheme (ETS). Analysis of interview data reveals that the development of an emissions market can be linked to the ability of firms to make an informed participation decision that take account of the interdependent dimensions of emissions trading. The paper concludes that the thin UK ETS market is as much a product of utility maximisation as it is of ad-hoc decision-making, fears of non-compliance and poor organisational capacities for managing trading.

Keywords: Emissions trading, emissions markets

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1 Introduction

In April 2002, DEFRA launched the UK Emissions Trading Scheme (ETS). Under the provisions of this four-year program, 31 organizations agreed to reduce their direct and indirect emissions of CO_2 equivalencies by almost 12 million tons from 2002-2006, in exchange for a financial incentive (DEFRA, 2001). Direct participants (DP's) were paid between £12-18 per ton/CO_2e[1] in incentives to make annual, absolute reductions in a basket of six GHG's weighted in equivalence of effect to carbon dioxide (CO_2e) (DEFRA, 2001). On average, each DP made a commitment to reduce their emissions of CO_2e by 12% from a baseline calculated on 1998-2000 emissions levels.

Market performance in the UK ETS has been tepid at best. Lack of interest in trading has been linked to 'hot air' emissions reductions that reflect incentive-seeking behaviour (eg. ENDS 2002; NAO, 2004). However, it is argued here that an emissions trading scheme (as distinct from the practice of 'trading emissions'), represents much more than an emissions market. Neo-classical economic drivers are not the only influences on business behaviour in an emissions trading scheme. Accordingly, in order to understand the development of an emissions market, it is important to take account of the multi-dimensional nature of emissions trading and the way those dimensions interact with the behaviour of firms.

These arguments are based on analysis of semi-structured, in-depth interviews with a selection of key businesspersons and government officials involved in UK emissions trading. The interviews were performed in 2003 and 2004 in the course of the author's PhD research on business participation in the UK ETS. The group of interviewees includes representatives from eighteen of the Direct Participants in the UK ETS, four senior members of the UK Emissions Trading Group (the business advocacy group behind the development of the UK ETS), and four government officials involved with the creation and management of the scheme. A good mix of business sectors and participation levels are represented in the group of DP's. Twelve represent firms trading primarily indirect emissions from electricity use, and six represent businesses trading in both indirect electricity emissions and direct emissions of high global warming potential (GWP) gases not covered by the IPPC directive. A list of DP's and other organisations interviewed is provided at the end of the paper.

2 Emissions trading schemes and emissions markets

Emissions trading is often cast as preferable to 'command and control' policies because it purports to deliver emissions reductions in a flexible manner through the addition of a market mechanism as a compliance option (Stavins 2000). This extra degree of flexibility hinges on the development of a relatively efficient emissions market that gives off appropriate price signals for abatement decisions

[1] The rate varies depending on a particular participant's tax rate - see DEFRA, 2002.

(Hahn 1993). Experience with emissions trading elsewhere indicates that an efficient emissions market tends to develop slowly, or at least somewhat tentatively. Perhaps the best example of this phenomenon is that of the market in the US SO_2 trading scheme.

The development of the US SO_2 market has generally been regarded as a successful transition to a well-traded and efficient market (Kruger 2005). Between 2000 and 2003, the latest period for which EPA trading data are available, about 11 million allowances were traded on average each year, with an average price around $200/ton (US EPA 2006). However, and despite these eventual successes, the first two years of the US SO_2 market were marked by much lower trading volumes and inelastic prices for permits (Bohi and Burtraw 1997; Schmalensee et al. 1998; Ellerman et al. 1997 among others).

The initial development of the UK ETS market followed a similar pattern to that of the SO_2 scheme. However, there is an important divergence here in that the UK ETS market performance did not improve with time. A network analysis of trading in the first year of the UK ETS indicates a fairly thin trading volume. Only 336 legitimate trades were made in the initial year (Environment Business 2003). Most of these originated from buyers outside the scheme, who were seeking to top up relative efficiency targets from within the so-called Climate Change Agreements (CCA) (NERA 2004; Enviros 2006). The direct participants on the other hand seemed reluctant or unwilling to trade allowances at any price. For the 2002 compliance year, 15 (or 47%), of the DP's made only one trade or did not trade at all. For the 2003 compliance year, 21 (or 65%), of the DP's in the UK ETS only traded once or not at all (NERA 2004). In total, there were approximately 3,500 legitimate trades between April 2002 and March 2006, the bulk of which originated from CCA compliance efforts. In years without CCA compliance targets, such as 2003, the trading volume is significantly lower (Enviros 2006).[2]

In the face of such sparse market activity, allowances prices have fallen dramatically. The UK market saw allowances prices peak at around £12.50 per tonne of CO_2e after the auction, (near the true incentive clearing price) and then fall to around £3 thereafter (Point Carbon 2003). Currently, (May 2006) emissions allowances are trading at about £2.30 (Natsource 2006), which is far beneath the auction-clearing price for incentive payments.

Of course a firm does not have to trade in order to benefit from the offered flexibility of an emissions trading market. This is a somewhat ironic facet of 'emissions trading' in that little to no trading is actually required. Merely retaining the option to do so could provide sufficient flexibility to achieve lower cost emissions reductions than mandated standards (Hahn 1993). Yet the consistent lack of

[2] The DP's do generally trade much larger volumes than the CCA participants, although Enviros (2006) is careful to note that this does not necessarily reflect comfort with the trading mechanism. Many of the DP's use brokers to trade and these may charge a prohibitive fee for lower volume trades. Interestingly, it seems that overall trading volume is also related to the volume of a particular trade. The NERA (2004) evaluation of the UK ETS found that the average size of trades for organizations trading only once was 0.8 $ktCO_2e$, whereas for those trading more than 100 times, the average trade size was 3.4 $ktCO_2e$ (2004, p. 5).

market activity from the DP side, even for year-end compliance goals and during end of year price spikes, is striking. The un-encouraging figures for the UK ETS market have lead some commentators to suggest that DEFRA's voluntary, incentive-based approach to emissions trading only managed to attract a small group of businesses with relatively undemanding (NAO 2004) targets made up of business-as-usual emissions reductions (ENDS 2002) which required little operational buy in from participants (Roeser and Jackson 2003).

There seem to be two related conclusions that can be drawn from the preceding discussion. Firstly, emissions markets tend to take time to develop. Even in mandated markets, firms may (at times irrationally) prefer to self-supply through fuel switching or shifting production methods (McDermott 1997; Bohi and Burtraw 1997; Rose 1997). Secondly, emissions markets are synthetic markets and therefore highly sensitive to the constraints of their design.

What the UK ETS example appears to demonstrate very clearly is that, if left to their own devices, businesses will not participate voluntarily in an emissions trading scheme in a robust manner. In essence, this leaves us at the more familiar conclusion that a lax allocation method will not produce a traded market because firms will optimise their participation, offering only minimal emissions reductions, which will lead to a lack of demand for permits (see Tietenberg 2001 for a discussion of design options and implications). However, this conclusion only follows if firms behave, *or are able to behave*, in a neo-classically rational manner in regards to allocation and participation decisions. Before discussing this facet of market participation in more detail, it is important to reflect briefly on the wider dimensions of emissions trading.

3 Emissions trading as a multi-dimensional instrument

Outside of the bounds of the emissions market, emissions trading represents a point where neoclassical economic rationality, physical emissions profiles, public policy and social responsibility and organizational capacities for managing carbon and markets intersect. These broad dimensions of emissions trading are summarised below:

- An **economic dimension** related to neoclassical assumptions of market behaviour, and the goal of economic efficiency and flexibility in climate change mitigation.
- An **environmental dimension** related to the need to mitigate climate change associated with business activities, historical emissions profiles, the stringency and acceptability of baseline allocations, and the ethics of using a market to combat a market externality.
- A **social and political dimension** stemming from the context of governmental commitments for climate change mitigation, generalised corporate environmental responsibility and accountability, and the social visibility of participation in the scheme.

- An **organisational dimension** related to corporate capacities for scheme management and the availability and quality of information for decision making.

Each of these four dimensions represents an important sphere of influence for policy choice, participation in emissions trading, and the eventual development of an emissions market. There are also clear areas of overlap between the elements within these broad categories. For instance, emissions profiles are directly related to potential allocation levels and thus potential market activity. The interconnected nature of these dimensions provides further support for characterising emissions trading as an approximation of a diverse set of interconnected drivers and motivations that go beyond the confines of the market itself.

Such a multi-dimensional stream of influence is likely to be especially relevant to the decision to participate in a voluntary emissions trading scheme like the UK ETS, in which the costs and benefits of participation can be constructed and evaluated in numerous ways according to the contexts in which the scheme is created. Important groundwork on the motives for business participation in the UK ETS has been performed by a variety of researchers and organisations (Von-Malmborg and Strachan 2005; Roeser and Jackson 2003, NAO 2004; NERA 2003; ENVIROS 2003, 2006; DEFRA 2002 among others). Generally, these studies identify four primary motives for business support of UK emissions trading: a desire to avoid payment of the Climate Change Levy, 'early mover' considerations associated with gaining experience in trading prior to the introduction of the EU ETS, socio-political motives associated with the value of being 'seen to be green' by government and the public, and a desire to take up the financial incentive offered by government in exchange for participation.

In similar fashion to the multi-dimensional construction of motives for participation in the UK ETS, the capacity of a firm to make strategic decisions about entry into an emissions trading scheme, and to behave optimally in an emissions market, depends on a fairly diverse stream of resources. To date, little research has been performed on the structure or nature of the choice to participate in the UK ETS, particularly in terms of the capacity of participants to make informed decisions about emissions trading. The remainder of this paper explores these resource-based elements of the choice to participate in the UK ETS in more detail. It then links these capacitates to the willingness and ability of firms to use an emissions market as an effective abatement tool and to the (lack of) development of the emissions market in the UK ETS.

4 Resources and capacities for participation in emissions trading

Baseline allocation levels in the UK emissions trading scheme were calculated as an average of three years' worth of emissions for gases to be included in the scheme. Bids for emissions reduction were, (or at least were intended to be) made through comparison of baseline levels to projected emissions profiles and the

value of the incentive (DEFRA 2001). The final targets in the UK ETS were calculated through a fairly complicated 'descending clock' auction mechanism in which levels of incentive/ tonne CO_2e were incrementally decreased until total bid levels reached £215 million in incentive monies (the total earmarked for use as an incentive). Ideally, all participants in a voluntary emissions trading scheme would be able to make an informed and rational projection about their emissions and energy use and to link this projection to the present and discounted future value of the financial incentive. This would in turn make for more targeted bidding behaviour in the incentive auction and streamline the supply of allowances within the scheme. However, the interview data indicate that such informed and financially strategic bidding behaviour was the exception, rather than the rule, for the majority of companies within the UK ETS.

Creating a strategically accurate reduction target is 'harder than it sounds', according to one of the larger participants interviewed, because it requires detailed levels of historical emissions information, and a degree of coordination between different business departments:

- [Target setting] was harder than it sounds because the target that we had set ourselves … it was a ten percent reduction on emissions levels in 1990. So we needed to find out three things really. What were our emissions as a company in 1990? What are they/what were they in the most recent period? So in that case it was in 1998. And what were our forecasts of emissions going forward? And you're asking people - you're going to a business unit and asking them 'what were your greenhouse gas emissions in 1990? 'And their answer is 'well I'm not even sure what we owned in 1990 or what our sales were in 1990.' So the first thing to recognize is that … our 1990 inventory has a bigger level of uncertainty on it than our more recent data *(Interview with a DP from the energy sector).*

Another respondent from the manufacturing sector expressed similar ideas, recalling that coordinating the requisite data from across the business made the choice to participate difficult:

- The whole subject is pretty unknown. You have to gain experience in trading itself, but also in order to have a good trading system in place you need a good data set. And in order to get the data set you have to include more or less every organization inside the company - like treasury manufacturing the energy department and the environmental department – everyone *(Interview with a DP from the manufacturing sector).*

In light of findings such as these, it appears that having or maintaining good data on emissions levels was a veritable prerequisite for participation in the UK ETS. A potential participant could not strategically enter the scheme if they were unable to accurately calculate a baseline due to a lack of information on emissions profiles. One interviewee offered an especially incisive insight into this phenomenon, linking the small number of participants in the UK ETS to a lack of consistent data on emissions profiles:

- Why didn't more people get involved? You've got to think back three years … because it is three years - the dates for the baseline data. Not many companies in my sector … would have had an adequate baseline, plus a firm idea of where they were likely to go, energy consumption wise, in the future. And that's what it comes down to. If you can't be sure where you are going to save energy from over the next five years, best not get involved *(Interview with a member of the UK Emissions Trading Group).*

Interestingly, the interview data indicate that poor data and capacities for managing emissions trading are not symptomatic of only non-participants. As discussed by Roeser and Jackson (2003) the majority of DP's in the UK ETS had relatively poor levels of data about emissions levels or energy use, especially as regarded historical information in these areas. This is particularly true for the smaller participants (with less expertise and management resources at their disposal), who appear to have become involved on an 'ad hoc' or unscientific basis (Roeser and Jackson 2003). However, even for those companies in which the decision was arguably well streamlined, where there was good quality information on current and past emissions levels, and for whom the option to participate in a financially opportunistic manner presented itself, reduction targets appear overly cautious and economically myopic (Roeser 2002). For the FTSE 100 companies in the UK ETS, targets do not even amount to 1% of the total climate change impact of the respective company (Roeser and Jackson 2003).

To some degree, these conservative targets reflect the voluntary nature of the scheme, in which no minimum level of effort was prescribed. However, the interview data also show that overly conservative targets also stem from uncertainty about emissions data and a (corresponding) inability to forecast emissions levels. The absence of a direct relationship in the auction between higher levels of the incentive payment and higher bid amounts provides strong evidence in favour of this conclusion.

5 Incentive seeking behaviour?

If potential participants had ample information about their emissions profiles, then one would expect to find a direct relationship between the value of the incentive at different stages of the auction and bid levels. However, DEFRA admits that only four participants appear to have had sophisticated bidding strategies (DEFRA, 2002). One government official highlighted the lack of a relationship between bid size and relative value of the incentive as evidence for the poor data quality and capacities for engaging in emissions trading on behalf of the majority of the DP's. This respondent also specifically addressed the importance of organisational capacities and resources to the choice to participate in the UK ETS by suggesting that larger companies with better resource capabilities might be less likely to make such static bids:

- The big question was, well if the price had dropped any further, would you have withdrawn some of your offered emissions reductions? And some of the commentators have been suggesting that the emitters didn't really have much idea about their cost curves. They just knew that they had a sort of lump of very low cost emissions - making a sort of vertical supply curve. And that any price much above zero, they would offer that same amount … . We know the bigger companies, certainly they have a more sophisticated view, and they do know a bit more about their marginal abatement curve. But it's not going to be universal. I think some of them now regret not knowing more about their cost curves, because it could have more incentive if they had finessed *(Interview with government official).*

These ideas were also expressed by several of the direct participants. One in particular, who had also been close to the UK ETG process, offered this response:

- The UK scheme when it was announced with the incentive money - you have an early scheme there – in which no company has any previous trading experience - apart from those which have been involved in the SO_2 markets in the US. The way that it's put forward is that you do have a fairly complex auction to participate in … You have got a lot of companies who really are not on top of things like abatement costs and so on. I mean very few companies entered the UK scheme with a view on what their abatement costs were, or used any sort of rationale, along those lines in terms of judging at what point in the auction or at what value of the incentive they would pull out *(Interview with a DP from the retail sector).*

In the face of such endemic uncertainty, many of the DP's simply offered heavily rounded emissions reductions that were overly cautious and unresponsive to varying incentive levels (see also Roeser and Jackson 2003). One participant summarised this bidding style in the following manner:

- We had a very simple bidding strategy. It was scientific, but it was also simple, in the sense that we were bidding the same volume all the way down to a certain price. beyond which it's not economic. It's a binary decision, not a sliding scale. We bid the same volume all the way down. Because we were either going to do it or we were not *(Interview with a DP from the materials sector).*

This 'all or nothing' bidding behaviour is certainly not 'utility-maximising' behaviour in the neoclassical sense of the term. For a lucky few, the inclusion of high global warming potential (GWP) gases within the scheme (which are favourably weighted as large amounts of CO_2e) created windfall incentive profits without equivalent abatement efforts for CO_2.[3] However, the data discussed above show that many participants were simply unable to take full advantage of the financial incentive, even though the offer of a financial incentive remained the most

[3] Just three participants have been allocated over 50% of the allowances (and the incentive payments) in all years of the scheme to date (ENDS 2002; Enviros 2006).

important general driver of participation in the scheme (VonMalmborg and Strachan 2005; Enviros 2003). One of the more striking conclusions that follows here is that the level of 'hot air' in the UK ETS might have been inflated if the participants had possessed better capacities for decision-making in this area.

These findings and the wider conclusions behind them about the multi-dimensional nature of emissions trading have direct implications for understanding both the environmental performance of the UK ETS and the development of its market. Although a significant amount of the targets within the UK ETS can be fairly characterised as undemanding (NAO 2004) that conservatism does not necessarily stem from financially opportunistic behaviour. The interview data show that the initial (and ongoing) concentration of sellers in the UK ETS market also stems from uncertainty about emissions levels and a resulting inability to make a targeted reduction bid. The final section develops these ideas in more detail, with application to longer-term participation in emissions trading and the development of the UK ETS market.

6 Resources, capacities and market development in the UK ETS

A 2006 evaluation of the first four years of the UK ETS by Enviros consulting found that motivations for trading emissions amongst the DP's centred on desires 'to meet targets, to sell surplus allowances and to 'stock up' on allowances to meet future targets" (Enviros 2006, p. 16). More importantly, the report goes on to note that 'although some DPs followed this strategy as the most cost effective approach, in other cases it was driven more by the level of understanding or resources available to facilitate a trade" (2006, p. 16). Further analysis of interview data reveals that a lack of resources for managing day-to-day trading and fears of non-compliance have a continuing prohibitive effect on the development of the UK ETS market.

7 Capacities for day to day management of emissions trading

Within a voluntary emissions trading scheme, the relative size of a reduction target creates the level risk and exposure to the fluctuations of the trading market. If that level of risk is fairly low, (as is the case for most of the DP's), then participation in emissions trading may be less likely to garner a good deal of financial or managerial attention. The interview data show that a resulting lack of integration of emissions management across different departments (and crucially between 'environment' and 'finance' divisions), may prohibit trading. One respondent linked minimal emissions market exposure to decreased involvement of senior management and a concurrent increase in the difficulty of trading:

- "In our company – we are just marginally effected … bottom line we're just talking about a couple of thousand tons - worst case scenario. This means £50.000 or something. And no one in our top management sees that it is a big deal. I have to manage it myself. So if I have to go buy £50.000 [worth of credits], These £50.000 are either coming directly from out of my pocket … or I have to find someone who is going to pay for this and then the whole issue is of course more difficult. Getting money in - they take it like that and it disappears. If you need money it's very hard" *(Interview with DP from the manufacturing sector).*

At the very least, this quote seems to suggest that this individual would have difficulty buying allowances in any kind of speculative manner in the scheme. At worst, it implies that this individual might find trading impossible. Through exploring these trading mechanisms in terms of the capacities for managing participation in the scheme, we can perceive a clear chain of influence between over-cautious targets and cautious market behaviour. The key point here is that this chain is not formed so much from economic drivers as it is from resource-based factors. Interestingly, the interview data also suggest that ongoing uncertainty about emissions trading (or a lack of capacity to trade effectively) may decrease the willingness of a firm to sell emissions allowances.

8 Fears of non-compliance

While the majority of the interviewees did indicate that they had purchased at least some carbon in the UK ETS market, fewer interviewees indicated that they had sold those credits. This finding is also supported by prior research on the UK ETS. For instance, the 2004 evaluation of the UK ETS market by NERA Consulting revealed that only one third of the UK ETS participants were net sellers in the first two years of the scheme (NERA 2004).

These are somewhat surprising findings - at least if we assume that many participants would be net sellers due over-cautious targets and an allocation mechanism that allowed large volumes of high GWP gases into the scheme (see Roeser 2002). However, it appears that the DP's did not approach the sale of emissions allowances in the same neo-classically rational manner as they might have done with other commodities. One government official who was instrumental in designing the UK ETS market offered this insight into the workings of an emissions market:

- It is a compliance market. This is why it is different to pure financial trading. It's a compliance issue at the end the day. There is a big cost - you get fined if you don't comply. So it almost does initially naturally sit within a compliance environment … .You see the banks coming in … and they say 'you need to have this that and the other in order for the markets to work' but we say to them 'hold on this is not just about having a market' this is about achieving an environmental policy goal … . A traded market might help you

to reduce emissions at lower cost, but it's still a compliance driven market. It's not the same as a pure foreign exchange commodity market *(Interview with a government official).*

Findings like these suggest that although an emissions market might be intendedly free in its operation, the threat of non-compliance may hinder the freedom of that market to operate efficiently, particularly in terms of the sale of allowances. The interview data offer further evidence in support of this conclusion. The following quote from an interview with one of the smaller UK ETS participants depicts an aversive view towards parting with purchased emissions credits that reflects both uncertainty about emissions levels and fears of non-compliance. This individual indicated that he had bought a large quantity of allowances at the start of one compliance year, which turned out to be unneeded and additional to an existing surplus of allowances generated through internal abatement measures. When asked whether or not he had sold any of these excess allowances during a price spike at the end of the compliance year, he offered this response:

- No we didn't. We've just in effect kept them sat in our bank so to speak, because I think this year we may not be … . Because obviously our target is ever reducing, … . So I think this year our actual energy usage has probably flat lined compared with last year. So I think we could well be relying on that … those extra allowances that we have *(Interview with a DP from the materials sector).*

What is noticeably absent from the above quotation, (and it does not occur later in the transcript), is any consideration of using the market to meet compliance goals. It seems that purchased or banked emissions allowances are not considered to be homogenous with allowances that *could be purchased.* An allowance banked represents guaranteed compliance at a cost that can be calculated now*,* rather than in a compliance future that is *dually uncertain* in terms of both emissions levels and market fluctuations. Indeed, some interviewees characterised meeting compliance targets with the market as akin to 'renting' or 'leasing' yearly compliance. One of the larger participants in the scheme spoke about these ideas in detail, admitting that his trading activity could be considered a short-term solution, at least in a financial sense:

- I would see it as a short-term solution. The reason being that if you are relying on trading, you are very much exposed to the tradable price of that commodity. So you have a very large exposure there. In a sort of financial sense you have an open position. Whereas if you know that you are reducing production or investing in some technology to reduce emissions, then you're sort of … . In terms of your exposure to the risk, then obviously you're reducing that quite substantially *(Interview with a DP from the energy sector).*

In consideration of these ideas, it seems that the tendency to bank allowances, rather than managing them in a more speculative, profit-maximising manner, reflects a fear of trusting the fluctuating market to meet yearly compliance targets. This fear stems partly from an inability to accurately forecast emissions levels,

and partly from a fear of financial penalties for non-compliance. In turn, these factors erode the attractiveness of the emissions market as either a long term or a 'spot' compliance solution. These conclusions are supported by research on emissions markets elsewhere, particularly the US SO_2 trading scheme. Apart from regulatory windfalls which made use of the market unnecessary in some cases (see Bohi and Burtraw 1997), the sluggish growth of the early US SO_2 market also reflects a lack of familiarity with the trading mechanism. Some utilities preferred abatement strategies centred upon self-supply of allowances, with little to no regard for potentially cheaper market-based compliance solutions (McDermott 1997; Rose 1997).

9 Conclusions and discussion

The resource-and-capacity-based factors explored in this paper provide strong evidence that without the ability to manage trading, both across departments and in terms of reacting to market fluctuations, a firm cannot properly or strategically engage in trading emissions or an emissions trading scheme. Alternatively, we can conclude that the performance of an emissions market appears to be especially susceptible to influence from both the parameters of the wider scheme, and the resource-based characteristics of scheme participants. The synthetic emissions market is only as good as the combination of *both* its design and the capabilities of its participants.

This dimension of participation in emissions trading seems to have been largely overlooked in much of the economic literature on this subject. The neo-classical underpinnings of emissions trading encourage us to assume that firms will have the information and resources to make flexible abatement decisions with reference to the market price for carbon, or to make strategic bids in allowance auctions, and that they will act upon this information to achieve compliance at least cost. However, the preceding discussion shows that when these capacities are lacking amongst a significant number of participants, then the development of the emissions market may suffer. In some cases, it may fail to develop at all.

Such a linkage between participant resources and market development may be amplified in the case of a voluntary trading scheme like the UK ETS in which firms can choose their own levels of abatement activity. Many participants appear to have become involved in the scheme on an ad-hoc basis, without the resources and capacities to make a strategic bid for the financial incentive or a robust environmental commitment. Perhaps more crucially, it also seems that uncertainty and over-cautious targets had an additional (although more indirect) effect on the development of the UK ETS market, in that these factors discouraged the development of capacities for trading amongst some participants. In the face of uncertainty about how emissions prices might fluctuate in the market, combined with endemic uncertainty over emissions levels and emissions management, many DP's were unwilling to trust their compliance obligations to market flexibility. Although no attempt has been made here to quantify the economic effects of uncer-

tainty and ad hoc decision-making on the development of the UK ETS market, it seems reasonable to qualify at least a significant portion of its sluggish growth in terms of these factors.

In a less negative light, these findings also highlight one of the potential sources of value for participating in an emissions trading scheme. The discussion of the relationship between reduction targets and exposure to the trading market reveals that emissions markets can also affect the degree to which a business is motivated to manage carbon in a more robust, integrated fashion. Financially accounting for carbon could encourage a wider range of business departments to take notice of emitting activities and emissions profiles – at least if exposure to the emissions market is taken seriously. Conclusions like these also serve to emphasise the importance of understanding emissions trading as more than a market. Outside of the vacuum of neoclassical rationality, an emissions trading scheme exists at the point where market forces, resources and capabilities for emissions management, corporate social responsibility and emissions profiles intersect. In this context, market forces are just one of many important drivers of activity in an emissions trading scheme.

Table 1. List of organisations interviewed

Organisation Name	Organisation Name
ASDA	Greenergy/Sommerfield Stores
Barclays	Imerys
Battle McCarthy Carbon Club	Kirklees Metropolitan Council
Blue Circle/Lafarge/IETA	Land Securities
British Airways	Lend Lease
British Gas (UK ETG)	Marks and Spencer
British Petroleum	Mitsubishi
Budweiser	Powergen (UK ETG)
Climate Change Capital	Royal Ordnance
Confederation of British Industry (CBI)	Shell
Department of Trade and Industry (DTI)	Spectron Markets
Dept for Environment Food and Rural Affairs (DEFRA)	UK Coal
Ford	UK Trade and Investment
GKN	

This table presents a listing of organisations and firms in the interview data used in this paper. At least one representative was interviewed from each organisation listed.

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Corporate response to emissions trading in Lithuania

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Abstract

The article highlights the preconditions for emissions trading in Lithuania, identifies the factors that influence companies in building a competitive advantage via participation in the European Union Emissions Trading Scheme (EU ETS), and presents the findings of empirical research targeted at Lithuanian companies covered by the scheme. The EU ETS is a market-based economic instrument aimed at pollution reduction at the minimum possible cost. The research findings indicate that, although there is potential for Lithuanian companies involved in the EU ETS to take an active role in the carbon market, uncertainty regarding the outcomes of the scheme prevents them from taking a proactive position at the beginning of the first phase of the scheme.

Keywords: Corporate response, emissions trading, carbon strategy, Lithuania

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1 Introduction

Internalization of externalities is the main approach dealing with market failure in the field of environment. The integration of climate change mitigation and energy policies is an imperative for sustainable development. The European Union's Emissions Trading Scheme (ETS) is an emerging market-based climate change mitigation instrument, the application of which could contribute to both development of economics and protection of the environment. Moreover, it can be used by both governments and business actors.

The research on economic instruments for environment protection is extensive. Economic instruments related to energy and climate change (taxes, emissions trading, subsidies) have been analysed in economic literature for the last couple of decades. However, particular investigations of the EU ETS have been carried out just recently. Efficiency of economic instruments and emissions trading have been analysed by a large scientific community, such as Pearce (1990), M. Munasinghe (1993), E. Vedung (1998), G. Klaassen (1996), T. Tietenberg (1999), M. Grubb (1999), K.G. Lofgren (2001), E. F. W. Wubben (2001), J. A. Kruger, W. A. Pizer, (2004), J. Ellis et. (2004), R. Antes et. (2006) and others. D. Štreimikienė, R. Bubnienė (2005), R. Čiegis, R Bubnienė (2006) and R. Čiegis, D. Štreimikienė (2006), who have analysed economic instruments and emissions trading in Lithuania.

The EU ETS has been a subject of the research by scientific and consultant groups such as Center for Environmental Policy CEPS (2006), Carbon Trust (2004), Climate Strategies (2002). Besides, research contributions pertaining to the topic have been made by international institutions such as Intergovernmental Panel for Climate Change IPCC (2001, 2006), International Energy Agency IEA (2003), Organisation of European Cooperation and Development OECD (1997) and European Environmental Agency (1996).

Despite a number of recent studies on the effectiveness of the EU ETS at the EU level, scientific research concerning the corporate response to this instrument in Lithuania is lacking. In respect to energy and climate change policy, Lithuania is a special case due to the forecasted change in its energy balance since the closure of the Ignalina nuclear power plant, where energy demand will be replaced by fossil fuel combustion. Consequently, emissions of carbon dioxide will increase. In light of international and European climate change policy, climate change may become a challenge for Lithuanian companies to cope with. Companies will need to plan investments into emissions reduction measures, such as energy efficiency improvements, to fulfil the obligations under the EU ETS. To make the instrument serve economic and environmental goals it is important to analyse the reasons for a passive position taken by companies in the EU ETS.

Policy developments on climate change have led to a relatively flexible regulatory approach (Grubb et al. 1999), which means that a number of strategic options for curbing greenhouse gas emissions have become available, including interaction with external parties to attain emissions reductions. On the other hand, external pressures such as environmental regulation and public perception can eco-

nomically harm a company or an industry and put competitiveness at risk (Shrivastava 1995).

From the viewpoint of the European Commission, the EU ETS will serve as an international benchmark. It is argued that "cap-and-trade" in carbon dioxide is not too expensive (Vis 2005). Introduction of the ETS would have positive effects on both private companies and society, as it would propose an opportunity for enterprises to choose the most economic method for reducing pollution and, thus, would increase financial profit of the enterprises that improve their environmental performance.

What regard to the impact of emissions trading on competitiveness, it should be noted that even though it may bring disadvantages for companies in a static perspective, taking into account a dynamic approach could turn to advantage, e.g. technological innovations in products and processes and the first mover's advantage.

Beside these advantages, emissions trading implies some concerns such as strong reliance on a political compromise, requirements for precise measurements and monitoring as well as transaction costs. The historical, economic, business and social environments of the new and the old EU member states are different; therefore, the effects of emissions trading on them may be different.

As the carbon market in the EU is, to date, both new and unstable the advantages and disadvantages of this instrument are not yet fully evident. Carbon demand is uncertain and depends not only on carbon prices but also on the allocation method applied in the EU ETS. The reaction to the price signal is not clear and the impact of the companies' position on the carbon market is also uncertain.

The aim of the research, from which results are presented here, was to perform an empirical pilot expert research of the Lithuanian companies which participate in the EU ETS, and to assess obstacles and motives for participation.

2 Emissions trading in Lithuania

Under the Kyoto Protocol as a new EU member state, Lithuania is committed to achieving an 8% reduction in greenhouse gas (GHG) emissions, as compared to the greenhouse gas emissions in 1990, by the period 2008 to 2012. Between 1990 and 2001 GHG emissions decreased significantly as a consequence of the decline in industrial production and respective fuel consumption. Once the economy started growing again, emissions rose but this was in part compensated by reductions achieved through energy efficiency and measures taken to reduce emissions. It is forecasted that by the period 2005 to 2007 average greenhouse gas emissions will amount to 27.3 Mt CO_2e. This makes up 54.6% of Lithuania's commitment under the Kyoto Protocol regarding the introduction of greenhouse gas emissions reduction measures in all sectors (Lithuanian Ministry of Environment 2004).

Although the energy infrastructure will change substantially after closing the nuclear power plant by the end of 2009 (Ignalina nuclear power plant currently produces about 80% of the consumed electricity, it is claimed that no additional

generation of energy is required for the meantime. With the closure of the Nuclear Power Plant, primary energy demand in the basic scenario would increase only by approximately 30% during the period up to 2020. However, total demand for fossil fuel would increase almost 1.9 times within 20 years, i.e. from 5 million tons of oil equivalent in 2000 to 9.4 million tons of oil equivalents in 2020 (Institute of Lithuanian Scientific Society 2004). The generation capacities will be overtaken by existing thermal power plants, combined heating plants and renewable energy sources that have inherited very different technological GHG reduction potential, however, the Kyoto limit will not be exceeded.

An updated Lithuanian strategy for climate change mitigation (Lithuanian Ministry of Environment 2006) regards the EU ETS as one of the climate change mitigation measures. However, as there is no pressure to reduce the GHG emissions to comply with the Kyoto commitment, climate change issues are not prioritized in Lithuanian environmental policy making. Subsequently, the National Allocation Plan (NAP) is the main regulatory document that creates incentives for companies to participate in the carbon market.

The lack of incentives for GHG reduction has also been reflected in the NAP which determines how many allowances each company under the EU ETS will receive in the first trading period 2005-2007. In Lithuania 93 installations are participating in the EU emissions trading scheme in 2005-2007 and, thus, are potential traders within the carbon market. For the period 2005 to 2007 36.80 Mt of CO_2 allowances have been allocated. The EU ETS in Lithuania includes heat and power supply installations (59), cement and lime production, glass, brick and ceramic production (13), oil processing (1), chemical, paper and pulp production (20). About 60% (36,81 Mt in 2005-2007) of all allowances have been allocated to the energy companies.

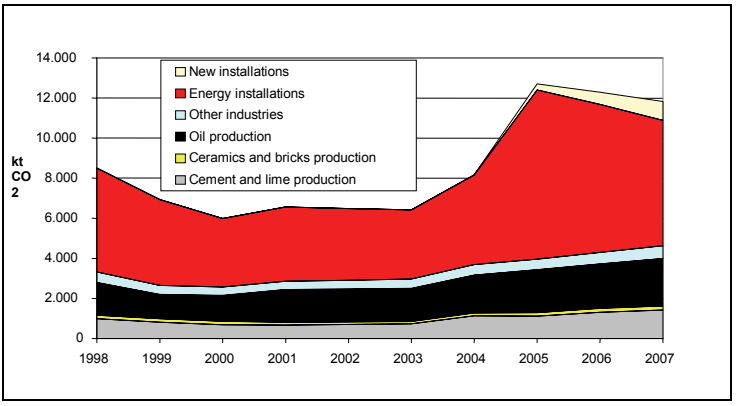

Fig. 1. CO_2 emissions trends and projections from installations under the EU ETS
Source: Lithuanian Ministry of Environment, 2004

Due to the small extent of the allowances allocated, it is likely that Lithuanian companies will not play a major role in the ETS market development. Lithuanian installations account for only 0.9% of the total EU installations and subsequently 0.007% of the total allowances allocated. Despite their minor contribution,

Lithuanian companies could provide an example worth analysing for how companies could meet the carbon market.

There was a significant surplus of allowances in the EU ETS in the first year of the operation of the scheme. The results of the first trading period 2005-2007 indicated that Lithuanian companies have received almost twice as many GHG emissions allowances as needed, compared to the actual GHG emissions. In 2005-2007 11.5 million allowances were allocated for Lithuanian enterprises and actual emissions amounted to 6.6 Mt of CO_2 (European Commission 2005). Thus, the enterprises were allocated 42% more allowances than their equivalence in CO_2 emissions.

The over-allocation of allowances in the first trading period could be explained by the fact that the closure of the first unit at Ignalina nuclear power plant in 2005 had no significant impact on the GHG emissions increase, as was predicted in the NAP 2005-2007. The second unit at Ignalina nuclear power plant operated very efficiently in 2005 and the time spent for regular maintenance was very short. Another factor, i.e. the electricity demand was covered not by increased energy production in Lithuanian power plants but by import of cheaper electricity from Russia and Estonia. On the other hand, Lithuanian companies in energy sector invested in biomass combustion technologies and energy efficiency measures.

Thus some Lithuanian companies used the opportunity to sell the surplus allowances. The biggest benefits were obtained by the enterprises which sold allowances in the summer of 2005 when the price per allowance reached 30€/t. However, only 3% of the operators were trading in 2005. In 2006 the number of operators involved in the trading amounted to 72% (Lithuanian Environmental Investment Fund 2007).

Taking into account the surplus of allowances in the first emissions trading period, the amount of allowances allocated for the second trading period 2008-2012 has decreased considerably. In the second trading period of the EU ETS (2008-2012), the number of installations has increased from 93 in the first trading period to 134, however, the annual allocation has decreased by 3.9% - from 11.5 million allowances per year to 11.0 million allowances per year (Lithuanian Ministry of Environment 2007). Consequently, the second trading period, due to the carbon restriction, is unlikely to be favourable for Lithuanian economic development and competitiveness of Lithuanian companies. On the other hand, positive impact of the EU ETS for Lithuania is that the scheme promotes use of bio fuels, combined heating plants and other advanced energy production and consumption technologies which have external benefits on society in terms of increased knowledge, skills, employment etc. (Čiegis and Štreimikienė 2006).

The analysis of the NAP for 2008-2012 indicates that seeking to maintain the average of annual GHG emissions at the level of 2005 with the growth of Lithuanian economy level up to 2012 CO_2, emissions per GDP should be reduced by 33% (Ekostrategija 2006). This is an important challenge for Lithuanian enterprises taking into account the switch from nuclear electricity production to electricity production mainly based on fossil fuel combustion.

3 Companies' responses to emissions trading

3.1 Theoretical background

In the current uncertain context of climate policy variuos corporate responses, carbon strategies and positioning in the market have been observed. Within the context of environmental management market response is defined as the way firms behave strategically, either to sustain a competitive advantage they already possess or to gain an advantage based on the opportunities that arise from environmental issues.

The introduction of an emissions trading scheme gives companies new incentives. It leaves companies the option to compensate for their emissions, instead of reducing them by changing products or processes. In addition, companies may take a more interactive approach to environmental management, such as a dialogue with members of the supply chain and the formation of partnerships with other companies and other stakeholders. Nevertheless, most companies' market-oriented climate strategies are still in an early phase, and it is not yet clear what factors will have the most influence on their decision making.

Moreover, climate change market strategies may be affected by both economic and political domain. Internal and external factors play a role in decision making. Contrary to the approach that firm-specific attributes are the main driving forces for the market response to environmental issues, J. A. Aragon-Correa and S. Sharma (2003) claim that the influence of the external environment should not be overlooked.

Lack of certainty about the international regime strongly affects quantitative indicators, such as the size of a market. The biggest opportunity on the demand side of GHG market is compliance cost for companies regulated by climate policies. Companies with comparatively low abatement costs may benefit from emissions trading. Uncertainty about the price of allowances and liquidity risks are important market risks. Regulatory barriers induced by international rules include possible import restrictions, levies on transactions and eligibility requirements for countries. At the national level, low compatibility of domestic climate policy regulations with the Kyoto mechanism and lack of incentives for market participants to engage in the Kyoto mechanisms could be named as the major barriers (Carraro, Egenhofer 2003). Therefore, stable regulations of the Kyoto mechanisms are very important for the private sector.

It is likely that the role of companies will grow in the emerging international regime aimed at governing climate change. The international regime has focused on market-based instruments rather than regulations and it is envisaged that international emissions trading will play a key role in the future climate change policy at the national, regional and/or international level.

The response of a company to the market instrument depends on the carbon strategy of the company. This is influenced by endogenous and exogenous factors. International climate change policy (joint implementation projects, international emissions trading), national commitments, features of the allowances distribution,

definition of the rules of emissions trading and characteristics of the carbon market – all these external factors impact companies' decisions regarding the carbon market. A company should assess national characteristics such as the structure of energy balance and the geopolitical conditions of the country in question. The main internal factors that influence the position of a company in the market is carbon intensity, financial incentives to use cleaner fuels, the rate of marginal abatement costs and the cost of allowances.

For the purpose of this research, companies were allocated into 4 categories on the basis of a response to the environmental requirements. R. Welford (1994) identifies four positions of companies in respect to their response to emissions trading which he defines as: "ostriches", "laggards", "thinkers" and "doers". Considering the companies' approaches to emissions trading, the category of "ostriches" in this paper means a non-compliant position, the one of "laggards" – a minimum compliance position, the one of "thinkers" – a cost optimisation position and the one of "doers" – an emissions trading position.

3.2 Response of the Lithuanian companies to emissions trading

A number of factors play a role in defining climate change strategies at an organizational level. In the assessment of the Lithuanian companies' potential to take an active part in the EU ETS, the internal and external factors have to be considered. Current and future energy infrastructure, production potential, the EU and national climate change policy, the regulatory framework and access to information will play a role in decision making.

The method of expert enquiry was chosen because quantitative issues had to be evaluated qualitatively as well. An expert questionnaire was prepared in order to analyse the readiness and motivation of Lithuanian companies to participate in the EU ETS. The scope of the research was limited to the Lithuanian companies included in the National allocation plan 2005-2007.

The research was conducted in December 2004. About half of the companies involved in the EU ETS were questioned. In total 37 respondents participated in the survey: 20 energy companies, 15 industry companies along with 2 representatives of industrial associations. Therefore, it can be claimed that the survey results represent the actual situation in Lithuania before the launch of the EU ETS.

A hypothesis was made that, despite structural changes in the energy sector by the phase out of nuclear in 2010, Lithuanian companies have a potential to trade in the carbon market.

It is noted that more than 50% of the companies which own operators covered by the EU ETS have been involved in the research. More than half of the respondents represented engineers or ecologists; about one third of the respondents were managers of departments or companies. The rest of the respondents had another position in the companies.

The questionnaire consisted of closed, direct multiple-choice answer questions about a current position and the perspectives of the companies in the European

carbon market. The questions covered the following aspects of the participation in the EU ETS:

1. Most appropriate way of the companies' involvement in the preparation of the National allocation plan (questions 1 and 2);
2. The reasons for CO_2 allowances trading (question 3);
3. A foreseen level of involvement in the EU ETS (question 4);
4. Obstacles for participation in the carbon market (question 5);
5. The most difficult tasks while preparing to trade in the carbon market (question 6);
6. Cost of the implementation of the EU ETS (question 7).

The questionnaire was prepared to address the installations involved in the EU ETS, to clarify whether Lithuanian companies are ready to meet a challenge of emissions trading, and to identify potential obstacles.

Other questions were aimed at clarification of the kind of information that would be needed by companies; how/whether the companies would like to be involved in drafting the National allocation plan for 2008-2012; the reason for companies to trade; the time when companies will trade; the main obstacles for engaging in emissions trading.

A variety of company sizes, capital and ownership have been represented in the survey. 43% of the respondents were representatives of small and medium size companies, almost half of the companies were state-owned and half of the respondents represented national capital companies.

Figure 2 illustrates the rationale of the companies to trade their CO_2 allowances. The trading motive for more than 50% of the companies is environmental liability, i.e. implementation of environmental requirements. 40% of the respondents are motivated by the possibility of improving industrial effectiveness. One-third of the respondents argued for trading through the gathering of experience and only 14% said that the trade is aimed at profit taking.

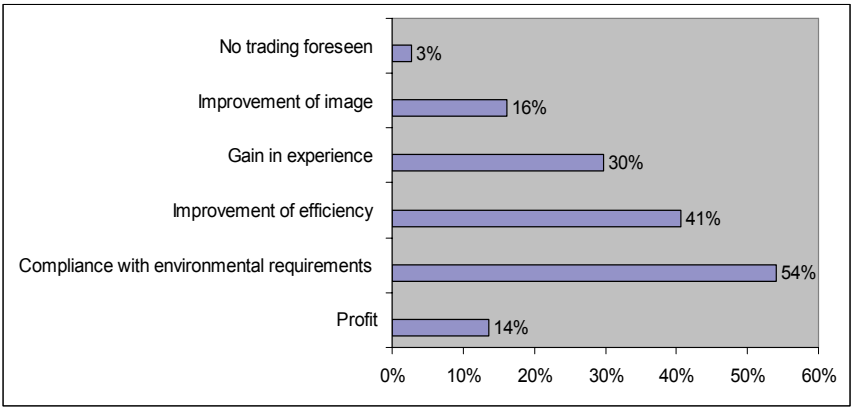

Fig. 2. Rationale for CO_2 allowances trading, percentage of respondents

The survey results show that Lithuanian companies will most likely engage in trading at the end of the first trading period 2005-2007. The answers to the question: "What would the company do if it were possible to trade immediately?" (See Figure 3), the majority of the companies (43%) responded that they would wait and see until the end of 2007. The results are similar to the ones in other countries in transition where small and medium size enterprises compose the majority of all companies.

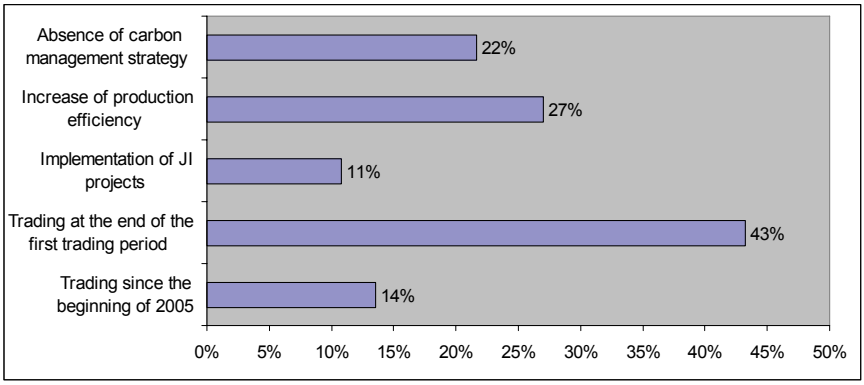

Fig. 3. Willingness to enter the emissions trading market, percentage of respondents

About one-third of the companies would like to increase energy efficiency and one-fifth of the companies argued that there is no CO_2 management strategy at their company. Such responses show that companies do not perceive allowances trading as a potential new market.

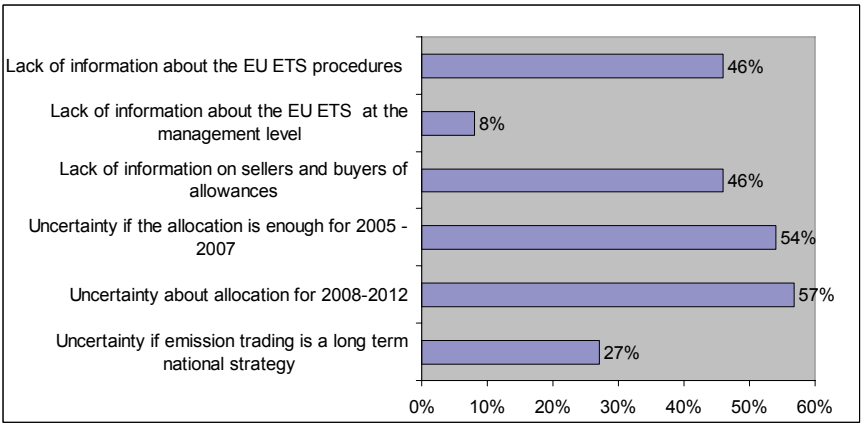

Fig. 4. Obstacles to entering the emissions trading market, percentage of respondents

Uncertainties for the first and the second emissions trading period were mentioned among the greatest obstacles to entering the market. On the one hand, few companies mentioned that managers are not aware about the emissions trading

regime. On the other hand lack of information on the EU emissions trading procedures, potential buyers and sellers of allowances were emphasized. Obstacles to entering the emissions trading market are presented in Figure 5.

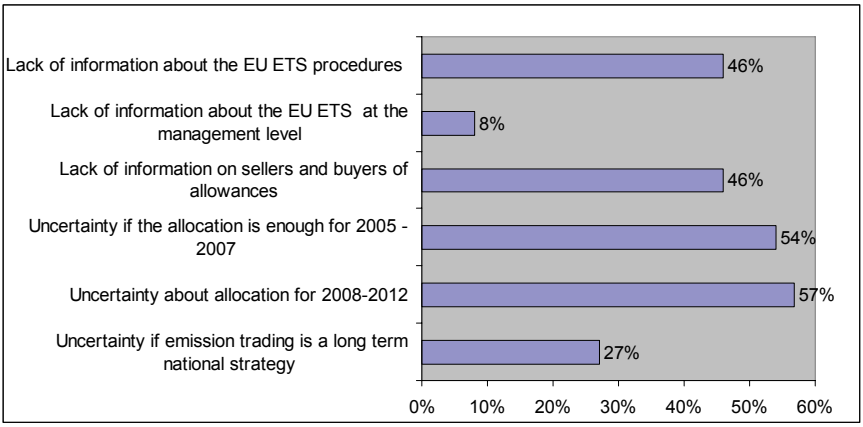

Fig. 5. Demonstrates the difficulties companies encounter or anticipate encountering during the implementation of the EU ETS. encounter

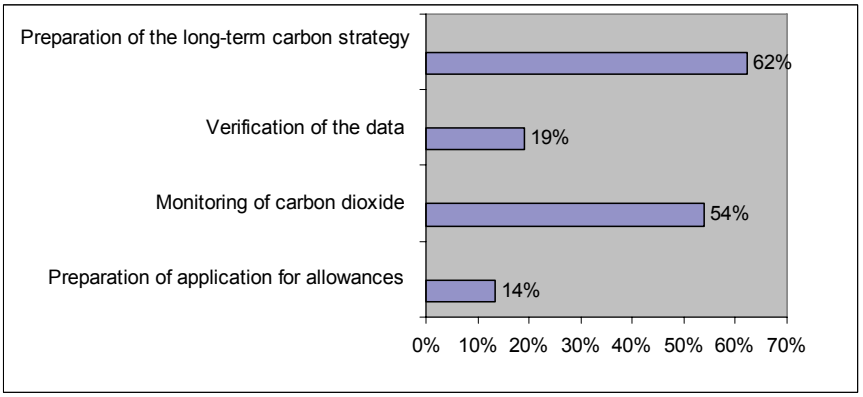

Fig. 6. Most difficult issues in emissions trading, per cent of respondents

Preparation of a long-term CO_2 reduction strategy (62%) and CO_2 monitoring (54%) were considered as the most complicated issues by the respondents. Preparation of the application and verification of the data were not considered as serious barriers.

The survey findings show that the companies have not estimated additional efforts and costs for compliance with the EU ETS directive. When asked the question 'what cost would be the highest', two-thirds of the respondents chose the answer 'difficult to say'. The most probable rationale behind the answers is lack of calculations of the transaction costs. Monitoring and reporting (35%) as well as finding buyers are considered as high cost activities.

Regarding involvement in the preparation of national climate change strategic documents, a number of the companies argued that they would like to take an active part in the preparation of the National Allocation Plan, or at least be informed in advance about the methodologies of the allocation. Workshops, e-mail lists and newsletters were considered as the most appropriate methods for distributing the information.

The research hypothesis has been confirmed. However, the preparation and, hence, potential of the Lithuanian companies to increase profits by participating in the EU ETS is weak because of the uncertainty in the global and national climate change policy, lack of knowledge about conditions and rules in the carbon market and lack of the companies' strategic position to engage in the EU ETS.

Most of the Lithuanian companies tended to select the position of minimum compliance, allowing them to be allocated to the category of "laggards", following R. Welford's (1994) classification. A cost optimisation approach could assist companies in moving towards a more active position and actual emissions trading.

It should be noted, however, that the research was undertaken in a very early stage of the EU ETS, when no definite legal and/or institutional framework had been established yet. These preconditions had influence on the respondents' answers and the results of the research. In order to analyse the dynamics of the companies' approach towards participation in the EU ETS, follow-up research should be carried out at the beginning of the second trading period.

4 Conclusions

The emissions trading scheme is a new market-based economic instrument for environment that aims at pollution reduction at the minimum possible cost. Research on the Lithuanian companies' preparation to engage in emissions trading has shown that there is potential for Lithuanian companies that are covered by the EU ETS to take an active part in the carbon market. However, at the beginning of 2005 when the EU ETS was launched, only a few Lithuanian companies were ready to use the advantages of the EU ETS.

Just a minor part of the Lithuanian companies foresaw emissions trading as a profit generation instrument. Positioning a company in the market, monitoring and reporting were among the most complex issues of the EU ETS implementation. The main rationale for participation in the EU ETS was implementation of environmental requirements and enhancement of industrial effectiveness. Therefore, more than half of the respondents chose a passive position, i.e. implementation of the environmental regulations. It is most likely that only large and advanced companies that have sufficient financial and human resources would take an active role in the emissions trading market. Most small and medium size Lithuanian enterprises would take a passive role. Consequently, following R. Welford's (1994) categorisation, the Lithuanian companies could be assigned to the category of "laggards".

A passive position taken by the majority of the researched companies could be explained by: lack of information on the EU ETS, lack of a definite national legal and institutional framework, and uncertainty regarding national and international climate change policy at the time the research was conducted (December 2004).

Although lack of information was identified as one of the obstacles for emissions trading, most of the managers of the companies were aware of the principles of emissions trading, which means that there exists potential for utilizing market opportunities in the future. This potential, as practice has shown, was realised later during the first trading period of the EU ETS.

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