Challenges of the Energiewende from a Policy Analysis Perspective:

Understanding the goals and improving the policy instruments of Germany's energy transition

vorgelegt von
Fabian Joas M.Sc.
geb. in Starnberg

von der Fakultät VI – Planen Bauen Umwelt
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Prof. Dr. Jan-Peter Voß (Vorsitz)
Prof. Dr. Ottmar Edenhofer
Prof. Dr. Prof. Dr. Markus Lederer

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Summary

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Germany is currently restructuring its energy system, an endeavor its chancellor, Angela Merkel, called the *project of the century*. This *Energiewende* has moved into rough waters in recent years. The relatively high and rapidly growing shares of fluctuating renewable energy sources (mainly wind and photovoltaic) have led to numerous technical and socio-economic challenges. The unclear and sometimes contradictory policy goals of the Energiewende as well as suboptimally designed policy instruments in key areas of the Energiewende are the two major areas of concerns of this dissertation.

The aim of this dissertation is to contribute to the solution of selected challenges of the Energiewende in the context of goals and policy instruments.

In this regard, the following four research questions are addressed:

1. What are the goals of the Energiewende and how do they interact with the design of policy instruments?
2. What are the impacts of the German nuclear phase-out on the electricity market and the security of supply?
3. How do different designs of support mechanisms for renewable energy affect the risk-distribution between society, investors in renewable energy and investors in conventional power plants?
4. What is the impact of ex-post transaction costs on the cost-effectiveness of selected climate policy instruments?

The main results and the subsequent policy conclusions of this thesis can be summarized as follows:

The research on the *goals of the Energiewende* was based on a survey among elite policy actors, which showed that climate protection is the most important goal of the Energiewende. However, climate protection is neither the only goal, nor an indispensable one. Additional goals such as the nuclear phase-out, import independence from fossil fuels and job creation also play an important role. A large majority agrees that the Energiewende would make sense even if climate change did not exist.

The following policy conclusions can be derived: first, there should be a clear, transparent and public debate on the goals of the Energiewende, i.e. a debate on what the Energiewende is actually bound to achieve. Second, economic policy analysis of the Energiewende should acknowledge the multiplicity of political goals and take them into account in their models.

Regarding the *phase-out of the German nuclear power plants* it is found that the precise date for the complete shut-down of Germany’s nuclear power plants has a relatively small effect on the wholesale electricity price and security of supply.

The following policy conclusion can be derived: the German nuclear phase-out will neither have a substantial effect on the wholesale electricity prices, nor on the security of supply.

Regarding the *design of RES-support schemes* it is found that the distribution of long-term electricity price risk between society and investors strongly depends on various set ups. A

design that exposes RES-investors to higher risks may result in more efficient investments. However, more risks for RES-investors means that small actors (e.g. cooperatives) have less opportunities to invest in the Energiewende, because they are less capable to hedge long-term price risks efficiently.

The following policy conclusion can be derived: the question whether investors in RES, investors in conventional power plants or society should carry the long term electricity price risk is a political (i.e. distributional) issue, which crucially depends on political goals such as actor diversity.

On the question of *transaction costs of climate policy instruments*: the ex-post transaction costs are relatively low for instruments such as emissions trading systems and affect the cost-effectiveness only slightly.

The following policy conclusion can be derived: Given the minor role of ex post transaction costs, they can be neglected as a source of significant distortions. However, this statement only refers to regions with strong institutions (such as the EU or the US). The focus in policy instrument design should be on properties that fundamentally influence cost effectiveness as well as equity and political economy considerations.

Zusammenfassung

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Deutschland befindet sich aktuell in einem umfassenden Umbau seiner Energieversorgung, den Bundeskanzlerin Angela Merkel als *Jahrhundertprojekt* bezeichnet hat. Diese *Energiewende* ist in den letzten Jahren in schweres Fahrwasser geraten. Die relativ hohen und schnell wachsenden Anteile fluktuierender erneuerbarer Energien (vor allem Wind und Photovoltaik) haben zu zahlreichen technischen und sozioökonomischen Herausforderungen geführt. Problematisch erscheinen vor allem die unklaren und teilweise widersprüchlichen Zielsetzungen der Energiewende. Zudem wurden die Politikinstrumente in wesentlichen Handlungsfeldern suboptimal konzipiert.

Das Ziel dieser Arbeit ist es, Lösungen für ausgewählte Probleme in diesem Zusammenhang zu finden. Dazu stellen sich folgende Fragen:

1. Was sind die Ziele der Energiewende, und welchen Einfluss haben diese auf die Ausgestaltung von Politikinstrumenten?
2. Wie werden sich die unterschiedlichen Abschaltzeitpunkte der deutschen Atomkraftwerke auf den Strommarkt und die Versorgungssicherheit auswirken?
3. Wie beeinflussen unterschiedliche Fördermechanismen für erneuerbare Energien die langfristige Risikoverteilung zwischen Gesellschaft, Investoren in erneuerbare Energien und Investoren in konventionelle Kraftwerke?
4. Welchen Einfluss haben ex-post Transaktionskosten auf die Effizienz von ausgewählten Klimapolitikinstrumenten?

Die zentralen Ergebnisse und die sich daraus ergebenden politikrelevanten Schlussfolgerungen dieser Doktorarbeit lassen sich wie folgt zusammenfassen:

Die Forschungsergebnisse zu den *Zielen der Energiewende* basieren auf einer Befragung politisch relevanter Akteure. Sie zeigen, dass Klimaschutz als das wichtigste, aber nicht als das einzige Ziel der Energiewende anzusehen ist. Auch der Atomausstieg, die Reduzierung der Importabhängigkeit von fossilen Rohstoffen und die Schaffung neuer Arbeitsplätze werden häufig als relevante Ziele genannt. Eine große Mehrheit der Befragten stimmt sogar der Aussage zu, dass die Energiewende selbst dann sinnvoll wäre, wenn es keinen Klimawandel gäbe.

Daraus ergeben sich folgende politikrelevante Schlussfolgerungen: Erstens sollte eine transparente und öffentliche Debatte über die Ziele der Energiewende geführt werden. Also eine Debatte, was genau mit der Energiewende eigentlich erreicht werden soll. Die Wissenschaft sollte zu dieser gesellschaftlichen Diskussion mit fundierten Informationen beitragen und Wirkungszusammenhänge verständlich erläutern. Zweitens sollten ökonomische Studien zur Energiewende transparent mit der Frage umgehen, auf welchen Zielsetzungen ihre Politikempfehlungen basieren.

Zur Frage der *Abschaltzeitpunkte der deutschen Atomkraftwerke*: Der Zeitpunkt des vollständigen Atomausstiegs in Deutschland hat nur einen relativ geringen Einfluss auf die Großhandelsstrompreise und die Versorgungssicherheit. Die Ergebnisse der Simulationsrechnungen haben deutlich gemacht, dass bestimmte Modellannahmen (wie Brennstoff- und CO_2-Preise) einen deutlich höheren Einfluss haben.

Politikrelevante Schlussfolgerung: Der deutsche Atomausstieg wird weder zu einem starken Anstieg des Großhandelsstrompreises noch zu maßgeblichen Problemen bei der Versorgungssicherheit führen.

Zur Frage der *Ausgestaltung von Fördermechanismen für erneuerbare Energien*: Die Wahl des Förderregimes für erneuerbare Energien hat einen starken Einfluss auf die Verteilung der langfristigen Strompreisrisiken zwischen Gesellschaft und Investoren. Förderinstrumente, die Investoren in erneuerbare Energien höheren Risiken aussetzen, können zu gesamtwirtschaftlich effizienteren Ergebnissen führen. Gleichzeitig sinken jedoch die Chancen für kleine Akteure (z.B. Bürgerenergiegenossenschaften), sich am Ausbau der Energiewende zu beteiligen. Denn kleine Akteure sind kaum in der Lage, langfristige Risiken effizient zu streuen.

Politikrelevante Schlussfolgerung: Die Wahl eines Förderinstruments für erneuerbare Energien ist eine vornehmlich politische Frage, da sie die Verteilung von Kosten und Risiken zwischen bestimmten gesellschaftlichen Gruppen regelt.

Zur Frage der *Transaktionskosten bei Klimapolitikinstrumenten*: Für Instrumente wie Emissionshandelssysteme sind die ex-post Transaktionskosten relativ gering und beeinflussen die Effizienz eines Instruments nur geringfügig.

Politikrelevante Schlussfolgerung: Für die Ausgestaltung von Instrumenten wie dem Emissionshandel spielen ex-post Transaktionskosten eine untergeordnete Rolle. Als Ursache von bedeutenden Marktverzerrungen können sie daher ausgeschlossen werden. Diese Aussage bezieht sich jedoch nur auf Regionen mit starken Institutionen. Der Fokus bei der Konzipierung von Klimapolitikinstrumenten sollte somit auf Faktoren liegen, welche einen stärkeren Einfluss auf die Effizienz eines Instruments haben.

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Dedicated to my grandfathers Günter Holtz, deceased in 2000 and Michael Joas, deceased in 1997.

Chapter 1

Introduction

Challenges of the Energiewende from a Policy Analysis Perspective

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I Introduction:

The Energiewende[1] has been described as the *project of the century* (Merkel, 2013) and Germany's *Man-to-the-Moon-Project* (Steinmeier, 2015). To achieve the G7 leaders' pledge to "decarbonise the global economy in the course of this century," and especially the UN's COP 21 Paris agreement to keep the increase in global average temperature "well below 2°C above pre-industrial levels", a global transformation of energy systems is necessary. With most models identifying the electricity sector as the first logical target of decarbonisation (IPCC WG III, 2014), the world is paying close attention to Germany, which has made significant steps in this area. However the rapid expansion of renewables in the electricity sector has been posing profound technological, economic, political and social challenges. These led Sigmar Gabriel, Vice Chancellor and Minister of the Economy and Energy, to liken the endeavour to *open heart surgery* (Gabriel, 2014). Transforming the energy production of a large industrialized country from a largely coal and nuclear-based system to a renewable energy sources (RES)-based system is a herculean task, which produces ample questions and contradictions to be tackled by researchers. This dissertation was motivated by these challenges and strives to contribute to the solution of practical policy problems by means of a thorough analysis of policy instruments as well as a definition of policy problems themselves.

While the Energiewende is often understood as mostly a technological revolution, from fossil and nuclear fuels to RES, it has a lasting impact on the economic and political features of Germany's energy landscape. The Energiewende has disrupted the domination of a few large companies in the energy system and is continuing to disaggregate the landscape into multiple smaller players who benefit from Germany's policy driven subsidies for RES. This development seems to be partially driven by a paradigm shift in the political sphere, where formerly radical *green policies* have become mainstream and are now adopted by Germany's centre left and centre right parties. Aspects of this substantial shift in the political economy of Germany's energy policy have been widely covered (see e.g.: Brunnengräber & Di Nucci, 2014; Gründinger, 2015; Jacobsson & Lauber, 2005, 2006; Lauber & Mez, 2004, 2006; Mez, 2003; Toke & Lauber, 2007; Weidner, 2008). This dissertation contributes to this stream of literature by analysing the goals and motives of this paradigm shift. It also goes a step further by analysing selected policy problems, using economic analysis.

Contributing to Policy Analysis

This dissertation is situated in the field of *policy analysis*. Policy analysis, according to Dunn (2012: 5), is a field of research at the cross-section of political science and economics that "is designed to provide policy-relevant information". Policy analysis is driven by a predefined set of questions. Each chapter of this dissertation can be attributed to one of these. The selection

[1] The term Energiewende is usually translated as energy transformation or energy transition.

of the topics depended on the policy issues that played a role (or were expected to play a role) in the political agenda at the time of writing.

Questions of policy analysis and questions of chapters of this dissertation are (Dunn, 2012: 5):

1. Problem Definition: *What is the problem to which a potential solution is sought?*
   Treated in Chapter 2: What are the goals (or problems) of the Energiewende?
2. Forecasting: *What are the expected outcomes?*
   Treated in Chapter 3: What are the expected outcomes of different nuclear phase-out dates?
3. Prescriptions: *Which policy should be chosen?*
   Treated in Chapter 4: Which policy for reform of the German Renewable Energies Act (EEG) should be chosen in order to reach certain political goals?
4. Evaluation and monitoring: *What ex-post policy outcomes are observed? To what extents do observed policy outcomes contribute to the solution of the problem?*
   Treated in Chapter 5: What are observed ex-post policy outcomes concerning transaction costs for different climate policy instruments?

Purpose of the Introduction

This introduction serves to embed and connect the chapters of this cumulative dissertation consisting of scientific papers that have previously been published elsewhere. Furthermore, this introduction is intended to provide the broader background and historical context of the Energiewende by briefly analysing and connecting selected historical events that have influenced it. For this purpose, the *multiple streams framework* developed by John Kingdon in the 1980's is applied. Kingdon's framework describes the incremental and non-linear agenda setting process[2] of policymaking and is applied in this introduction to explain how the Energiewende became such an important item on Germany's policy agenda. The introduction is structured as follows:

Section 1.1 defines the concept *Energiewende*. Section 1.2 gives insights on the background and the origin of the *multiple streams framework* and explains the decision to apply it in this introduction. Section 1.3 explains the concept of the *streams* and of the *policy window of opportunity* and illustrates the application of the *multiple streams framework* in a case study on the events following the nuclear incident in Fukushima. Section 1.4 links selected historic events of German energy policy to the three *streams* and, furthermore, relates the chapters of this dissertation to the different *streams*, also indicating the research questions of each chapter.

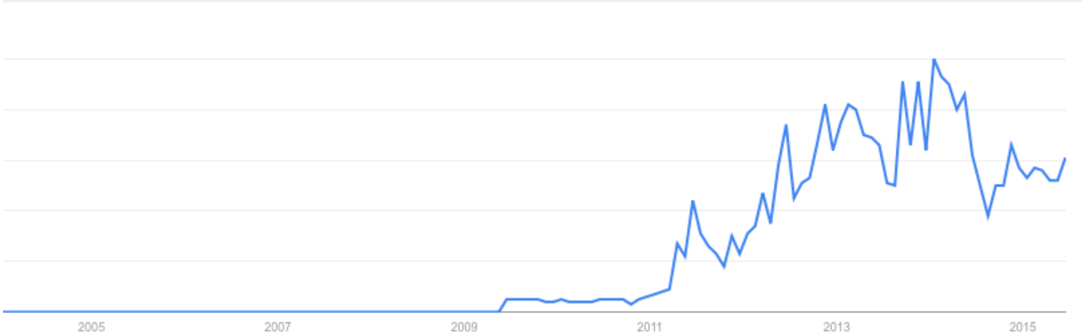
1.1 Definition of "Energiewende"

The term *Energiewende* was first introduced in 1980 by the German think tank *Institute for Applied Ecology* and described a transition from an energy system based on fossil fuels and nuclear energy to a system based on RES (Öko-Institut, 1980). Accordingly, the *Energiewende*

[2] The agenda is defined as "the list of subjects or problems to which governmental officials, and people outside of government closely associated with those officials, are paying some serious attention at any given time" (Kingdon, 2014: 3).

describes a broad and evolutionary (policy) process, which has existed as a concept for more than 30 years.

However, the term *Energiewende* only entered the political community and the public debate with some prominence in 2009. It gathered significant public recognition in the aftermath of the Fukushima-Daiichi nuclear incident of 2011. Graph 1 shows Google search hits for *Energiewende*, indicating that in the German public debate, the term only started to develop into a political brand as late as 2009 and became more prominent in 2011.[3] At this time a heated discussion regarding the lifetime extension of existing nuclear plants combined with a long-term strategy for Germany's energy policy occupied the political agenda. Within expert policy circles, however, the term *Energiewende* had already developed into a customary label.



Graph 1: Google search hits for the term Energiewende from 2005-2015 Source: Google Trends

In the course of the 2011 post-Fukushima debate on Germany's future energy policy, politicians and the media eagerly adopted the term to describe the stipulated renewed exit from nuclear power, whereas previously, it was more closely linked to the expansion of renewable energies (Öko-Institut, 1980). The rapid increase in searches in March of 2011 shows that the Fukushima incidents are closely and directly related to the term's evolution (see Graph 1).[4] At the same time, a collection of other, long on-going transformative processes within Germany's energy policy —including the move towards sustainable transportation, increasing energy efficiency, improving the insulation of buildings, reduction of greenhouse gas emissions and especially the expansion of RES —were subsumed in the public debate under the new trending term *Energiewende* (Bundesregierung, 2011).

This dissertation distinguishes between the long-evolving notion of the Energiewende, which has been ongoing for over 30 years, and the *Energiewende decisions of 2011.* These decisions set the course for the achievement of several policy goals, laying down quantitative objectives that were adopted in 2010 by the liberal-conservative coalition in the so-called *energy concept* (Bundesregierung, 2010) and the decision of 2011 to exit nuclear power by 2022 (see Table 1) (Bundesregierung, 2011).

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[3] Google Trends provides a time series index of the volume of queries users enter into Google in a given geographic area. The query index is based on query share: the total query volume for the search term in question within a particular geographic region divided by the total number of queries in that region during the time period being examined. The maximum query share in the time period specified is normalized to be 100 and the query share at the initial date being examined is normalized to be zero (Choi & Varian, 2012; Google Support, 2016).

[4] A mere accidental correlation without any causal relation is unlikely in this case, since alternative explanations for this sudden rise are not apparent.

Category	*Medium-term-objectives*	*Long-term-objectives*
GHG Emission	Reduction by 40% by 2020 (base year 1990).	Reduction of at least 80% by 2050 (base year 1990).
Renewables (all sectors)	By 2020 renewable energies are to account for 18% of gross final energy consumption.	Increase to 30% by 2030, 45% by 2040 and 60% by 2050.
Renewables (electricity)	By 2020 electricity generated from renewable energy sources is to account for 35% of gross electricity consumption.	Increase to 50% by 2030, 65% by 2040 and 80% by 2050.
Efficiency	Decrease primary energy consumption by 20% by 2020. Decrease electricity consumption by around 10% by 2020. (base year for both 2008)	Decrease primary energy consumption by 50% by 2050. Decrease electricity consumption by around 25% by 2050. (base year for both 2008)
Nuclear Power 2010 decision (pre Fukushima incident):	The operating lifetimes of the 17 nuclear power plants in Germany will be extended by an average of 12 years. In the case of nuclear power plants commissioned up to and including 1980 there will be an extension of 8 years. For plants commissioned after 1980 there will be an extension of 14 years.	Long-term nuclear phase-out is confirmed as there is only mentioning of a „limited extension“.
Nuclear Power 2011 decision (post Fukushima incident)[5]:	The role assigned to nuclear power in the energy concept was reassessed and the seven oldest nuclear power plants and the one at Krümmel were shut down permanently. Phase-out operation of the remaining nine nuclear power plants by 2022.	Phase-out by 2022.

Table 1: Quantitative objectives according to the energy concept and legislative package of the nuclear phase-out decision (BMUB, 2011)

The term *Energiewende* has also been embraced internationally and is now frequently used to describe Germany’s energy transformation (Steinmeier, 2015). One reading of this development suggests that Energiewende’s adoption as a loanword signals the unique characteristics of this peculiar policy endeavour. It remains to be seen, however, whether its connotation will be coined by a perceived irrational *German angst* over nuclear power or

[5] On 6 June 2011 the Federal Government adopted the energy package, which supplements the measures of the energy concept of 2010 and speeds up its implementation. The decisions on both the energy concept of 2010 (with the exception of the passage on nuclear power) and the transformation of the energy system of 2011 describe the Federal Government's current energy policy.

whether it will be associated with a new *leitmotiv* as Germany's transformation into a modern and sustainable industrial powerhouse. For the purpose of this dissertation, *Energiewende* (in the electricity sector) is defined more narrowly than in the public discourse, namely as Germany's long-term transition into the age of renewables with the intention to combat climate change.[6] In order to explain how the *Energiewende* grew into such an important item on Germany's policy agenda, I next apply John Kingdon's *multiple streams framework*.

1.2 The Multiple Streams Framework: Background, Origin and Application

The *multiple streams framework*, developed by John Kingdon in the 1980's is very helpful to illustrate how different historic events culminated into the bundle of policies that is today known as the Energiewende. While the *multiple streams framework* is one of the *theories of the policy process* (Sabatier, 1999) it mainly focuses on the agenda setting process. According to Kingdon, agenda setting is driven by three largely independent *policy streams* (described below). According to Blum & Schubert (2011), John Kingdon's work is regarded as the most renowned and influential in the field and has inspired a significant body of literature (e.g. Birkland, 1998; Howlett, 1998; Liu, Lindquist, Vedlitz, & Vincent, 2010; Pollack, 1997; Scheberle, 1994). In his main work, Kingdon (2014: 2) "[aims] to understand why important people pay attention to one subject rather than another, how their agendas change from one time to another, and how they narrow their choices from a large set of alternatives to a very few."

Origins of the Multiple Streams Framework

Kingdon builds on the work of Lindblom's model of incremental policy making, i.e. the method of progressing in many small steps instead of large jumps, thereby recognizing the cognitive limitations of policy makers (Lindblom, 1959). However, in empirically analysing the agenda setting process, Kingdon raises issues with Lindblom's argument that policy making is incremental, and concludes that it is only true in some foreseeable and regular policy making processes such as the budgetary process. Instead, Kingdon finds that the agenda setting process can be quite non-linear and discontinuous. To account for these jumps in attention, Kingdon develops a revised version of the Cohen-March-Olsen *Garbage Can model* of organizational choice in order to explain agenda setting and the creation and selection of policy alternatives (Cohen, March, & Olsen, 1972). The Garbage Can model explains the political process as an *organized anarchy* with problematic preferences and "a loose collection of ideas [rather than] a coherent structure". It "is a collection of choices looking for problems, issues and feelings looking for decision situations in which they might be aired, solutions looking for issues to which they might be the answer, and decision makers looking for work" (Cohen et al., 1972).

[6] The definition of the term *Energiewende* can however be only preliminary. Chapter 2 discusses the issue that the *Energiewende* is linked to various goals. A solid definition can only be stated after a debate in society has taken place what the *Energiewende* is actually bound to achieve.

Critique of the Comprehensive Rational Model of Policy-Making

Kingdon also follows Lindblom in his criticism of the comprehensive rational model of policy-making (Lindblom, 1959). Weimann (2006: 10), for instance, takes a normative approach, demanding that politicians set clear goals and implement means to achieve them because "without clarity over goals no rational policy decisions are possible".

Kingdon criticizes such demands, arguing that this model presupposes intellectual capacities and sources of information that policy makers do not possess. Rational policymaking would require policy makers who "first define their goals rather clearly and set the levels of achievement of those goals that would satisfy them. Then they would canvass many (ideally, all) alternatives that might achieve these goals. They would compare the alternatives systematically, assessing their costs and benefits, and then they would choose the alternatives that would achieve their goals at the least cost" (Kingdon, 2014: 78). Because Kingdon believes that this model is unrealistic, he uses a framework that is descriptive rather than normative, describing how things are, not how they ought to be.

The role of political goals in the policy process will be treated in more detail in Chapter 2. Chapter 2, on the one hand, follows the normative claim that for the sake of effective and efficient policies, a public debate and a clear specification of the top-level goals are indispensable. On the other hand, it shows that goals are often not used as ends to be achieved, but rather instrumentally, i.e. understanding them as means to induce consensus among different societal groups.

Focus on Agenda Setting

The *multiple stream framework* can be used to examine how the topics related to the Energiewende made it to the top of the agenda. The *multiple streams framework* explicitly does not specify which actors are involved and how decisions are made but instead tries to explain how a topic comes to the decision stage. It does not aim to describe the entire *policy cycle*[7] (Jann & Wegrich, 2009).

1.3 Policy Streams and Application

Explaining the Streams and Policy Window of Opportunity

Kingdon conceives of three *process streams* flowing through the political system: *streams of problems, policies, and politics*. They are generally independent from one another, and each *stream* behaves according to its own dynamics and rules. However, at critical moments they link together, and the changes with the most impact on policy emerge from the simultaneous convergence of problems, policy proposals, and politics (Kingdon, 2014: 19; Sabatier, 1999). The three *streams* are described below, supplemented with a case example, namely the political events in Germany following the nuclear incident in Fukushima.

[7] According to Jann and Wegrich (2009) the stages of the policy cycle are: *agenda setting, policy formulation and decision making, evaluation and termination*. These stages also correspond with the central questions of policy analysis as introduced by Dunn (2012) and mentioned above.

The *problem stream* describes the process of problem recognition in a society. Various topics are struggling in this *stream* for policymakers' attention. Depending on various factors, one problem may receive more attention than the other. The Energiewende can be understood as the answer to a set of policy problems, which decision makers deemed sufficiently important and pressing to be considered for the political agenda. The Energiewende's history is closely connected to a specific set of problems, with risks of nuclear power and climate change being the most notable.

The *political stream* consists of political events such as public mood, pressure group campaigns, election results and changes of administration (Kingdon, 2014: 145). The election of the Red-Green coalition in 1998, and the strong bipartisan opposition to nuclear power after the Fukushima incident in 2011, are examples of changes in the political *stream*.

Kingdon considers the *policy stream* as a *policy primeval soup,* where policy ideas, much like small organisms in the beginning of evolution, compete for survival (Dawkins, 2006). It is where specific policy alternatives are formed, discussed, taken apart and recombined. The *policy stream* is a space inhabited by experts including bureaucrats, interest group representatives, parliamentarian staff, specialist journalists, consultants and above all academics, who work within a rather intimate policy community. This is an area where ideas matter more than political pressure and where a fair evaluation of policy proposals is possible (Kingdon, 2014: 116).

The separate *streams* can merge at critical times, creating a *policy window of opportunity*. Such situations occur, when a problem is recognised, a solution is available, a political impulse is felt and potential constraints are negligible (Kingdon, 2014: 165). In such constellations, a topic becomes *hot* or the political constellation is such that an issue moves up the agenda. The chance that a decision regarding this topic will be made increases significantly as policymakers collectively shift their attention towards this issue.

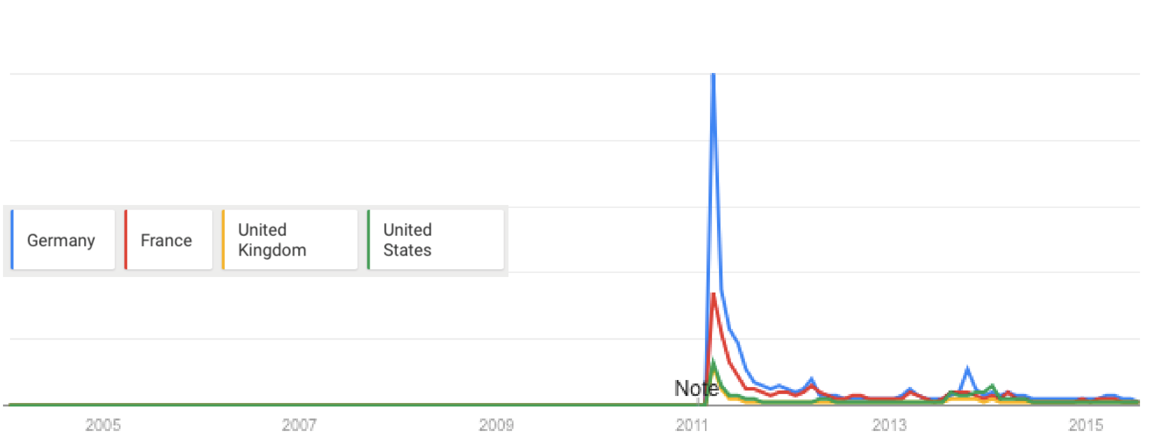
1.3.1 Multiple Streams Application to the Events of Fukushima and the Nuclear Phase-Out

It may seem at first difficult to rationalize that an earthquake on March 11, 2011 off the coast of Japan triggered not only a catastrophic wave and a nuclear incident in the Fukushima-Daiichi nuclear plant, but also caused a tsunami that swept the political landscape in Germany, 9.000 kilometres away. These events opened a political *window of opportunity* in Germany, which ultimately led to the nuclear phase-out of 2011. This window of opportunity was the result of a problem being recognized, a solution lying at hand and a political class that was ready to act.

The events in each *stream* that enabled the policy change shall be briefly described: *Problem Stream:* The German media coverage of the events was unparalleled in any country outside of Japan. Graph 2 shows the Google search hits of the term *Fukushima* in Germany in comparison to France, the UK and the US, all countries that use nuclear power and were geographically comparably far away from the events.[8] One would think they would have had

[8] Google Trends provides a time series index of the volume of queries users enter into Google in a given geographic area. The query index is based on query share: the total query volume for the search term in question within a particular geographic region divided by the total number of queries in that region during the time period being examined. The maximum query share in the time period specified is normalized to be 100 and the query share at the initial date being examined is normalized to be zero (Choi & Varian, 2012; Google Support, 2016).

equally large reasons to be worried. However, the analysis shows that the subject received unmatched attention in Germany, indicating the extraordinary importance of the nuclear power issue in the German consciousness. In April of 2011 a poll reported that 86% of Germans would support a nuclear phase-out by 2020 (Gründinger, 2015). Advocates of nuclear power had practically disappeared and were no longer heard in the public debate.



Graph 2: Google search hits for the term Fukushima from 2004-2015

Policy stream: This *stream* provides implementable solutions for a problem. This was an easy task in this case since an action plan to phase-out nuclear power in Germany already existed. The 2002 exit plan and the *energy concept* of 2010 had predefined a policy path for a nuclear phase-out, which only needed to be adjusted for earlier shut down dates. Furthermore, a phase-out agreement for the nuclear phase-out of 2000[9] had already been negotiated and merely needed to be revived. Given the overcapacity of conventional energy, the increasing interconnectedness to its EU-neighbours and the rise in RES, Germany was ready to immediately shut down seven nuclear plants without noticeable dangers to the security of supply. Studies (see Chapter 3) also showed that foreseeable effects to prices and CO_2 emissions seemed manageable depending on the workings of the EU ETS as well as the German Renewable Energy Act (EEG). Therefore, Germany's *policy stream* enabled decision makers to enact a quick phase-out.[10]

Political stream: The intensive debate over nuclear power following the Fukushima-incident led to an unseen rise in the polls for the Green party, a group that had always strongly opposed nuclear power. The pending regional elections in March 2011 in the highly important state of Baden-Wurttemberg, where the Green party had become a serious challenger to the Christian-Democrats (CDU), put immense pressure on Angela Merkel's pro-nuclear stance.[11] It is fair to speculate that adverse polling data influenced the federal CDU-led government to announce a *moratorium on nuclear energy*, which meant that eight out of 17 nuclear power plants were taken off the grid three days after the incident in Japan. Despite this quick reaction, the Green party managed to win the state elections in Baden-Wurttemberg, posting their first Minister

[9] This nuclear phase-out plan was taken back and changed into a lifetime extension in 2010.

[10] Substantial legal questions regarding potential compensation payments to nuclear providers were, however, unsolved.

[11] According to the polling institute *Forschungsgruppe Wahlen*, in March of 2011 only 10 % of the total electorate of Baden-Wurttemberg and a mere 20% of CDU followers supported the CDU's 2010 decision to extend the lifetimes of nuclear plants. The Greens were identified as the party with competence for nuclear policy (53%), in contrast to the CDU (18%) (Gründinger, 2015).

President in history. However, national polls continued to show the Green party at historic heights.[12] With the obvious significance of energy policy influencing these results, there was immense pressure for the federal conservative-liberal coalition to act in order to regain the public's trust regarding energy issues. The immense public opposition to nuclear power and the bad election result in the state election in Baden-Wurttemberg for the governing coalition had created opportunity in the *political stream*. With the announcement of the *moratorium on nuclear energy*, a political *window of opportunity* had opened. The fear of nuclear power dominated the *problem stream*, solutions from the previous nuclear phase-out plan were available in the *policy stream* and the *political stream* provided the necessary political pressure to act.

After the expiration of the three months *moratorium on nuclear energy* in June 2011, the government passed a rapidly constructed policy package on a new nuclear phase-out, renewable energies, grid expansion, and energy efficiency (Bundesregierung, 2011). This legislative package of 2011 was passed in parliament with a cross-party consensus and is understood by many to mark the launching point of Germany's Energiewende (e.g. BWE, 2015).

1.4 Description of Streams and Linking to Chapters

The following section links selected historic events in Germany's energy policy to the *streams*, and associates the chapters of this dissertation to the *problem stream* and the *policy stream* and thereby gives a short summary of the research questions of each chapter.

1.4.1 Problem Stream

The Energiewende can be understood as the answer to a set of policy problems which decision makers deemed sufficiently important and pressing to be considered for the political agenda. The Energiewende's history is closely connected to a set of problems, which attained significant attention in the *problem stream*. The following paragraphs illustrate typical examples of historic issues that were perceived as problems relating to energy policy:

- The German nuclear programme of the 1960s and 1970s and its perceived danger for the population.
- Environmental damages such as the increase of acid rain due to emissions from coal-fired power plants and transport emissions, leading to forest dieback.
- The perceived dominance and power of Germany's (formerly state-owned) energy utilities, which were perceived as impervious to citizen demands.
- Advancing climate change and the lack of abatement measures.

These problems are not fully independent from one another. However, historically they appeared at different times. While acid rain was a problem of the 1980s that has widely disappeared from people's minds today (Der Spiegel, 1981; Spelsberg, 1990), climate change only emerged as a major problem in the early 1990s. The United Nations Conference on

[12] In April 2011, the Forsa (Forsa, 2015) institute reported the Green Party polling at an all -time high of 28 %, the SPD at 23 %, the CDU at 30 %, and the FDP at a dismal 3 %, giving a potential Green-SPD coalition a 20 % lead over the incumbent CDU-FDP government.

Environment and Development (UNCED) in 1992, also known as the Rio Earth Summit, and the Intergovernmental Panel on Climate Change's (IPCC) assessment reports AR1 in 1990 and AR2 in 1995, are events that brought the issue into Germany's public debate.

Nuclear power, on the other hand, became a perennial issue starting in the early 1970s when massive protests rose against nuclear power (Roth, 2010). With the nuclear meltdown in Chernobyl in 1986 and the Fukushima incident in 2011, the risk of nuclear power has been a permanent issue in Germany's energy policy debate.

The perceived problem of dominant energy providers is closely connected to nuclear energy, since the four large conventional power producers, formerly state oligopolies,[13] also operate Germany's nuclear plants. The concentration of power was deemed a problem from both market and political perspectives. From a market perspective, oligopoly power was seen to inhibit ideal competitive market outcomes (Brunekreeft & Keller, 2000) and the companies' political power was seen to inhibit Germany's transformation towards alternative forms of energy production (Jungk, 1977). The Energiewende, therefore, seems to be historically connected to several different problems. Chapter 2 of this dissertation analyses the problems (or goals) that motivate the Energiewende today.

Chapter 2 – Which Goals are Driving the Energiewende? Making Sense of the German Energy Transformation

Chapter 2 researches the seemingly straightforward question regarding the political goals of Germany's Energiewende. Rather surprisingly, the particular goals that drive and justify this *project of the century* (Merkel, 2013) have been left largely undefined by the government, leaving observers from both Germany and abroad to puzzle over what the Energiewende is actually bound to achieve. This fact concerns economists who state that without clarity over goals, no rational policy decisions are possible (Weimann, 2006: 10). Government should set out a clear, overarching vision and top-level goals – something that, according to (Hepburn, 2010), can be reasonably expected from it, and not doing so can be termed a *government failure* in the terms of economists. The lack of clearly defined goals seems to motivate others (often scientists) to fill this vacuum and formulate goals themselves. However, it should not be the objective of science to formulate goals, as the deliberative process of balancing diverging goals and finding compromise between them is the inherent field of politics and not science (Edenhofer, 2011). However, in the past years numerous studies gave recommendations on policy design for the Energiewende, largely disregarding this principle (Diekmann, Kemfert, Neuhoff, Schill, & Traber, 2012; Feld et al., 2014; Haucap, 2013; Lehmann & Gawel, 2013; Monopolkommission, 2013; Sachverständigenrat für Umweltfragen (SRU), 2013; Sachverständigenrat zur Begutachtung der gesamtwirtschaftlichen Entwicklung (SVR), 2013; Weber & Hey, 2012). These studies either omitted a discussion of goals and went straight to policy recommendations, or they put forth certain goals without properly discussing their origin. It appears that many studies made policy recommendations based on the normative values of their authors or of the institutions that commissioned the study. These studies, mostly

[13] The *big four* German utilities are: E.ON, RWE (Rhine-Westfalia Power Plant), EnBW (Energie Baden-Württemberg AG) and Vattenfall.

written by renowned experts, often produced diametrically opposing policy recommendations and played a prominent role in the public debate causing confusion among leading political actors. The lively political discussion over means (i.e. policy instruments) such as carbon pricing vs. renewable support schemes often seems to be a proxy debate over differing ends (i.e. policy goals). Against this background this study attempts to move the debate from a discussion over policy instruments to a discussion of the goals of the Energiewende.

In particular the chapter aims to answer the following questions:

- What are the goals that are commonly used to justify the Energiewende in the public discourse?
- How do German elite policy actors rank these goals? Do they leave goals out or add others?
- Are there goals that are often ranked higher than other goals?
- Is there a justification for intentionally leaving political goals vague?

1.4.2 Political Stream

Political events in Germany strongly influenced the decisions on energy policy in Germany. The *political stream* may be the key to understanding why the Energiewende is taking place in Germany and not in other large industrialized countries with similar problems. The issues described in the *problem stream* can be found in other major industrialized nations; however, the *political stream* is where the differences may be found that may explain why the environmental pillar of energy policy issues is so prominent in Germany compared to other countries. While analysing this *stream* in detail is not part of this dissertation, this issue would, however, be subject to further interesting research. Selected events that significantly impacted Germany's energy policy in the *political stream* shall be briefly described.

Anti-Nuclear Sentiment:

As described above, anti-nuclear sentiment originated in the US (Radkau, 2011), and entered the political discussion in Germany in the 1970s. The movement celebrated its first success in 1975, when activists prevented a nuclear power plant already under construction in Whyl in the state of Baden-Wurttemberg from being finished (Jungk, 1977). Also, the 1976 protests and the attempts to stop the construction of the nuclear power plant in Brokdorf (in northern Germany) can be understood as a success that increased support for the movement. The (partial) nuclear meltdowns in Three Mile Island, USA (1979), Chernobyl, Ukraine (1986), and Fukushima, Japan (2011) further increased the importance of the movement in Germany.

The movement was also fuelled by the protests against the nuclear rearmament (based on the NATO-Twin Track decision of 1979). Although the topics of nuclear power for electricity production and strategic nuclear weapons are somewhat distinct, the two movements reinforced each other (Radkau, 2011). Many of the groups that had been organizing the anti-nuclear and the anti-rearmament protests merged in 1980 and formed the Green party. Despite its heterogeneous make-up, the party had a clear stand on nuclear power and nuclear weapons. In this anti-nuclear melting pot, the two subjects intermingled, as some protagonists such as Petra Kelly and Gert Bastian fought prominently for both goals (Der Spiegel, 1992). It is fair to assume that the combination of these subjects was not accidental. It rather seems that the topics were intentionally linked in the political debate so that the fear associated with nuclear weapons would also be associated with the peaceful use of nuclear power for electricity production (Radkau, 2011). This anti-nuclear movement represented by the Green party first made its way into the federal parliament in 1983. It continuously campaigned for an exit from nuclear power and gave the anti-nuclear movement a loud voice in the German parliament. The public mood against nuclear power was so strong that in 1998 the Greens and the Social Democrats (SPD), who withdrew their support for nuclear power in the late 1980s, campaigned with a promise to phase-out nuclear power and won the federal election. Today about 80% of the population in Germany, and all parties represented in the current parliament (2013–2017), advocate for the nuclear phase-out (Emnid, 2015).

Growing Strength of the RES-Lobby

An often-underestimated political force supporting the Energiewende has been the ever-growing influence of the RES lobby. The RES industry had for a long time been well connected with environmental NGOs and had its allies (mainly) in the Federal Ministry for the Environment. Strongly increasing revenues in the RES industry, and, therefore, more funds for governmental relations, led to a professionalization of the lobby (Gründinger, 2015). Furthermore, several companies, often in structurally weak regions, had grown large enough to make meaningful economic arguments as providers of jobs. Therefore, the pro-renewables coalition could count powerful organizations such as the IG Metal (metal workers union) and the VDMA (engineering association) as their allies. The renewables lobby also benefited from historic animosity against the large utilities, and a public mood that favoured the idea of autonomous, self-reliant, energy production. This fight between the powerful German utilities and the dispersed supporters of decentralized renewables with their solar cells and their small windmills had the ingredients of an epic struggle. The narrative of *arrogant* large utilities on the one side and of renewable *pioneers* on the other side steadily increased the public and political support for these perceived underdogs. This power shift in favour of renewable interests changed the political landscape as politicians favouring renewable energy now also had a powerful industry lobby behind them, meaning that not only environmental but also industrially oriented policymakers could support renewable energy (Gründinger, 2015).

1.4.3 Policy Stream

The *policy stream* is where experts such as public servants, consultants and academics form and adapt policy proposals. This *stream* is relevant for agenda setting insofar as an issue may fall off the political agenda if no plausible policy solution is available.

The constant academic and political debate over policy instruments has yielded a broad fundus of policy ideas that are more or less fitting solutions for the problems in question. The applicability of the various proposals are furthermore a function of external factors such as technological change, fossil fuels prices and a changing regulatory framework. For instance, the cost reductions of technologies such as RES or fracking, the ban on technologies such as subcritical coal plants and nuclear plants, as well as political changes such as the continuing integration of European energy markets strongly influence the course of the *policy stream*. In this context the evolution of some influential Energiewende-policies shall be briefly illustrated.

The Renewable Energy Act (EEG)

The ideas and proposals underlying Germany's Electricity Feed-in Act (Stromeinspeisungsgesetz) of 1991, the predecessor of the EEG, were created in an evolutionary and incremental process. In the 1980s, the so-called association agreements (Verbändevereinbarungen) set tariffs for hydropower plants. Due to several conflicts between the power companies and the owners of RES-plants, payments were legally formalized in the Stromeinspeisungsgesetz in 1991 (Lauber & Mez, 2004). Payments to RES plants depended on the average proceeds of the regional energy operators (regulated monopolies), who were responsible for the payments to RES within their region. The EEG (2000) changed this system and guaranteed renewable installations fixed tariffs for 20 years as well as unlimited priority feed–in and access to the grid. The costs of these tariffs, far above market prices, were now allocated to the transmission system operators and distributed nationally in the form of a surcharge on electricity rates (Leuschner, 2010). The fixed, cost-covering tariffs with a feed-in guarantee were designed to give security to a wide range of RES investors, who could now experiment with the technologies and lead them to market maturity (Bensmann, 2010). The significance and complexity of the *policy stream* surrounding the EEG has grown along with the law: while the EEG of 2000 was a relatively straightforward law developed by parliamentarians, consisting of 12 articles on 6 pages, the EEG of 2016 has grown into a highly complex piece of legislation running to 79 articles on over 400 pages and occupying several ministry units and an armada of lobbyists. In 2016, € 24.8 billion annually were transferred through the EEG surcharge (TSOs, 2015).

The EU Emission Trading Scheme

Another example of a policy that has developed from an idea in the *policy soup* is emissions trading. The thoughts underlying the European Emissions Trading Scheme (EU ETS) can be traced back to John H. Dales (1968) who based his *cap and trade* ideas on the *Coase Theorem* famously developed by Ronald Coase in *The Problem of Social Cost* (Coase, 1960). The idea was first implemented in the US *Lead Phasedown Program* of 1974 (Newell & Rogers, 2003). The use of this instrument for the reduction of GHG emissions gathered traction in the course of the negotiations regarding the Kyoto protocol (1997). The EU ETS was therefore based on a substantial body of academic literature as well as first trials with emissions trading schemes in the US. The development of the EU ETS, with its complex exemptions and free allocation mechanisms, was aided by a range of consultants and academic institutes.

Germany as Policy Front-Runner

Due to the novelty of the endeavour to transform an energy system to RES, the expert community often finds itself in the position of having to innovate new policy solutions and answer partially unforeseen questions. Consequently, the Energiewende's *policy stream* is a rich fishing ground for other countries looking for proposals, which can be adapted for their own needs. Research in policy diffusion shows that this is in fact happening (Steinbacher, 2015) and that many countries around the world have adopted guaranteed feed-in tariffs that are very similar to the ideas of the EEG (Jacobs, 2012). The Energiewende can therefore be considered as a front-runner for driving not only technological, but also regulatory innovation in the globally transforming energy sector. Germany has made it a part of its foreign policy initiatives to help facilitate the uptake of sustainable energy policies abroad (Steinbacher & Pahle, 2015).

Chapters 3 through 5 of this dissertation add to the analyses of three policies within the Energiewende's *policy stream*: the nuclear phase-out, the reform of the Renewable Energy Act (EEG) and the issue of transaction costs for climate policy instruments with a focus on the EU ETS. The role of policy relevant research in the context of agenda setting has been described in general terms above. The (possible) contribution of each Chapters 3 - 5 to the German agenda setting process in the *policy stream* of the years 2011-2016 will not be undertaken since this would be outside the scope of this introduction. Here, merely the central ideas and the research questions of Chapter 3 to 5 shall be briefly described.

Chapter 3 – Germany's Nuclear Phase-out: Sensitivities and Impacts on Electricity Prices and CO_2 Emissions

The chapter is based on a study that was commissioned by the Friedrich-Ebert-Stiftung (Knopf et al., 2011). It contributed to the debate on a possible German nuclear phase-out after the reactor accident in Fukushima in 2011. The study was aimed at policy makers who faced decisions under high uncertainty.

The chapter aims to answer the following questions:

- What options are available for replacing nuclear energy and how are they to be evaluated economically and environmentally?
- How would CO_2 emissions and the electricity prices (on the wholesale market and for end consumers) develop for different nuclear phase-out scenarios and with different replacement options?
- How is security of supply affected?
- How do the results change when individual model assumptions are varied?
- How do the results compare to other studies with similar research questions?

Chapter 4 – RES Support Schemes and Associated Risks: an Economic Analysis of the Debate of the EEG Reform in Germany

In summer 2014 the German government implemented a reform to the EEG. The two major changes consisted of (i) making direct marketing of RES power compulsory and (ii) the implementation of an auction scheme. After a decade of largely shielding RES investors from economic risks, one motivation of this reform was to carefully rebalance the risk distribution between RES investors, investors of conventional power plants and electricity consumers (i.e. society at large). The hope behind this reform was that it would lead to more efficient investments (i.e. lower support costs), better capacity control, better system integration and finally to achieve the Energiewende objectives with lower overall societal cost. This chapter was written prior to the decision in the parliament, and aimed to analyze the various reform options concerning their risk distribution using economic analysis. Despite the fact that the risk distribution is the major distinguishing feature between the different proposals, it was treated superficially in most other studies that covered this issue.

The chapter aims to answer the following questions:

- What is the purpose of *risk* in the electricity sector and how does it relate to *uncertainty*?
- What particular risks are involved in the promotion of RES?
- How do different support schemes influence risk, and how does this influence the risk distribution between RES-investors and the society?
- Can increased risk for RES-investors increase the system friendliness of RES installments and thus their overall efficiency?
- How does the question of risk distribution relate to the achievement of political goals such as actor diversity?

Chapter 5 –The (Ir)relevance of Transaction Costs in Climate Policy Instrument Choice: an Analysis of the EU and the US

This chapter is concerned with transaction costs of various GHG abatement policies focusing on the EU and the US. Many experts in the scientific community see carbon pricing as the policy tool, which should drive the transition into a low-carbon economy not only in Germany but also around Europe and, eventually, on a global level (Edenhofer, 2015; EEEP Symposium, 2015). Although a seemingly minor aspect, transaction costs may become an important issue in the future when more countries start setting up climate policy instruments and focussing on implementing them at the lowest possible costs. This chapter adds to this research by comparing the transaction costs of various climate policy instruments, such as emission trading versus an emission tax.

The chapter aims to answer the following questions:

- Do transaction costs play an important role for climate policy instrument design?
- How do different climate policy instruments compare with respect to their transaction costs and how does this influence cost-effectiveness?
- How can transaction costs considerations be incorporated in climate policy instrument design?
- How do different cost components (e.g. monitoring costs) scale with certain variables such as the number of regulated entities or the level of abatement?

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Chapter 2

Which goals are driving the Energiewende? Making sense of the German Energy Transformation*

Fabian Joas
Michael Pahle
Christian Flachsland
Amani Joas

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Which goals are driving the Energiewende? Making sense of the German Energy Transformation

Fabian Joas[a,b,*], Michael Pahle[a], Christian Flachsland[b,c], Amani Joas[d]

[a] Potsdam Institute for Climate Impact Research (PIK), Telegraphenberg A 31, 14473 Potsdam, Germany
[b] Mercator Research Institute on Global Commons and Climate Change (MCC), Torgauer Straße, 12-15, 10829 Berlin, Germany
[c] Hertie School of Governance, Friedrichstraße 180, 10117 Berlin, Germany
[d] Next Kraftwerke GmbH, Lichtstraße 43 g, 50825 Köln, Germany

H I G H L I G H T S

- We examine the goals of German energy policy called the "Energiewende".
- We show that policy experts relate up to 14 goals with the Energiewende.
- So far the political goals of the Energiewende, and especially their ranking is unclear.
- We call for a public debate and a clear specification of the top-level goals of the Energiewende.

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A B S T R A C T

In 2010, Germany agreed a plan to increase the share of renewables in power consumption to 80% by 2050, and in 2011 the decision was taken to phase-out nuclear power by 2022. This policy is now widely known as the "Energiewende". While many global observers consider this program to be primarily driven by the need to tackle climate change, the precise political goals of the Energiewende are, by and large, unclear. In our study we compiled a list of 14 goals put forward in political debates and conducted a "mapping" survey among more than 50 policy experts. We asked them to prioritize the goals based on their personal views and provide arguments for their rankings in ensuing interviews. Our main findings are as follows: (i) a large majority named climate protection among the top-level goals of the Energiewende; at the same time, around 80% of all participants also identified additional goals; (ii) when asked if the Energiewende would make sense even if climate change did not exist, two thirds of the participants agreed, which, when taken with the first finding, demonstrates that the goals and motivations driving the Energiewende are more complex than often assumed. We conclude that for the sake of effective and efficient policies and ever rising climate policy ambition, a public debate and clear specification of the top-level goals are indispensable.

1. Introduction

In 2010 the German Federal Cabinet approved a policy package that included a long-term objective to achieve an 80% share of annual renewable power consumption by 2050,[1] and in 2011 the phase-out of nuclear power by 2022 was decreed. This has become known as the "Energiewende"[2] and sparked many comments around the globe ranging from acclaim to scepticism. At first glance the intention behind it seemed apparent. The New York Times for example commented that "[o]f all the developed nations, few have pushed harder than Germany to find a solution to global

* Corresponding author.
E-mail addresses: Fabian.joas@gmail.com (F. Joas), michael.pahle@pik-potsdam.de (M. Pahle), flachsland@mcc-berlin.net (C. Flachsland), amani.joas@gmail.com (A. Joas).

[1] This legislative package furthermore included greenhouse gas reductions of 80–95%, decrease of primary energy consumption by 50%, both by 2050, and increased R&D in new technologies.

[2] The term "Energiewende" entered the German public debate around 2009. In the course of the 2011 post Fukushima debate on Germany's future energy policy, politicians and the media eagerly adopted the term to describe the renewed exit from nuclear power. However in expert circles the term has been known since the 1980s when the Öko-Institut, a think tank, published a study titled "Energiewende - Growth and Prosperity without Oil and Uranium" (Öko-Institut, 1980). The policies that are today considered as the "Energiewende" can also be traced back to at least the 1990s.

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warming" (Gillis, 2014). In fact the particular goals that drive and justify this "project of the century" (Merkel, 2013) have been left largely unclear by the German federal Government – leaving interested observers from both Germany and other countries puzzled over what the Energiewende is actually meant to achieve.

Current discussions in German research and politics surrounding the Energiewende reveal divergent viewpoints about relevant goals and their prioritization. One extreme view held by some economists is that climate change mitigation is the only legitimate goal of the Energiewende (Sinn, 2013; Weimann, 2013). In the same vein the expert commission that monitors the Energiewende states that the reduction of GHG emissions and the nuclear phase-out are the two major goals (Löschel et al., 2014). In contrast, other researchers argue that additional goals such as reduced import independence from fossil fuels, technology development, job creation, industrial policy and the reduction of air pollution are equally important (Lehmann and Gawel, 2013). Not surprisingly, divergent views also prevail among politicians. The Federal Minister of Economy and Energy, Sigmar Gabriel, has declared the following five goals for the Energiewende: (i) nuclear phase-out, (ii) the reduction of dependence on imported oil and gas, (iii) the development of new technologies, growth and new jobs, (iv) climate change mitigation, and (v) motivation of others to imitate the Energiewende (Gabriel, 2014). Hans-Josef Fell, co-author of the German Renewable Energy Act (EEG) and former member of the Bundestag for the Green Party, adds the following goals to the list: environmental protection, health, homeland security, landscape protection and the protection of human rights (Fell, 2014).

In addition, legal documents are ambiguous in their description of the goals of the Energiewende. The Renewable Energy Act (EEG, 2014),[3] which is the central policy driving renewable deployment in the power sector, states that the following goals should be achieved through this law: (i) climate and environmental protection, (ii) sustainable development of energy supply, (iii) reduction of the economic cost of energy and internalization of long-term external effects, (iv) conservation of fossil energy resources, and (v) development of technologies for the production of electricity from renewable energy sources (RES). The latest government report on the progress of the Energiewende (Bundesregierung, 2015) states the following goals and framework conditions: security of supply, nuclear phase-out, competitiveness, power grid expansion, research and innovation, investment and jobs.

At first glance, there is overlap in stated goals and many of those mentioned seem complementary. However, there are significant trade-offs. For example, considering climate protection as the only goal nuclear power is a viable option for some. Most others however consider nuclear phase-out as a major Energiewende-goal. Therefore, adding, scratching and re-weighting specific goals within an overall system of goals can fundamentally affect policy choice, justifying a discussion aimed at clarification in this regard.

Is this apparent lack of clarity over the goals driving the Energiewende problematic? The answer is positive in a rational policy design perspective, where policy instruments, programs, and strategies are needed to achieve a clear and specific set of policy goals (Dunn, 2007; Howlett, 2011; Weimer and Vining, 2011). Policy design, guided by unclear or even contradicting goals, can lead to ineffective and opposing policy outcomes. Some even consider a lack of a clear set of explicit policy goals as a "government failure" (Hepburn, 2010).

Robert and Zeckhauser (2011) suggest that in situations where policy goals are unclear and/or contested, clarification of such goals held by key actors can catalyse policy debates to help identify novel compromises. Building on Edenhofer and Kowarsch (2015), it can be further argued that explicit discussions of goal systems and related means can induce individual and collective changes with a potential convergence of the systems. This would facilitate policy design in the sense of the rational tradition.[4] In addition, Robert and Zeckhauser (2011) point out that empirically reconstructing the debates over goals driving policy programs can guide research towards clarifying the key factual relationships that are assumed in the underlying lines of arguments. This would be particularly relevant where empirical claims underpinning policy goals are strongly contested.

Against this background, the aim of this paper is to inform the debate by providing an empirical map of the goals and related lines of argument put forward by 54 elite policy actors engaged in the German Energiewende. To the best of our knowledge, Keeney et al. (1987) is the only comparable study for Germany and is clearly outdated given the many fundamental developments that have occurred since then.

In particular, this paper aims to address the following questions: what are the goals and related arguments that are used to justify the Energiewende; are there policy goals that are more widely shared by policy actors (offering perhaps a particularly solid basis for the design of Energiewende policies); and which goals are particularly contested in terms of their underpinning factual claims, indicating where future research might contribute to resolving related key controversies?

The paper is structured as follows: Section 2 defines key concepts required to capture the Energiewende goal debate and explains the approach and method of the study; Section 3 presents the results of the survey and interviews, and offers a reconstruction and discussion of the arguments for each goal; Section 4 concludes.

2. Concepts and methodology

2.1. Concepts: goals and systems of goals

A "goal" is a widely used concept across different disciplines and is also used in colloquial language. In psychology, a goal is defined as a desirable future state to be attained by a person (Schmidt-Sudhoff, 1967). The main difference between personal goals and political goals is that the former are geared towards maximizing personal well-being while the latter are guided by a normative notion of a "good society". In this sense Fischer, (2006, 78) describes political goals as "vehicles for moving concrete action in the direction of broadly understood social and political values. They seek to realize the conditions, institutions, and practices that make possible the realization of these values".

The terms,"goals", "aims", "objectives" and "targets" are often used interchangeably in both colloquial language and the scientific literature (see e.g. Dunn, 2007; Edvardsson and Hansson, 2005; IPCC WG3, 2014; Rosencrantz, 2008). For the purpose of this study we follow the definition provided by Dunn (2007, 134): "Goals are not quantifiable; but objectives may be and often are. Statements of goals usually do not specify the time period in which policies are expected to achieve desired consequences, while statements of objectives do". With this definition of "goal" it is clear that we are not interested in the (quantitative) objectives of the

[3] The EEG first entered into force in 2000. The 2014 version is after 2004, 2009, and 2012 already the fourth revision.

[4] The Energiewende itself may be considered an example for such long-term change in goals across different societal groups: at its core it ended decades of societal conflict and debate over the goal of phasing out nuclear power (Leipprand et al., 2015).

Energiewende, e.g. achieving 80% renewables share in annual power production by 2050, but more fundamentally in its value for society. In other words, to attain a high share of renewables in the energy system will not usually be of value to society as such, but is rather a means of achieving a certain goal such as climate protection, technology development, market leadership etc.

If several goals exist in parallel, the interrelationships between them are also important. Goal relations can take one of the following three forms: preference, interdependency, and instrumental (ZFOG, 2007); for a more formal treatment see Rosencrantz (2008):

- The *preference relationship* indicates whether the achievement of one goal is valued as being superior to the achievement of another goal, i.e. if it has higher priority. In our study, this was investigated by asking participants to rank goals related to the Energiewende.
- The *interdependency relationship* can be characterized by complementarity, neutrality or competition. Complementarity means that the achievement of one goal also leads to the achievement of another goal. Neutrality means that the achievements of two goals do not influence each other. Competition means that the achievement of one goal makes the attainment of another goal more difficult and is often also referred to as a trade-off.
- The *instrumental relationship* describes the link between fundamental goals and instrumental goals, i.e. the achievement of the latter supports the achievement of the former. The distinction between fundamental and instrumental goals depends on the empirical decision context and value systems (Eisenführ, 2003). A goal is only "fundamental" in a certain decision context (e.g. the Energiewende), and goals can be fundamental and instrumental at the same time. In the words of Dewey (1986, 179): "[…] there is a continuum of ends and means: Means of one inquiry can become the ends-in-view [goals] of another inquiry […]." Hence goals in this study are always considered in the context of the decision, i.e. the Energiewende, for which they can, in principle, have both meanings.

2.2. Approach and method

The empirical study comprised two steps. In the first step we collected and conceptualized the goals that are commonly used to justify the Energiewende, through content analysis of oral and written statements in the public discourse. Studies, newspaper articles and other documents on the Energiewende, appearing mainly between 2009 and 2014, were used, but most goals were derived from a content analysis of 175 speeches in the federal parliament (Bundestag) between 1999 and 2012. The Bundestag debates cover the legislation of the Renewable Energies Law (EEG) and the Energy Industry Act (EnWG), being the two major laws associated with the Energiewende (Joas, 2013). Altogether we identified 14 goals[5] that were frequently mentioned and although survey participants (in the second step) were given the opportunity to add goals, they rarely did so.[6] Therefore we assume that the most important goals were indeed identified in this first step.

In the second step, a survey complemented by an interview (60 min on average) on these goals was conducted among 54 German elite policy actors. Elite policy actors are those prominently involved in the German energy and climate policy debates and/or policy making at high-level in key organizations and institutions. The sample included representatives from politics, public administration, lobby organizations and enterprises, science, and media (see Table 1). Theory, in particular the "Advocacy Coalition Framework" (Sabatier, 1998; Sabatier and Weible, 2007), suggests that these are the main organizations capable of influencing the policy process. Individuals were asked for their *personal* Energiewende-related goal rankings, their understanding of the goals, and the arguments for their ranking.

The interviewees were selected in order to achieve balance across the entire political spectrum represented in the German parliament. The study, however, does not claim to be representative in this respect, nor does it claim to be representative of the opinions of the German population. The primary reasons for focusing the empirical analysis on elite policy actors are: (i) this approach delivers an overview of positions within the expert policy debate which is of particular relevance for eventual policy formation; (ii) these individuals can be expected to be articulate and reflective in their views over goal rankings and the arguments underpinning them; (iii) in a democratic system, it can be expected that the positions of policy actors reflect, at least to some extent, the views held by the broader population – although this need not always be the case. A final reason are that resources are limited; combining a survey of goal ranking with an interview is costly in terms of time, and requires careful selection and restriction of the survey panel.

The survey and accompanying interviews were conducted over a period of eleven months beginning in late 2013. Ninety percent were conducted in person and 10% via telephone. They were structured as follows. After a brief introduction, the respondents were asked to rank the 14 potential goals of the Energiewende based on their relative importance from top (most important) to bottom (least important). The respondents were explicitly asked to consider *their own goals* for the Energiewende, stating how the goals relate to each other in *their personal view*. It was made explicit that the interviewers were looking for their personal goals rather than the goal rankings of the organizations and institutions for which the interviewees were working. This was done on purpose because pre-tests indicated that the aggregate goal rankings of organizations are often unclear (due to internally diverging views) and it would not have been possible for individuals to consistently answer in the name of their organization.

A methodological difficulty that may have caused bias must be flagged in this context; it is possible that, in their answers, interviewees prioritized certain goals (e.g. climate protection) for strategic reasons, i.e. that they did not answer "truthfully". This could be the case if they actually pursue certain goals with the Energiewende but believe that these goals can be best achieved in the slipstream of other goals. In fact, the survey could be interpreted as indicating some evidence for such strategic behavior. However, the main interest of this study is to identify which goals are put forward and supported in the public policy debate, and the

[5] In a first step all identified goals were collected as mentioned in the Bundestag-speeches or in media publications. In a second step the goals were clustered and consolidated along their thematic overlap. In the next step goals were formulated in a way that (i) they captured the concept of the goal as clearly as possible and (ii) that they were mutually exclusive with minimal conceptual overlap. In most cases we used the formulations from Bundestag-speeches that were deemed precise and self-explanatory. Goals that were mentioned only very rarely or seemed too far-fetched were excluded.

[6] The following goals were added by interviewees to the list of goals: Affordable electricity prices, long-term affordable electricity prices, safeguard Germany as an industrial producer, safeguard of competitiveness, safeguard competiveness for German industry (all of these were interpreted as complying with the goal "Low short- to medium-term electricity prices for end-consumers" see Fig. 1); increase of energy efficiency, Investment in RES, creating a regulatory and institutional framework, EU integration, better coordination with European neighbours, market opening and democratization, integration of electricity and heating sector, better coordination of RES expansion and grid planning, and strengthening of municipalities and districts.

Table 1
Elite policy actor groups and institutional affiliations of survey and interview participants, and criteria for selection.

Actors	Institutions	Criteria	Interviews Partners:[a]
Politicians	Federal Lower House of German Parliament (Bundestag)	Specialised politicians in the area of energy and climate policy. Members of the parliamentary committees „Environment, Nature Conservation and Nuclear Safety“ and / or „Economics and Technology“	11 Interviews: Christian Democratic Union (CDU): 3 Christian Social Union (CSU): 1 the Social Democratic Party of Germany (SPD): 0[b] Die Linke: 1 The Greens: 4 Free Democratic Party (FDP): 2
	State Parliament (Landtag)	Specialized politicians in the area of energy and climate policy	1 Interview: The Greens: 1
Civil servants / administration	Federal ministries	Members of the two lead ministries of the Energiewende (Federal Ministry of Economics and Technology, and Federal Ministry for the Environment, Nature Conservation and Nuclear Safety)	2 Interviews: Federal Ministry of Economics and Technology (BMWi), Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU)
	State ministries	Responsible for energy and climate issues and the representation of the state's interests at the federal level	5 Interviews: Bavarian Ministry of Economic Affairs and Energy, State chancellery North Rhine-Westphalia, Federal Chancellery of the Free State of Saxony, Ministry of Energy and the Environment Schleswig-Holstein, State chancellery Brandenburg
Lobbyists and association representatives	Government relations offices	Responsible for energy and climate issues	19 Interviews: Association of the Chemical Industry (VCI), Wacker Chemie AG; Association of the Energy and Power Industry (VIK); Confederation of German Industry (BDI); Association of the German Energy and Water Industries (BDEW); EnBW Energie Baden-Württemberg AG; E.ON SE; EWE AG; 8KU; Association of Municipal Companies (VKU); Thüga group; 50Hertz Transmission GmbH Union for the Mining, Chemical and Energy industries (IG BCE), Ernst & Young GmbH, G5-Partners Dynamic Decision Advisory, European Climate Foundation (ECF), Federal Renewable Energy Association (BEE), World Wide Fund For Nature (WWF), Clean Energy Sourcing GmbH
Scientific policy advisors	Universities, research institutes, think tanks	Publications of studies in the context of the Energiewende	10 interviews[c]
Journalists	Print media with national distribution	Responsible for energy and climate policy coverage	6 interviews[c]

[a] If not otherwise indicated, only one person per organization was interviewed.
[b] Four members of the Social Democratic Party of Germany (SPD) were asked for an interview but declined due to a lack of time.
[c] Anonymity was guaranteed to the interviewees. Since a disclosure of their organisation would easily create a link to the interviewed individuals the names of the organisations are not named.

arguments backing these as advocated in public. It is not concerned with goals that policy actors actually want to achieve “in secret”.

In order to assess the participants' rankings, goals were written on cards and their meaning as conceived by the interviewers was explained according to the goal descriptions and conceptualizations in Section 4 below. Interviewees could ask questions on the meaning of the goals while defining their goal hierarchy. It was also possible to rank goals of equal importance at the same level, to exclude “non-goals”, and add extra goals. The goal ranking exercise usually took about 15 minutes. After the ranking, interviewees were asked to explain the arguments underpinning their personal goal-hierarchy, thereby further specifying the meaning of the goals and their relationships.[7] A particular focus was put on understanding the rationale underpinning the highest ranked goal, i.e. the fundamental goals justifying the Energiewende. Subsequently, a number of open-ended questions were asked which were tailored to the position and affiliation of the interviewee.

[7] Due to time constraints not every interviewee was asked to state their view on each goal. The interviewers focused the questions on the goals that seemed to generate the most relevant replies. This is the reason why the numbers in Section 4 do not total 54.

3. Results

3.1. List of goals

From the previous content analysis we identified the following 14 goals that had been repeatedly mentioned in the context of the Energiewende debate. The list provides an overview of these goals together with a brief general characterization. The descriptions were used to explain the goals to the interviewees.

In order to provide structure, the goals are grouped thematically.

3.1.1. Prevention of global climate change

- *Prevention of climate change by reducing national GHG emissions:* reference to Germany's contribution to global GHG emission reductions, as for example implied by the IPCC AR4, i.e. reducing GHG emissions by 80-95% by 2050 in industrialized countries in order to achieve the global 2 °C target.
- *Front-runner in global climate protection***:** the early achievement of GHG emission reductions by high shares of RES so as to provide an example to other nations.
- *Cost reduction of RES through learning effects***:** the realization of learning effects, and therefore global technology cost reductions, through the support of RES development in Germany. This

is usually closely associated with climate front-running.

3.1.2. Protection and conservation of the national and global environment (beyond climate change)

- *Nuclear phase-out*: giving up the use of nuclear power and mitigating the related risks by an early phase out of nuclear power plants.
- *Protection of the regional and national environment (e.g. clean air)***:** avoiding harmful emissions by fossil power plants and environmental damage from fossil mining activities.
- *Conservation of exhaustible resources***:** preserving all natural resources that are finite.

3.1.3. Further "energy triangle" goals

- *Maintain the current level of security of supply***:** the maintenance of security of supply at current levels as usually determined by power black-outs.
- *Low short to medium term electricity prices for final consumers***:** reference to the broader goal of "competitiveness", interpreted as avoiding rising electricity prices in the near to medium term, or alternatively limiting electricity prices to a level which is still affordable.
- *Import independence from fossil fuels (economic dimension)***:** an increase in the security of supply by means of reducing the dependence on fossil fuels whose supply in terms of both physical volumes and prices is insecure, particularly oil and natural gas. For a second meaning of this goal, see below.

3.1.4. Goals related to other policy domains

- *Job creation and regional value-added in RES industries***:** regional creation of jobs and income through the deployment of RES; thus closely related to structural economic policy.
- *Technology and market leadership in RES***:** building up of domestic companies that can become international market leaders; thus a form of industrial policy.

3.1.5. Other goals related to political ideals

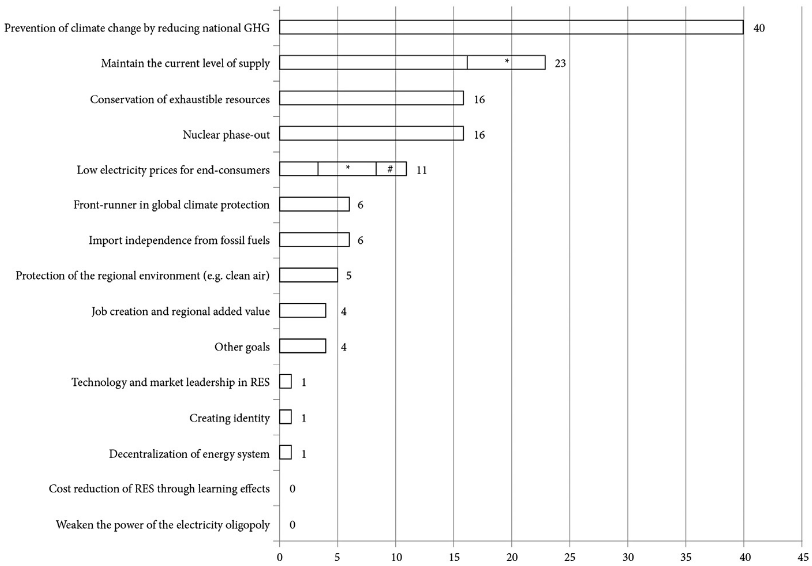
- *Import independence from fossil fuels (political dimension)***:** by reducing the dependence on imported fossil fuels, political conflicts related to their production, trade and use (blackmailing, violent conflicts, etc.) could be avoided or at least reduced.
- *Weaken the power of the German electricity oligopoly:* reduction of the economic and political power of the market oligopoly usually associated with the four largest German utilities (RWE, E.On, EnBW and Vattenfall).
- *Decentralization of the energy system (e.g. private roof solar PV and wind-cooperatives):* the overall society should participate (or even be locally autonomous) in the production of essential goods and services, rather than relying on a few large and powerful companies.
- *Creating identity:* uniting the German population behind a project which is internationally highly regarded. People should identify with the Energiewende which establishes societal integration and a collective sense of purpose.

3.2. Survey findings and discussion

3.2.1. Goal ranking

The major results of the study, in search of the fundamental goals of the Energiewende as viewed by elite policy actors, are as follows (see also Figs. 1 and 2):

- Fig. 1 shows the goals of the Energiewende as ranked by 54 elite climate and energy policy actors in Germany. The horizontal axis indicates the number of interviewees that placed the respective goal at the first level of their personal goal hierarchy.
- A large majority (40 of 54 respondents) consider "climate protection by reducing GHG emissions" as a top-level goal of the Energiewende (first level in their hierarchy of goals). Moreover, another goal related to climate change, i.e. "front-runner" is ranked on position 6. This underlines that combating climate change is widely viewed as an important goal underpinning the Energiewende.



*) These goals were named as „essential ancillary conditions"; 5x electricity prices; 7x security of supply.
#) Three interviewees did not agree with the formulation „short to medium term low electricity prices for end-consumers." Instead they chose different formulation that however also referred to the aspect of electricity costs: These were: „secure competitiveness" and twice „secure Germany as industrial site."

Fig. 1. Ranking of goals by survey participants.

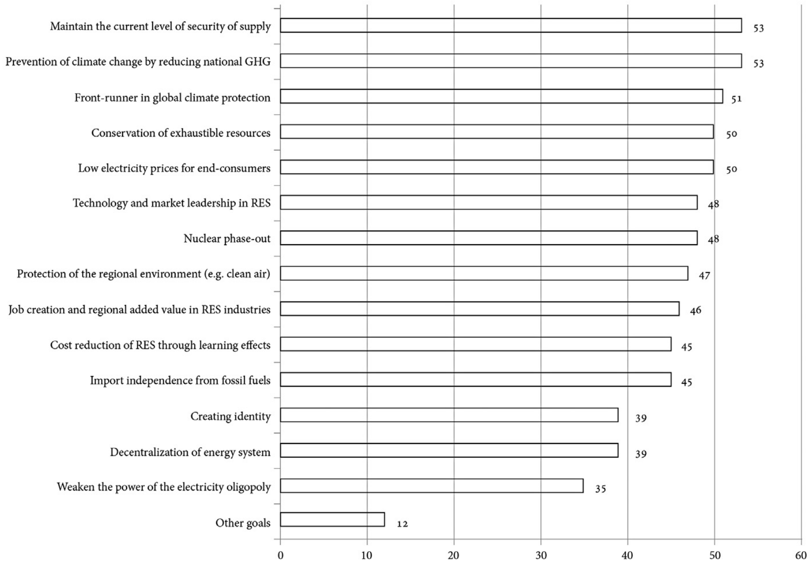


Fig. 2. Goals of the Energiewende incorporated into goals ranking.

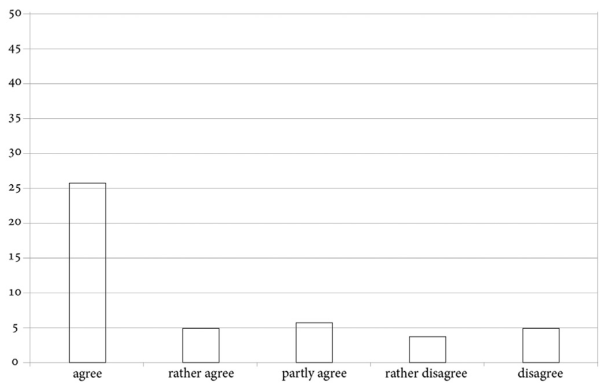


Fig. 3. Responses to the question: "would the Energiewende make sense if climate change did not exist? ".

- Many of the highest-ranked goals can be attributed to the energy policy triangle (comprising competitiveness, security of supply, and sustainability) in the wider sense, which confirms its relevance among policy actors. Fig. 2 illustrates the goals of the Energiewende as incorporated into the ranking by 54 elite climate and energy policy actors in Germany. The horizontal axis indicates how often a goal was acknowledged as a relevant goal and used in the ranking. The figure does not state how high the goal was ranked. Fig. 2 also shows that nearly all interviewees included many goals in their ranking. The results however also show that energy triangle goals are not exclusive and that other goals, such as "job creation**"** or the "decentralization of electricity production**",** are also important. In fact, 43 out of 54 respondents considered that at least 10 of the 14 suggested goals are part of the Energiewende's goal system. Only eleven participants excluded four or more goals from their goal system.

- For most interviewees the goals other than climate change are important enough to justify the Energiewende policy project. We asked the following control question at the end of the survey: "Would the Energiewende make sense even if climate change did not exist?" because it is unclear exactly how all the goals and their rankings are weighed and totalled, and how they interact and to compare to the highest-ranked goal (climate protection). Over two-thirds of the respondents agreed with the statement, although the majority of them (24) ranked climate protection as their top goal (see Fig. 3).

3.2.2. Lines of argument

After determining their individual goal hierarchy the interviewees were asked to explain the reasoning underpinning their rankings. The main arguments are analysed in the following. Note that it is not the aim of this study to determine the validity of the arguments, but rather to reconstruct and report them so as to stimulate further discussion and research.

3.2.2.1. Prevention of dangerous global climate change

3.2.2.1.1. Prevention of climate change by reducing national GHG emissions. The argument most frequently put forward by proponents of this goal was that Germany, as a rich and industrialized country, carries a responsibility to significantly reduce GHG emissions (8 interviewees explicitly cited this argument[8]). Some claim that Germany should reduce GHGs unilaterally even if others do not follow (5) while eight respondents did *not* prioritize climate protection at all. Most of these stated that national emission reductions only make sense in the context of a global climate agreement (5). Moreover, five interviewees from the entire sample reported that climate protection is an important goal, but only for instrumental reasons. They argued that climate protection serves as a "spiritual and moral superstructure" or a "common denominator" which is used by politicians in "soap-box speeches" and as an "aesthetic theme".[9]

[8] In the following, numbers in brackets indicate the number of interviewees explicitly supporting a statement in the interview.

[9] These interviewees prioritized the goals of job creation, nuclear phase out, import independence and creation of identity. Also, they obviously deviated from the task by only presenting their *personal* goal hierarchy. One interpretation of this behavior would be that they also use climate mitigation as a strategic argument underpinning Energiewende policies in public (because they know it is widely shared), while they are not personally convinced by it and actually support the Energiewende for other reasons.

3.2.2.1.2. Front-runner in global climate protection. Proponents of this goal argue that Germany can only substantially contribute to climate protection by taking a front-runner role since its contribution to global GHG emissions is very small (only 2% of global GHG emissions) (18). It is argued that Germany should provide and finance a "lead market".[10] In such a market the current problems of power-system RES, such as variability, electricity market design, institutional barriers and demand-side management would be solved (10). Once these problems are solved, the lessons on how to deal with the challenges of energy system transformation would be available to other countries, reducing cost and uncertainty. Other countries are then thought to be more likely to begin switching from fossil fuels to RES in the power sector or abandoning fossil energy system path dependencies in favor of RES capacity additions, thereby contributing to global climate protection. It is argued that if this strategy proves successful, i.e. countries begin investing in relatively low-cost RES because this creates national welfare benefits, it could become a "game changer" for global climate negotiations and pave the way for a meaningful global agreement (8).

Interviewees distinguish two front-runner strategies. First, it is argued that the reduction of domestic GHG emissions should be the focus. Only if Germany quickly and substantially reduces domestic emissions and maintains attractive business conditions, will others follow (13). By contrast, other respondents state that while climate protection is the major goal, the reduction of domestic GHG emissions should not be the first priority (8). This group claims that it is, in the long run, more important to develop a showcase for a low-carbon energy system, with high shares of RES, which can be readily adapted by other countries to achieve emission reductions elsewhere. Cost-effective low carbon technologies and systemic and institutional solutions on the integration of high shares of RES into the energy system are considered important to achieve this (10).

Interviewees agree that the Energiewende is closely watched by other countries (10). However, several respondents (5) state that in their view, for other countries, the Energiewende primarily provides an example for the attainment of goals other than climate protection. These include cleaner air, import independence, job and regional added value creation, or covering a rapidly growing energy demand. These goals are especially important for emerging economies such as China and India which are expected to demand a substantial increase in energy over the next decade. More generally, there is broad consensus that other countries will only follow if the Energiewende turns out to be an economic success (i.e. if the costs of RES are not higher than conventional power plants from an overall welfare perspective) (23). Interviewees arguing against the front-runner goal consider the Energiewende to be a dangerous pathway; they claim that Germany will remain a "leader without followers" and that currently the Energiewende serves as a warning, rather than a good example, especially in terms of costs and efficiency (8).

3.2.2.1.3. Cost reduction of RES through learning effects. This goal is closely linked to the front-running goal. Supporters of this goal claim that Germany has responsibility for providing "climate development aid" (10) because it has the know-how and the financial resources to do so (4). Furthermore it is claimed that bringing down the learning curve of RES is a fair price for Germany to pay for its "climate debt" caused by its relatively high cumulative historic emissions (4). One interviewee even went so far as to link this point to the German moral responsibility for World War II and the holocaust. Opponents of this goal see no moral obligation or responsibility on Germany to pay for the learning curves (7), especially since they claim that the rest of the world is free-riding at the expense of German electricity consumers, which is not clearly communicated to the German public. It could be considered that pursuing "climate development aid" in this manner cannot be politically legitimized (1).

3.2.2.2. Protection and conservation of the national & global environment (beyond climate change)

3.2.2.2.1. Nuclear phase-out. This goal is supported by the following arguments: (i) the uncontrollability of the technology and the associated potential for catastrophe after natural disasters, technical or human failure (6) or terrorist attacks (1); (ii) the unresolved disposal of nuclear waste, its subsequent risks for future generations, and the long term costs of storage (8); (iii) the incompatibility of inflexible nuclear power plants with high shares of fluctuating RES (1); and (iv) the potential high societal costs that result from the non-insurability of nuclear power plants (2). The high costs for newly built plants are also cited, which, however, does not apply in the German context, since new nuclear power plants have not been seriously planned in recent decades (6). Furthermore the argument of "settling a long lasting societal dispute" was often used by actors who have continued to support nuclear power until recently. This group argues that they do not fully agree with the phase-out but accept it since it obviously reflects the majority opinion in Germany (5). Opponents of the phase-out consider the risks of nuclear power plants to be overestimated and disagree with the phase-out using economic- and climate-related arguments (12). A majority of this group considers the phase-out as politically irreversible (8). However, other members of this group believe that another life-time extension might be possible in the future if RES and other back up capacities and grids are not built in time and the security of supply goal threatens to be compromised (3).

3.2.2.2.2. Protection of the regional and national environment (e.g. clean air). Respondents consider this goal as minor in the context of the Energiewende or consider that major environmental problems in Germany are resolved (3). Several respondents stated, however, that this goal is important from a political perspective since local issues such as air pollution, agricultural monocultures, and selection of disposal sites for nuclear waste or power grids have much greater potential to cause political conflicts through powerful local initiatives than "abstract threats" such as climate change (2).

3.2.2.2.3. Conservation of exhaustible resources. Given the vagueness of this goal, interviewees were asked to define the specific resources they understood it to relate to. Answers range from (i) fossil fuels (7), (ii) rare earths (2), (iii) uranium (1), (iv) soil and land that is needed for renewable raw materials (2), (v) land for open-cast mining (1), and (vi) the environment in general (2). Two respondents also claim that this goal is deliberately ill-defined since its role is largely to induce an agreement (2). Proponents of the goal express a general discomfort with the fact that resources, which were built up over millions of years, are being exhausted in only a few generations and that "such precious materials" should rather be saved for physical and material use (8). Furthermore a wide range of global problems were cited as relating to the extraction of energy resources, including global injustice (9), wars over fossil resources (2), "resource extractivism" (3) and the capitalist economic system based on growth (1). Critics of this goal claim that there is no shortage of resources and that the market mechanism will resolve scarcity problems by price changes and substitution (2). This group claims that a reduced demand for

[10] Lead markets are defined as "geographic markets characterized by producing or processing innovations, which are designed to fit local demand preferences and local conditions. They can also subsequently be introduced successfully in other geographic markets and commercialized world-wide without many modifications. In the model of international diffusion of innovations a lead market is the core of the world market where the local users are early adopters of an innovation on an international scale (Beise, 1999)".

fossil fuels by some world regions (e.g. Europe) would not change the picture because the savings would be offset by higher consumption in other world regions (2). They point out that the limiting factor is the disposal space in the atmosphere rather than scarce fossil resources. A goal of conserving finite resources is therefore redundant to a goal of climate protection (1).

3.2.2.3. Further "energy triangle" goals

3.2.2.3.1. Maintain the current level of security of supply. This goal is considered by most interviewees as a necessary boundary condition[11] in the sense that the current very low level of blackout periods in Germany must be maintained (28). They argue that these very low blackout times guarantee Germany's attractiveness for industry (3). Many state that this is not only a matter of energy security but also of communication. If the impression was created that high shares of RES lead to more blackouts this would be a public relations disaster for the national and international marketing of the Energiewende (6).

3.2.2.3.2. Low short- to medium-term electricity prices for end-consumers. There is wide agreement that costs are a key concern since distributional matters play a major role in the political discourse (16). Most respondents agree that price increases are still acceptable for most households (22). However the regressive effect of rising electricity prices can become a problem if they are not remedied e.g. by an increase in welfare payments (8). Most respondents also state that electricity prices play an important role for energy intensive industry and that excessive price increases must be avoided in order to prevent carbon leakage (17). Proponents of low prices argue that generous exemptions should be granted to industry since even the relocation of seemingly insignificant production processes could lead to a break-up of the close-loop value chains, which are one of Germany's main locational advantages (8). It is furthermore argued that for industries that compete on the world market there is no "high" or "low" price of electricity, but only a "competitive" or a "non-competitive" price (2). Thus, the falling spot market price for electricity in Germany plays only a minor role from a competition perspective since prices in the US have declined even further due to low gas prices (1). Others argue that it is only companies that fulfil strict criteria of a high export share and high energy intensity that should be granted privileges (5). Several interviewees explicitly called for electricity prices to be further increased, as they lead to efficiency improvements and stimulate innovation (9).

3.2.2.3.3. Import independence from fossil fuels (economic dimension). This goal is supported by the following arguments. First, it was argued that reduced import dependence would stop the financial flows towards fossil resource rich countries and that these funds could instead be invested in domestic RES. In this way foreign fossil fuel expenditures would be substituted by domestic labor (6). Second, it is expected that growing fossil resource demand and decreasing reserves will lead to increasing prices of fossil fuels in the long run (4). However one interviewee contradicts this view by pointing out that technological progress in resource extraction technologies might overcompensate for fossil demand increases and RES cost reductions for several decades. Furthermore, reduced imports are considered to make the domestic economy less vulnerable to extreme price fluctuations that have been a characteristic of energy resource markets in the past (3). Several interviewees explicitly expressed that import independence should not be a goal of the Energiewende for the following reasons. First, for a country that profits substantially from international trade, it should not be a goal to become self-sufficient in one sector (9). Second, and more importantly, less trade would lead to welfare losses on both sides, as trade is only carried out if both parties gain from it (as importing and using fossil fuels is cheaper than implementing domestic RES) (10).

3.2.2.4. Goals related to other policy domains

3.2.2.4.1. Job creation and regional added value in RES industries. There is relatively wide agreement among proponents and critics of this goal that jobs play a crucial role in the political discussion of the Energiewende (10). The job argument is also a major benefit for promoting the Energiewende abroad because creating jobs is a major political goal of politicians all over the world (1). Proponents argue that the Energiewende has led to positive net job effects (7) because RES is a substitute for fossil fuel imports (2) and because RES industries have a high export share (1). Furthermore it is argued that RES can create a positive future for rural areas (1) because jobs are mainly built up in the periphery (7). In this sense RES investments are useful for regional structural policy, especially for the economically underdeveloped regions in the east and the north of Germany (3). Jobs in RES are considered by one interviewee as particularly valuable because "social capital" is created. Working in the RES sector also provides meaning because employees get the feeling of contributing to a higher cause (1). Finally it is argued that the direct participation of the population (such as those employed in RES) can stabilize political support for the Energiewende (2). Critics respond that the creation of subsidized jobs in the renewables sector necessarily means job losses in other sectors. The net job balance is therefore considered at best zero but is more likely to be negative (5).

3.2.2.4.2. Technology and market leadership in RES. Proponents of this goal claim that an industrial policy for RES technologies fits with the comparatively advanced German industrial capabilities (10). There are advantages in areas such as mechanical engineering, which can be applied to efficiency technologies and gearboxes for wind turbines as well as biogas plants (9). Furthermore Germany has a strong electrical engineering industry, which either has enabled or might enable the country to become or remain market leader for inverters for PV and energy management systems, system solutions such as smart grids, load management systems, storage, and virtual power plants (5). The chemical and materials industry is also considered to lead, for example, the development of high quality materials. These are used, for example, in corrosion coatings for offshore wind turbines (3). Critics consider technology leadership not as a goal but, at most, a desirable side effect (11). They claim that industrial policy in the area of RES has failed spectacularly, referring to the dramatic reduction of German photovoltaic (PV) panel production over recent years, and that this should have provided a lesson (12).

3.2.2.5. Other goals related to political ideals

3.2.2.5.1. Import independence from fossil fuels (political dimension). This goal is supported by the following arguments. First, it is considered imperative that security policy keeps the dependence on other governments as low as possible in order to avoid political blackmail (13). In this context, independence from Russia and Gazprom was explicitly mentioned several times (5) although the Ukraine political crisis had not begun at the time of the interviews. Several interviewees point out that international conflicts over raw material extraction can cause wars, human rights violations and poor working conditions (7). There was also criticism over the neglect of geostrategic aspects in Germany's energy policy debate (1). However, while arguing against import independence as a political goal, the point is made by many that international interdependencies (especially in the area of strategic resources) and integration can promote peace and stability in the international system (14), and that the risk of political blackmail and boycotts of fossil imports is considered extremely low (2).

[11] A boundary condition is a goal that must always be fulfilled.

3.2.2.5.2. Weaken the power of the electricity oligopoly. None of the interviewees considered this as a top-level goal of the Energiewende. This stands in sharp contrast to the evaluated speeches of the Bundestag, in which the Green and the Left Party (die Linke) in particular, often put a focus on this goal (Joas, 2013).

3.2.2.5.3. Decentralization of the energy system (e.g. private roof solar PV and wind-cooperatives). Most respondents consider this as an instrumental goal (13), or as an inevitable consequence due to the nature of RES, but not as a major goal of the Energiewende. Supporters of this goal claim that it generates a "democratization of the power supply", which is necessary because services of general interest should be owned by citizens and not by companies (2). They argue that those who produce their own electricity, derive value and status from it as they feel independent from large power utilities (6). This creates a sense of autarky (apparently considered a fundamental goal) and furthermore helps to break the German oligopoly in the electricity sector (6). Ownership is believed to create a sense of participation in political processes, which is widely considered to increase political support for the Energiewende (16). In this role this goal serves an instrumental purpose. Many interviewees did not consider decentralization as a legitimate goal of the Energiewende (they removed the respective card from their goal-set) (19); they altogether reject arguments in favor of decentralization, with some even scoffing at proponents of this goal as having a "romantic understanding" of energy supply (7). Furthermore, some claim that only high subsidies, rather than ethical value decisions, have induced the large decentralization over recent years (4). This group considers electricity a homogenous good that should be produced in the most economically efficient way. Location and ownership questions must be subordinated or should not play a role at all (12). They furthermore warn that decentralization will lead to an erosion of solidarity in society since decentralized "prosumers"[12] do not carry the increasing system costs and strain of other electricity consumers who bear the additional costs (12).

3.2.2.5.4. Creating identity. Few agree that the Energiewende has the potential to increase the cohesion in society (2). The large majority do not see the integrative effect of a project to establish identity (5). One respondent even called the idea of using major political projects for social integration as "totalitarian.".

3.2.2.6. Trade-Offs. In the interviews the trade-offs between goals played an important role. It became clear that views on trade-offs strongly depend on the personal normative views towards the Energiewende. While proponents of the Energiewende claim that all (or at least most) goals are mutually enforcing and trade-offs are minimal, others see major contradictions between the goals. Several trade-offs that were largely unambiguous are briefly described below.

The clearest example is the trade-off between the nuclear phase-out and the reduction of GHG emissions. The baseload electricity production from the phased-out nuclear power plants must be replaced by fossil fuels that harm the climate, at least in the short- term. Another example is the trade-off between large shares of variable renewables and the security of supply. Large shares of variable renewables require additional (and often costly) measures such as demand-side management, grid reinforcements and the readiness for flexibility by power consumers, to maintain a high security of supply. Finally the trade-off between short-term electricity costs for end-consumers and several other goals (such as the nuclear phase-out, job creation and decentralization), that create costs (at least in the short-term) were repeatedly mentioned.

[12] Prosumers are market participants who consume (i.e. buy electricity on the market) and produce (i.e. sell electricity to the market).

4. Conclusions and policy implications

There are three major findings emerging from this study. First, a large majority of respondents named climate protection as the most important or one of the most important goals of the Energiewende. At the same time, around 80% of all participants also believe that additional goals are achievable with the Energiewende.

Second, two thirds of the participants go as far as to agree that the Energiewende would make sense even if climate change did not exist, thus questioning the singular importance of the climate protection goal. This more generally demonstrates that the empirical goals and motivations behind the Energiewende go beyond "finding a solution to global warming".

The third major finding relates to the controversies and trade-offs around the different goals, as revealed by the further analysis of arguments and reasonings. Here climate protection stands out as the goal receiving the strongest consensus. Many of the other goals do not benefit from such consensus. Particularly prominent controversies in the positive domain concern the attainability of the goals of job-creation and climate front-running. Research in these directions would be particularly worthwhile to put related factual claims on a more solid evidence base. This particularly holds for the goal of climate front-running as measured by the impact German climate action has on inducing climate action in other countries. The achievement of this goal, however, is very difficult to assess (Steinbacher and Pahle, 2015).

Turning to policy implications, it is important to first put the above findings into perspective. The reason why the German government has left the goals largely unclear may be that there are major controversies over them. As Fischer (2006: 158) points out "politicians find it advantageous […] to leave the meanings [of goals] vague, permitting different groups to read into them what they want. The ambiguity of meanings is often the very thing that makes political compromise between groups with conflicting views possible". Or as stated by one respondent: "the PV boom in Germany was only possible because it fulfilled goals of different societal groups. The farmers in the south received additional revenues, it filled the order books of engineers and installers of photovoltaic plants, politicians in eastern Germany could use it as structural policy and green groups got what they always wanted". A broad and stable consensus is arguably an essential requirement for a long-term energy transformation – and many rather vague goals reflecting different societal interests seem to be helpful in achieving it.

However, using goals instrumentally, i.e. understanding them as means to induce consensus or avoid conflict rather than as ends to be achieved, has two potentially important implications. The first, as described in Section 1, is that unclear or even contradicting goals are likely to lead to ineffective and counteracting policy outcomes, especially when ambitions are rising and hard trade-offs occur. More specifically, in such a situation it is very challenging to design policies because it is unclear what they should achieve. For the same reason, it is equally challenging to evaluate these policies; the performance of policies in terms of effectiveness and efficiency – also with a view towards policy and societal learning – can only be evaluated relative to the policy goals they were meant to achieve. If these goals were never clearly communicated or confounded in a thorough policy process, a later evaluation becomes difficult or even impossible. This is also exemplified in the analysis of US energy policy by Ellerman (2012) who argues that the conflation of climate protection and energy security goals has led to ineffective policies that achieve neither goal. A necessary remedy to this situation is to clearly define goals. This could be done for example along the lines of the pragmatist approach to policy deliberation and analysis outlined by Edenhofer and Kowarsch (2015).

The second implication concerns the existence of multiple goals. Unlike the missing clarity of goals, this is not *per se* problematic. It may just reflect the fact that different societal groups have different policy preferences that do not fall together into a single goal. However, this complicates policy design and particularly implies that from the point of view of any single goal, policies must necessarily be second best – and thus are more costly and potentially less effective. For the particular case of climate change, being the most widely shared top-level goal in our survey sample, an escalation of policy costs over time may mean that it will become difficult to attain currently envisaged future national greenhouse gas reductions in Germany. Consequently, and as underlined by current trends, Germany may fail to reach its quantitative climate objectives and thus not live up to its self-ascribed aspiration of being a climate leader.

Finally, the plea for stable, long term and clearly ordered top-level goals can conflict with the free formation of political will in a democracy. Political goals in society can, and do, change due to new and changing knowledge and problems perceived by citizens, and can be expressed by supporting parties and civil society groups that promise to change policies accordingly. While this fickleness may seem inefficient and suboptimal from the rational policy design perspective, it is a central feature of democracy, where the primacy of politics holds. There is a trade-off between stable long-term goals enabling the implementation of reliable policies, and resulting in intertemporally efficient governance on the one hand, and the constitutional obligation of the executive to translate the (potentially changing) will of the people (represented by parliament) into law on the other hand. This is an irreconcilable tension in any democratic system. Good governance requires balancing this trade-off.

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Chapter 3

Germany's Nuclear Phase-out: Sensitivities and Impacts on Electricity prices and CO2 Emissions*

Brigitte Knopf
Michael Pahle
Hendrik Kondziella
Fabian Joas
Ottmar Edenhofer
Thomas Bruckner

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Germany's Nuclear Phase-out: Sensitivities and Impacts on Electricity Prices and CO_2 Emissions

BRIGITTE KNOPF,[a,*] MICHAEL PAHLE,[a] HENDRIK KONDZIELLA,[b] FABIAN JOAS,[a,c] OTTMAR EDENHOFER,[a,c,d] and THOMAS BRUCKNER[b]

ABSTRACT

Following the nuclear meltdown in Fukushima Daiichi, in summer 2011 the German parliament decided to phase-out nuclear power by 2022. When this decision was taken, a number of model-based analyses investigated the influence this decision would have on electricity prices and CO_2 emissions. They concluded that CO_2 emissions would be kept at levels that are in line with national reduction targets but that the phase-out would result in an increase in wholesale electricity prices. We show by means of a sensitivity analysis that results crucially hinge on some fundamental model assumptions. These particularly include the development of fossil fuel and CO_2 prices, which have a much larger influence on the electricity price than the nuclear phase-out itself. Since the decision of the nuclear phase-out, CO_2 prices have decreased and deployment of renewables increased ever since. This partly counteracts the negative effect of the nuclear phase-out on electricity prices, but on the other hand challenges the mitigation of CO_2 emissions and security of supply. This underlines the importance of sensitivity analyses and suggests that policy-makers need to consider scenarios that analyze the whole range of possible future developments.

Keywords: Nuclear policy, Climate protection, Renewable energy, Electricity market modeling, Energiewende

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1. INTRODUCTION

Following the nuclear reactor accident in Fukushima Daiichi, the German Parliament decided in summer 2011 to phase-out nuclear power by 2022. This involved a controversial public discussion (e.g. Ethics Commission, 2011) and the decision also raised a lot of interest on the international level (e.g. The Economist, 2011; New York Times, 2011; Nature News, 2011). But the phase-out in 2011 was not the first decision to withdraw from nuclear power. In 2002, the former Government already agreed to phase-out nuclear through the "nuclear consensus" between the Federal Government and the industry. Based on an average operational life-time of 32 years for a nuclear power plant, a phase-out was agreed upon with the last nuclear power plant to go off the grid by around 2023. However, in 2010, the new conservative

[a] Potsdam Institute for Climate Impact Research (PIK), Research Domain Sustainable Solutions.
[b] Institute for Infrastructure and Resources Management (IIRM) at the University Leipzig.
[c] Mercator Research Institute on Global Commons and Climate Change (MCC) Berlin.
[d] TU Berlin, Chair Economics of Climate Change.
* Corresponding author. E-mail: brigitte.knopf@pik-potsdam.de.

Government opted for a life-time extension of nuclear power up to 2038 as a "bridging technology" in order to facilitate the "road into the age of renewable energies" (Federal Government, 2010), i.e. the energy transition (Energiewende). In that sense, the second decision on the phase-out in 2011 constituted (again) a strategic reversal. Without discussing the details of this decision and the potential political reasons for the life-time extension, this leaves the question not only on the influence of the phase-out on prices and emissions but also if the now earlier phase-out might imply serious challenges for the overall energy transition compared to the previously mandated prolongation. In this paper, we analyze different pathways for the nuclear phase-out and narrow our scope by looking at its impacts regarding the originally envisaged role, i.e. to curb the increase of electricity prices and to decrease CO_2 emissions. Although already a number of analysis of the nuclear phase-out are available (e.g. enervis energy advisors (2011), Prognos/EWI/GWS (2011), IER/RWI/ZEW (2010), r2b energy consulting/EEFA (2010), Nestle (2012), Samadi et al. (2011), Fürsch et al. (2012)) the added value of this paper is to explore a range of sensitivities, including a model comparison, and to provide a fresh perspective of the model results in light of current developments.

The first part of the analysis looks back at the time before the nuclear prolongation was revoked and allows us to evaluate the different policy options that were discussed then. Besides the precise date of exit from nuclear energy, an important and long-term political discussion concerns the possible replacement options of nuclear power. We identify how much generation capacity needs to be replaced and use a power market model to analyze the differences in prices and emissions between early (2015 and 2020), the currently decreed (2022) and the previously planned (2038) phase-out. In that context, a range of different replacement options (for example, giving priority to coal or gas-fired power plants) is evaluated. As model results depend heavily on input assumptions, these paths are tested for their robustness in sensitivity analyzes in which individual assumptions are varied. In this way, a range of alternative scenarios is explored. This sensitivity analysis is completed by a comparison with electricity prices from other model-based studies that evaluate the difference between a phase-out in 2022 and a life-time extension until 2038.

While the model-based analyses concentrates on the effect of the nuclear phase-out on wholesale electricity prices and CO_2 emissions, in the second part of the analysis we relate the model-based analysis to the current situation. The comparison of different studies in combination with the results from the sensitivity analysis allows us to assess the range of results for the situation-as-is and their potential underlying causes and to distil some policy implications over the whole portfolio of available scenarios. We widen the perspective from the isolated effect of the nuclear phase-out towards the challenges of the overall Energiewende (see e.g. Nature, 2013).

The paper is organized as follows. In Section 2, we present the scenario set-up, the applied electricity market model and evaluate the effect of the nuclear phase-out on electricity prices and CO_2 emissions. In Section 3, we accomplish this with a sensitivity analysis and a comparison with results from other studies. Section 4 reviews the modeling results in view of current developments and derives some policy implications. Section 5 concludes.

2. IMPACT ON ELECTRICITY PRICES AND CO_2 EMISSIONS

Scenario definition and model description

For exploring the different pathways, an assessment of different scenarios is required. We define them along two dimensions: the year of the nuclear phase-out and the different tech-

TABLE 1
Scenario definition

Scenario Name	Exit year	Replacement by conventional power plants based on . . .
Exit2015-gas	2015	gas
Exit2015-coal	2015	coal
Exit2020-gas	2020	gas
Exit2020-coal	2020	coal
Exit2022	2022	combination of gas and coal
Exit2038	2038	combination of gas and coal

TABLE 2
Exogenous input assumptions to the model

	2015	2020	2025	2030
Gas price* [€/MWh]	27.4	30.6	34.2	37.1
Coal price (hard coal) [€/MWh]	12.6	14.4	15.8	16.9
CO_2 price [€/tCO_2]	26.0	31.2	34.3	36.4
Electricity production from RES [TWh/yr]	165	227	293	360
Gross electricity consumption [TWh/yr]	575	560	550	550

* The gas price refers to the border price.

nologies by which nuclear capacities are to be replaced, i.e. gas or coal power plants. Both aspects were most heavily debated at the time shortly after the nuclear accident in Fukushima Daiichi in March 2011. The full set of scenarios is shown in Table 1.

Regarding the development of renewable capacities, we assume the deployment path described in Nitsch et al. (2010) for all scenarios. It breaks down to an increase in renewable energies from 165 TWh in 2015 to 360 TWh in 2030 leading to a share of renewable energies in the electricity mix of 65% by 2030. Our assumptions for electricity demand, electricity production from renewable energy sources (RES), fossil fuel and CO_2 prices are based on the same study (price path B). The full set of assumptions is shown in Table 2.

All scenarios are analyzed with regard to the development of electricity prices and CO_2 emissions using the MICOES (Mixed Integer Cost Optimization Energy System) model. MICOES is a bottom-up electricity market model for power plant scheduling based on Theofilidi (2008) with an extension by Kondziella et al. (2011), Bruckner et al. (2010), Harthan et al. (2011). From a methodical point of view, MICOES is a mixed-integer optimization model that is capable to consider short-term marginal cost, start-up and shut-down costs as well as limited ramp rates. It uses a least-cost approach to optimize the hourly scheduling of the conventional fleet of power plants in the market. Going beyond a simple merit order approach, it is therefore able to take into account the constrained flexibility of conventional power plants.

The input to the model stems from a database with fossil-fired power plants in operation in Germany (block by block for a unit capacity of greater than 100 MW, aggregates for smaller units). For each power plant, installed net capacity and electric efficiency are available (or estimated from literature). Furthermore, technical restrictions of thermal power plants such as minimum load, load change ratios, minimum downtime, minimum uptime, etc., are incorporated in the model. Renewable generation serves as an exogenous input and hourly fluctuations by intermittent sources like wind and solar power are taken into account.

For this analysis we assumed that Germany has to manage the nuclear phase-out with own capabilities. However, the model is able to utilize an additional supply opportunity (import) at a very high price (300€/MWh). This additional degree of freedom is used by the model only in a limited number of hours. More details concerning the input assumptions and the modeling approach are given in Knopf et al. (2011a) and Knopf et al. (2011b).

Projection of conventional replacement capacity

A complete withdrawal from nuclear energy in Germany means that 21 GW in net power plant capacity have to be replaced until 2022 that equals 21 % of the total conventional capacity. The first eight out of 17 nuclear power plants that were taken off the grid by March 2011 (the so-called "Moratorium on nuclear energy", Federal Government, 2011) so that around 10 GW in power plant capacity were out of operation in mid-2011. This capacity was replaced by making use of existing overcapacity as well as by reducing net electricity exports. Furthermore, according to the German Association of Energy and Water (BDEW) (BDEW, 2013a), a series of fossil fuel-fired power plants are under construction whose capacity of around 9.2 GW, mainly coal-fired power plants, will be available by 2015. Another net extension of 2 GW was already commissioned between 2011 and 2013. This was taken into account by the model-based analysis. In this way, the capacity of the nuclear power plants could be completely replaced by 2015. However, it is also planned to shut down 14 GW in power plant capacity from old fossil fuel-fired power plants. And by 2020, a further 13 GW in fossil fuel-fired power plant capacity are to be shut down because they reach the end of their technical lifetime. This means that, in addition to the exit from nuclear energy, a total of 27 GW in fossil fuel-fired power plants will have to be replaced within the next decade. The options primarily deployed in our model for filling this gap include the expansion of renewable energy and of (centralized and decentralized) cogeneration capacity, the reduction of electricity demand by increasing energy efficiency and the import (although only for a limited number of hours per year) of electricity from other European countries. Apart from these replacement options the construction of fossil fuel-fired power plants or the refurbishment of older fossil fuel plants has to be considered. Based on economic considerations and our model-based analysis, 8 GW of additional conventional capacity is required (see Figure 1).

The scheduling of the capacity expansion can be deferred further into the future depending on the date of exit (Figure 1). This means, e.g. in the case of a nuclear exit in 2020, not only all the power plant capacities currently under construction need to be ready, but that further fossil fuel-fired power plants currently planned or to be planned will have to be put into service. Alternatively, a prolonged use of older coal-fired power plants may be considered. An even earlier exit in 2015 would represent an even greater challenge and would probably

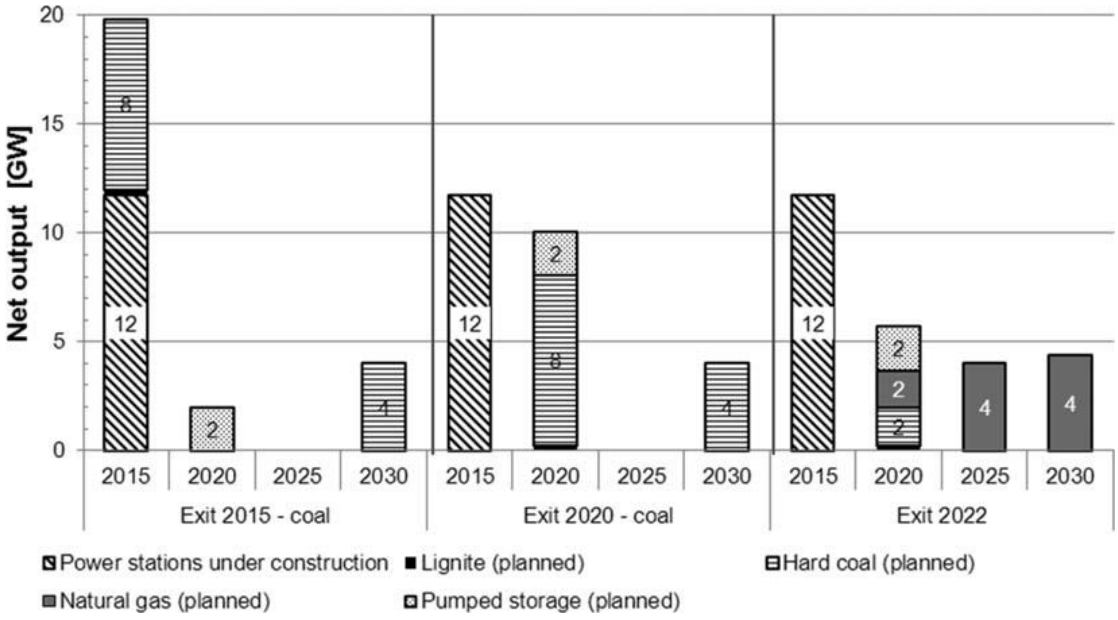

FIGURE 1
Replacement capacity required in conventional power plants. Comparison of scenarios *Exit2015-coal, Exit2020-coal* and *Exit2022*

endanger energy security. This involves many other open questions and assumptions requiring further investigation that is beyond the scope of this paper (see discussion in Section 4).

Impact on electricity prices

Within liberalized electricity markets, spot market prices are based on the supply-cost curve (merit order) of all plants in the market. The marginal plant, i.e. the plant with the highest (short-term) generation costs still needed to meet a given demand, establishes the spot market price. Accordingly, nuclear energy, with low generation costs, would be the economically preferred technology within the merit order followed by lignite, hard coal and gas-fired power plants.

If nuclear power plants are to be decommissioned, the spot market price will rise in average in response, at least temporarily, since then gas fuelled power plants will set the marginal price due to the shift of the supply curve to the left. The increasing proportion of renewable energy in the German electricity mix (23% in 2012 (BDEW, 2013b), and envisaged at 40 % in 2020 and 65 % in 2030 according to the Government's decision (Federal Government, 2010)) will work in the opposite direction, bringing about a long-term fall in the spot market price level by shifting the supply curve to the right. The reason is that, in accordance with the feed-in-tariff system (and the low short-term generation cost), renewable energy must be supplied at "negative" cost at the wholesale market in order to be able to ensure the obligation of grid operators to purchase all renewable energy and sell it to the market. As a result, the spot market price will rise until 2020 but then fall again to below the initial level by 2030 due to the ever increasing proportion of renewable energy (Figure 2).

For the scenario *Exit2015-coal*, the spot market price in that year would be 67 €/MWh and thus 8 €/MWh higher than the price in the corresponding year in the case of an exit in

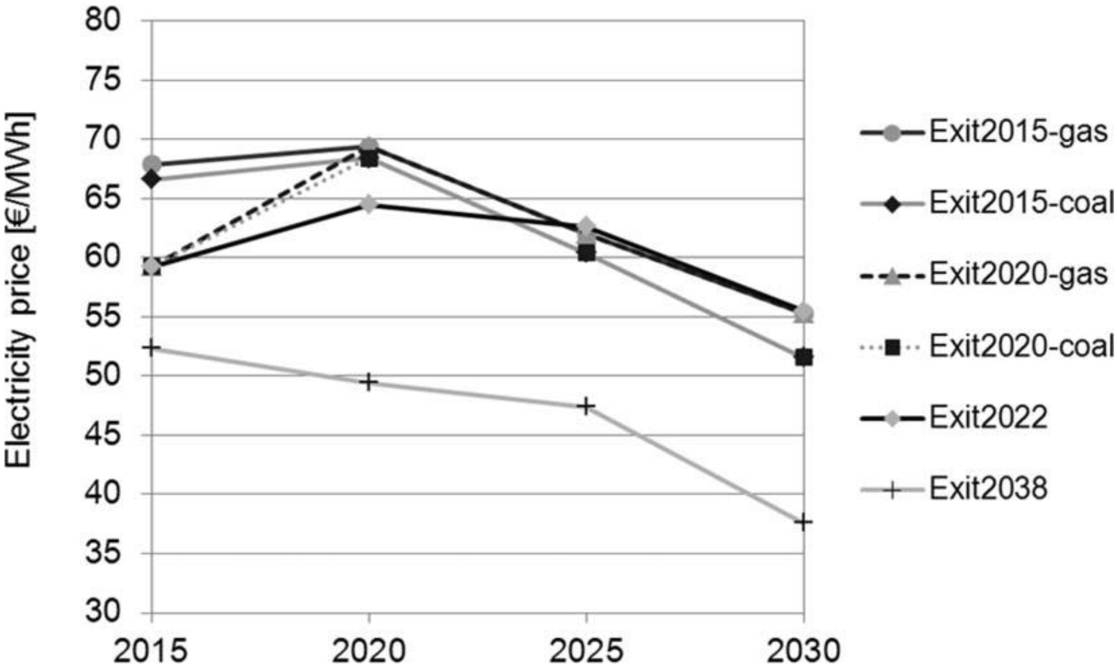

FIGURE 2

Development of the electricity price at the spot market (baseload). For comparison: The average price at the spot market (baseload) was 56 €/MWh in 2011

2020 or 2022. The reason for this is the need to draw on cost-intensive replacement capacities ahead of time. However, prices in the *Exit2015-coal* scenario are not higher in 2020 than those of the *Exit2020-coal* scenario since replacements only occur a few years later but still before 2020 (cf. Figure 1). In the case of *Exit2022*, replacements are put back a bit further so that the prices in 2020 will be 4 €/MWh lower. Long-term spot market prices, however, remain slightly lower in the case of an early exit with coal (*Exit2020-coal*) as the replacement option than under the *Exit2022* scenario. This is due to the intensified expansion of gas-fired power plants in the case of *Exit 2022* (Figure 2) which have a slightly higher cost level.

Furthermore, the results show that prices will reach nearly equal levels if nuclear power plants are replaced by either gas or coal-fired power plants. The reason is that, on the basis of the assumed fuel and CO_2 prices, electricity production costs for both technologies are approximately equal. Accordingly, if—apart from the projects under construction—exclusively gas-fired power plants are built instead of coal-fired power plants, for the scenario *Exit2020-gas* the spot market prices in 2020 will be only around 1 €/MWh higher than those under the scenario involving intensified expansion of coal-fired power plants *Exit2020-coal*.

Figure 2 also makes clear that a life-time extension of nuclear power (*Exit2038*) would have led to much lower wholesale prices and would thus have indeed facilitated the energy transition in Germany by reducing costs. In numbers, there is a price increase of 11% between *Exit2038* and *Exit2022* in 2015 and 23% in 2020.

The prices for household consumers are determined only to a minor extent by the wholesale market price and the distribution that together currently make up only about 30% of the overall consumer price (BDEW, 2013c), while taxes and other expenses are responsible for 50%, while grid charges account for another 20%. From these 50% the feed-in-tariff (FIT)

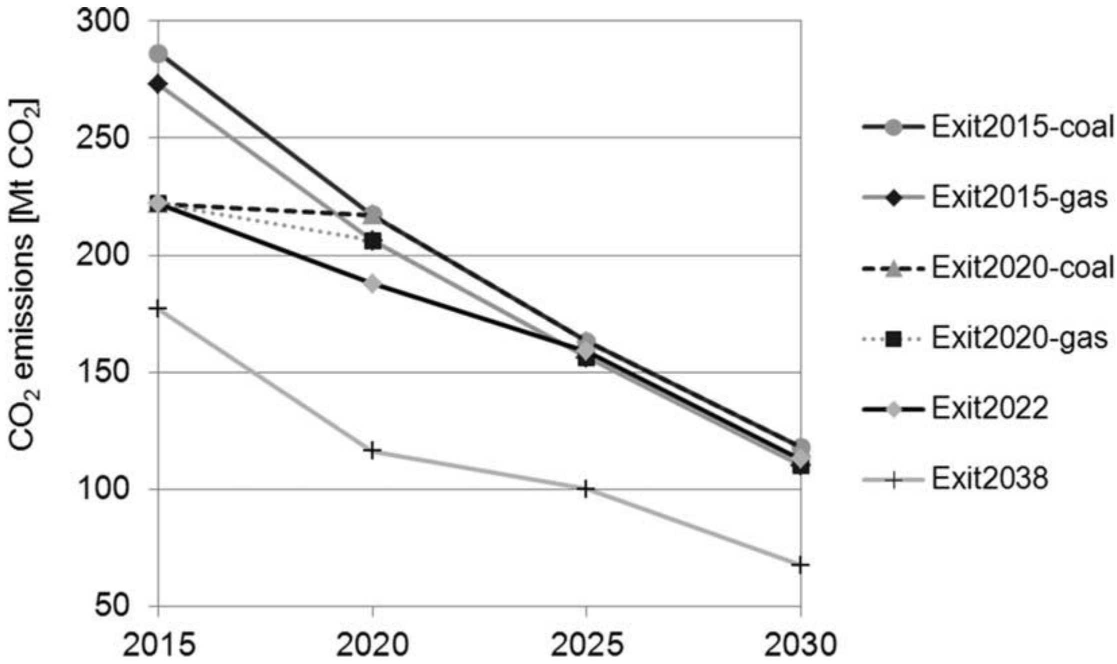

FIGURE 3
CO_2 emissions from conventional power plants 2015–2030

levy is the most important component which makes up around 19% of the consumer price. The German FIT levy which is paid by all electricity consumers with some exceptions for electricity-intensive industries is based on the difference between compensation under the FIT system and the average electricity procurement costs on the electricity exchange. Thus, a price increase on the spot market is compensated by a reduced FIT levy for the end consumers and vice versa. The largest influence on the consumer prices is therefore determined by the interplay between spot market prices and renewables deployment. As the latter is given exogenously in the model, it is not subject of the model-based analysis and will be discussed in Section 4.

Impacts on CO_2 emissions

The year of the nuclear phase-out has a clear impact on CO_2 emissions (see Figure 3) as the substitution with coal-fired power plants or gas-fired power plants the CO_2 emissions of the electricity generation sector would increase. The earlier the phase-out, the higher are the emission at least until 2025. In the long term, however, for the scenarios *Exit2015*, *Exit2020* and *Exit2022*, the emissions would be similar. An exit in 2020 instead of 2022 would of course mark only a short-term rise in CO_2 emissions (Figure 3). Nonetheless, a complete exit in 2015 would increase CO_2 emissions: In 2015, they would be 64 $MtCO_2$ higher than in the case of *Exit2020* or *Exit2022*. The additional emissions could be reduced by 20 % if the expansion of gas-fired power plants was pursued instead of coal-fired power plants. An increase of 64 $MtCO_2$ would raise German CO_2 emissions of the electricity sector by almost a quarter in 2015.

A life-time extension of nuclear power until 2038 would have reduced emissions in Germany by 45 to 70 $MtCO_2$ between 2015 and 2030 but the *Exit2022* scenario still reaches roughly 70% reduction against 1990 by 2030 solely in the power sector. In fact, the German nuclear energy phase-out in 2022, as consensually enacted in 2011, only means a return to the old "status quo" before the prolongation of the operational life of nuclear power plants in autumn 2010. Climate protection is not endangered by the earlier phase-out since the total quantity of emissions in the European electricity sector is limited by the cap of the EU emissions trading system that was set up in 2005 when the decision on the first nuclear phase-out in Germany was already taken. In that sense, the nuclear phase-out has no effect on the overall CO_2 emissions of the EU. This means that larger emissions in one region are offset with lower emissions in a different region. This may indeed affect the regional distribution of CO_2 emissions across the EU but not the overall emissions.

Nevertheless, increasing emissions can lead to an increase in CO_2 prices. This is not considered here but is topic of the sensitivity analysis in Section 3. Increasing CO_2 prices would mean that across Europe, power plants would be utilized that emit less CO_2. Since nuclear power plants have lower marginal costs, their capacities are, as a rule, already fully utilized within the framework of the existing possibilities. Rising CO_2 prices would therefore lead mainly to the utilization of more efficient fossil fuel-fired power plants across Europe.

Our analysis solely focuses on the electricity sector but the emission path is very much in line with that of the Nitsch et al. (2010) that reaches an economy-wide emission reduction of 85% by 2050 with CO_2 emissions from the electricity sector accounting for 213 $MtCO_2$ in 2020 and 105 $MtCO_2$ in 2030 compared to 188 and 113 $MtCO_2$ in our scenario *Exit2022*.

3. SENSITIVITY ANALYSIS AND COMPARISON WITH OTHER STUDIES

In this Section we analyze how the results depend on come critical modeling input assumptions and how our results compare to other studies in terms of outcome and assumptions. Within the framework of a sensitivity analysis the following assumptions were considered (for the numbers see overview in Table 3):

(a) Stronger increase of fuel and CO_2-Prices

The reference scenario assumes a moderate increase of the input prices according to the "Lead study 2010" (price scenario B) of the German environmental ministry (Nitsch et al., 2010). That price scenario relates to price forecast of the WEO 2007. Due to optimistic assumptions the price scenario B turns out to be at the bottom line of the future price trend. The sensitivity of a stronger increase of future input prices according to price scenario A of the "Lead study" is analyzed for the scenario "Exit 2020" in the year 2020. That stronger increase of fuel prices is derived from oil price forecasts of the WEO 2009.

(b) Constant instead of decreasing electricity consumption

The reference scenario assumes a slight decrease of gross electricity consumption for Germany from 587 TWh (2010) to 550 TWh (2030) due to economic and demographic forecasts (Nitsch et al., 2010). Hence the increase of the annual primary energy productivity has to reach 2.7 % relating to efficiency targets of the federal government (for comparison: the average value is 1.8 % for the period 1991–2008). The sensitivity analysis investigates a failure of the efficiency target and keeps the gross electricity consumption at a constant level.

(c) Only modest expansion of decentralized cogeneration

According to the reference case the contribution of decentralized cogeneration units to electricity demand is doubled until 2030. For the sensitivity analysis in 2020 we regard

TABLE 3
Model parameters for the sensitivity analysis for 2020

	Reference	Sensitivity	Difference
a) Higher fuel and CO_2 prices			
Gas [cts_{2007}/kWh]	3.86	4.85	26%
Hard coal [cts_{2007}/kWh]	2.59	3.30	27%
Lignite [cts_{2007}/kWh]	1.70	2.09	23%
CO_2 [€/t]	31.17	40.52	30%
b) Constant instead of decreasing electricity consumption [TWh]	560.0	587.0	5%
c) Only modest expansion of decentralised cogeneration [TWh]	63.8	49.5	− 22%
d) More rapid expansion of renewable energy [TWh]	227.0	267.0	18%
e) Additional system flexibility		5GW and 30GWh	

a temporal failure of capacity extension targets about five years. Comparing to the reference case the capacity is reduced by 3 GW (14.3 TWh) that has to be substituted by conventional generation.

(d) More rapid expansion of renewable energy

The share of renewable energies in the German electricity market is expected to reach 40% by 2020 in the reference scenario (Nitsch et al., 2010) that is equivalent to an electricity generation of 227 TWh. Recent projections have frequently underestimated the extension path that is triggered by the German feed-in-tariff-system. Therefore in this sensitivity analysis renewable extension targets are pushed up by three years, i.e., in 2020 we assume the renewable capacity available in 2023 for the reference case, leading to additional supply from renewable generation of about 40 TWh in 2020.

(e) Effect of additional system flexibility

The integration of large amounts of fluctuating renewable energies requires a flexible energy system to match supply and demand instantaneously. One option assumed in the model is pumped-hydro storage. The installed capacity in Germany is about 7 GW and 40 GWh. The sensitivity analysis assumes an additional flexibility of 5 GW and 30 GWh. This can be seen as a proxy for other flexibility options, such as demand-side-management or grid expansion.

For these five sensitivities, we take the scenario *Exit2020-gas* as the reference and compare results for the year 2020. The largest influence on spot market prices is exercised by the assumption about the future development of increasing fossil fuel and CO_2 prices which lead to a 25 % increase from 69 to 86 €/MWh in 2020. The reason for the large influence of the fossil fuel price and especially the gas price lies in the merit order (see section 2.3). As in most

TABLE 4
Sensitivities in relation to spot market prices (baseload) in 2020 with regard to the scenario *Exit2020-gas*

	Spot market price (baseload) in 2020 [€/MWh]
Reference scenario: Exit2020-gas	69
Sensitivities:	
Higher fuel and CO_2 prices	*86 (25%)*
Constant instead of decreasing electricity consumption	*76 (10%)*
Only modest expansion of decentralized cogeneration	*72 (4%)*
More rapid expansion of renewable energy	*66 (− 4%)*
Additional system flexibility	*68 (− 1%)*

cases, the power plant with the highest (short-term) generation costs is a gas turbine; the gas price therefore has a large influence on the spot price.

The assumption of not fulfilling energy efficiency improvements also exerts a big influence. If electricity consumption, contrary to policy targets, remains at its current level, wholesale prices will increase by 10%. The influence of these assumptions on the electricity price is thus similar to or even greater than the timing of the exit itself, compare Figure 2. In contrast, the impact of load shifting measures (demand-side management) can reduce prices only slightly: Likewise less cogeneration has also a relatively low impact on prices. Again, as already explained in Section 2.3 the influence on the price for households is very limited, the spread is between 22.3 ct/kWh (with DSM) and 23.5 ct/kWh (for high fossil fuel and CO_2 prices), i.e. only an increase of 4%.

As the sensitivity analysis shows, the assumptions have a strong influence on the electricity prices that is even stronger than the exact year of the phase-out. Therefore, it can be expected that other studies likely differ in their projected price paths—given different assumptions. We compare our results (labeled as PIK/IIRM in Figure 4) with results from other studies that analyze a phase-out in 2022 compared to a phase-out in 2038 and that have been performed in the years 2010 and 2011 to inform the discussion about the life-time expansion of nuclear power. These studies are enervis energy advisors (2011), Prognos/EWI/GWS (2011), IER/RWI/ZEW (2010) and r2b energy consulting/EEFA (2010).[1]

Whereas the difference between a phase-out in 2022 and a life-time extension until 2038 leads to differences in wholesale prices between 6 €/MWh in 2015 and 17 €/MWh in 2030 (see Figure 4, cf. also German Council of Economic Experts (2011)), the absolute numbers show a very large divergence between the studies (see Figure 5a) as large as 26 €/MWh already in 2015. This means that the differences in absolute price levels between the different studies

1. The models in these studies differ in terms of regional and temporal resolution or investment decisions are modeled, but this kind of analysis is beyond the scope of the paper.

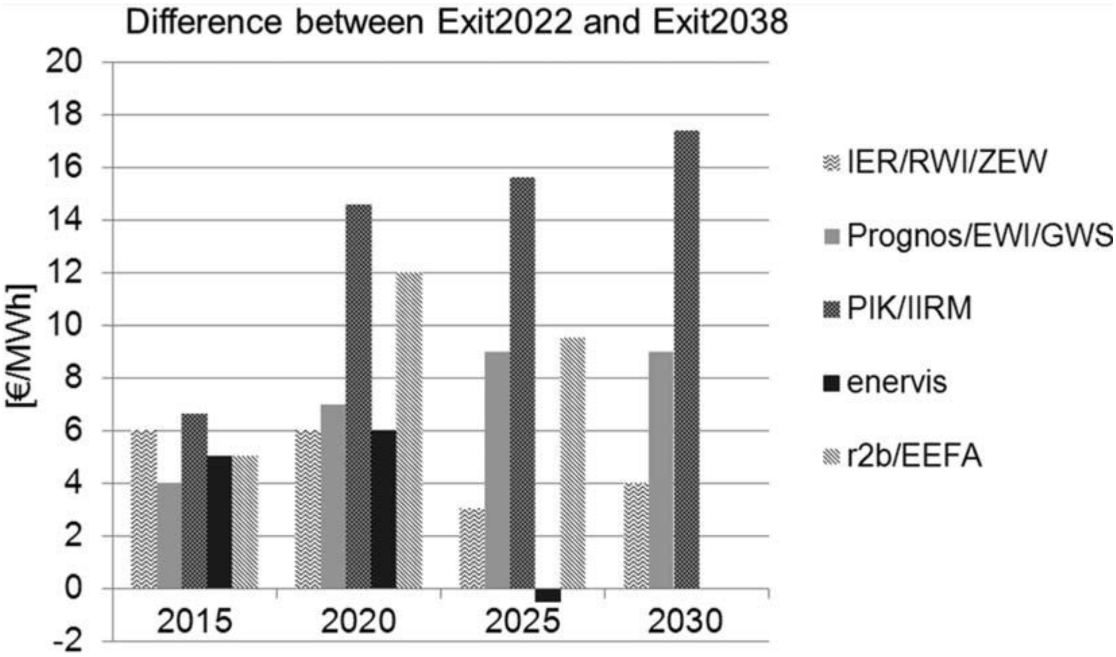

FIGURE 4

Difference in wholesale prices between a nuclear phase-out in 2022 and 2038 for different studies. For enervis a comparison between 2020 and 2038 is shown. PIK/IIRM refers to this publication.

are much larger than the relative differences between the scenarios with and without a lifetime extension of nuclear power.

The electricity price path for the different studies does not only show a large divergence in absolute numbers but also the tendency of increasing (in three studies) or decreasing prices (in two studies) is not clear. In Knopf et al. (2012), the reasons for these differences are analyzed in more detail. It turns out that the studies are based on very different assumptions concerning i) fossil fuel and CO_2 prices, ii) the future electricity demand and iii) the deployment path of renewable energies and, see Figure 5b–d.

It is not astonishing that electricity prices are so different given the widely differing assumptions on the future gas price and CO_2 price development (see Figure 5b and c). As seen in the sensitivity analysis, energy efficiency—represented by the reduction of electricity demand—is also an important driver for the electricity prices. Whereas the demand decreases in three studies (PIK/IIRM, Prognos/EWI/GWS and r2/EEFA), it increases in the two others (IER/RWI/ZEW and enervis), see Figure 5d. This partly explains the low prices for PIK/IIRM and Prognos/EWI/GWS. The decreasing prices in the PIK/IIRM scenario can mainly be explained by the assumption of a very ambitious deployment path for renewable energies along the numbers in Nitsch et al. (2010) that reaches 360 TWh in 2030, whereas in the other studies only between 212 to 267 TWh (not shown here).

The sensitivity analysis and the comparison show that many other factors besides the decision of the nuclear phase-out determine the electricity prices. These driving factors are often exogenous assumptions in the models and can only to a certain degree be influenced by political decisions and regulatory frameworks. We will elaborate on the policy implications of this in the next section.

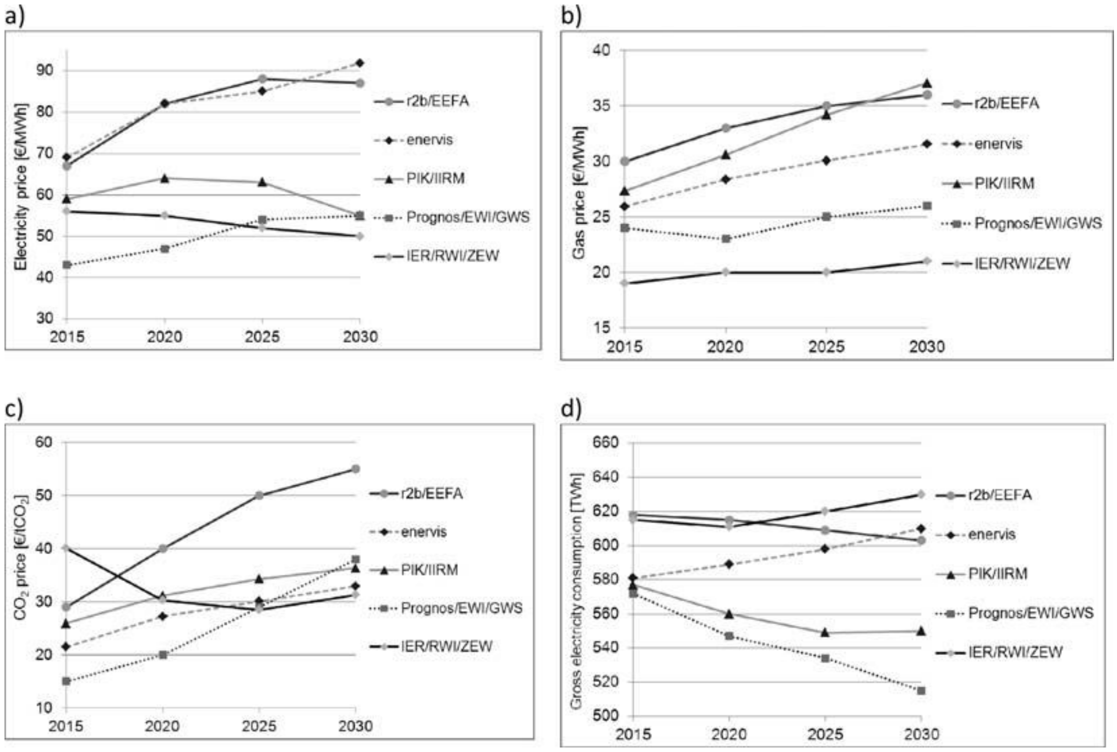

FIGURE 5

Results and assumptions from different studies. a) Wholesale prices for a nuclear phase-out in 2022, and input assumptions for b) gas prices, c) CO_2 prices and d) gross electricity consumption. PIK/IIRM refers to this publication. Enervis assumes a phase-out by 2020.

4. POLICY IMPLICATIONS OF THE MODELING RESULTS

The model-based analyses were mainly performed in the years 2010 and 2011, so the results are based on core assumptions that reflect the expectation of that time, namely the development of renewable capacities and the development of CO_2 prices. Do the assumptions of that time hold in the current debate about the Energiewende? And what can we learn from these modeling results today and for the future, retrospectively, around two years after the decision on the nuclear phase-out was taken? In the following, we relate the policy implications of this analysis to the three energy policy goals of competitiveness, environmental effectiveness and security of supply. We compare model results with de facto developments and trace back the differences to model assumptions.

The model-based studies concentrated mainly on the aspect of *competitiveness* in terms of the magnitude of spot market prices, as increasing prices might potentially challenge the competitiveness of the German industry (e.g. dpa, 2011; Handelsblatt, 2012; Manager-Magazin, 2012). Most models show increasing spot market prices, while at the moment the opposite is observed. The modeling studies all assumed increasing fossil fuel prices and, more importantly, increasing CO_2 prices (except in one study). However the situation today is very different: we are a long way off the assumed starting price of at least 15 €/tCO_2 in 2015 (see Figure 5c), and currently face the lowest prices since 2008 at 3€/tCO_2 in May 2013 (EEX, 2013). This, inter alia, has an effect on the spot market price which at 32€/MWh as a monthly average in May 2013 is at its lowest level since 2009 (IWR, 2013). In addition, fossil fuel prices have increased only slightly between 2011 and 2012 and currently show a decreasing trend (BDEW, 2013c). These two developments—together with the merit-order effect of renewables (see below)—explain why retail prices for industrial consumers (excluding taxes and FIT levy) have been stable between 2009 and 2012 and are decreasing in 2013 (BDEW, 2013c). Thus the expected effect of the nuclear phase-out on the spot market price has been partly compensated for, and the burden for the German industry from the nuclear phase-out is in fact smaller than projected by the model-based analyses. This emphasizes that nuclear energy is mainly important for curbing the increase of electricity prices when CO_2 prices are high. In response to the low spot market prices the FIT levy increased considerably from 3.6 ct/kWh in 2012 to 5.3 ct/kWh in January 2013, due to the counteracting effect of both price components described in Section 2.3. As a result, the most debated issue in the context of the Energiewende is currently the increase in consumer electricity prices and the related distributional issue (Neuhoff et al., 2013), but this goes beyond the model analysis.

Environmental effectiveness, i.e. the influence of the nuclear phase-out on CO_2 emissions, was not the key aspect of the modeling studies. However, it is becoming increasingly important in Germany and Europe, due to the decreasing CO_2 allowance price. This not only affects the spot market price directly, but also via the merit order, so that coal will be more cost competitive in comparison to gas (see Section 2.3). However, since coal is more emission intensive than gas, this would result in an increase in total CO_2 emissions. This has important implications both in the short-term and the long-term. In the short-term, as argued in Section 2.4, emissions are capped at the EU level. However, this could endanger the national target of 40% GHG emission reduction by 2020 (Ziesing, 2013). In this context it is important to note that energy related CO_2 emissions have increased slightly in 2012, partly due to a colder winter and more heating demand, but also due to higher emissions from hard coal and lignite (AGEB, 2013). For the long-term, a low CO_2 price sets problematic incentives: if investments into coal capacities instead of gas power plant are incentivized, this has an effect on future CO_2 emissions. In Figure 3 we have shown, based on the model results, that a switch from coal to gas could decrease the emissions, which would not happen at low CO_2 prices. For the future, the low CO_2 price at the European level and a switch from gas to coal could endanger not only Germany's emissions targets, but also European emissions, especially if no clear signal for a GHG reduction target at 2030 is provided. Therefore, the discussion about a new EU framework for 2030 is of considerable importance (European Commission, 2013). Otherwise a lock-in into coal-based power plants might occur in Germany and in the EU, driven by the combination of the nuclear phase-out and a low CO_2 price (see Pahle et al., 2013) that reflects the lack of a reliable future framework and targets.

Security of supply is not directly addressed by the models, but it is implicitly assumed that enough replacement capacities are available. This might be the strongest (model) assumption and—besides increasing consumer prices—currently one of the most debated and crucial issues in the nuclear phase-out discussion (BMWi, 2013). As assumed in the models and as planned during the first decision of the nuclear phase-out, fossil fuel replacement capacities are indeed being built, see Section 2.2. In addition, the increase in renewable capacities has greatly exceeded expectations. The models in Section 3 assume that electricity generation from renewables will account for about 130–165 TWh in 2015. In fact, renewables were already generating 135 TWh in 2012 (BDEW, 2013b), so that expected deployment by 2015 will be higher than assumed by the models. In general, this has a positive effect on the security of supply, but it also comes with some drawbacks.

First, renewables are not necessarily deployed where nuclear power plants are taken off the grid. Current transfer capacity is limited or is under construction (Bundesnetzagentur, 2012) and is often not yet available. This might lead to regional supply problems, especially in Southern Germany. Many observers expect this to become apparent when the nuclear power plant in Grafenrheinfeld in Bavaria is switched off in 2015 with no available (regional) replacement capacities or new power grids (BMWi, 2013). This problem is exacerbated by the current price developments (see above), which cause gas power plants to become increasingly unprofitable and go offline. While this is not worrying from the overall market perspective, the plants located in the south are deemed relevant for system stability. Largely for this reason, there is currently a political debate as to whether an energy only market can provide the relevant price signals, or whether specific capacity mechanisms are needed (see Agora Energiewende (2013) for an overview of different proposals). However, from an economic point of view, such a market-wide long-term mechanism is clearly the wrong solution for a transitory and regional problem (Cramton and Ockenfels, 2012). Moreover, if such a mechanism is to be set up, it should be considered, for efficiency reasons, in the framework of the European internal energy market. This requires European coordination.

To conclude, model projections differ from current observations because some crucial assumptions of the model-based analysis have not held. This implies that it is not possible to isolate the effect of the phase-out decision on electricity prices and CO_2 emissions. In such a context it is important to note that the results stem from partial electricity sector models that only investigate the influence of the phase-out on some central variables, such as the electricity price. In all of these models the deployment of renewables is given exogenously. Therefore, they miss the (positive or negative) welfare effects of the expansion of renewable energy (Edenhofer et al., 2013) and the interplay with the nuclear phase-out. The deployment of renewables has largely grown through policy intervention and the justification and the degree of subsidies for renewables is part of the current debate. These questions are beyond the modeling frameworks and need further research. This is in addition to the analysis of the interaction of renewable supporting schemes with other instruments, such as the EU ETS (Kalkuhl et al., 2012).

5. CONCLUSIONS

In this paper we have reconsidered modeling studies that were performed to analyze the German nuclear-phase out of 2011. The core of the modeling exercise, with the electricity market model MICOES, was an extensive sensitivity analysis on critical input assumptions, such as fossil fuel prices, CO_2 prices and the development of renewable energy deployment. By comparing our model results to those of other studies, we have concentrated on the crucial drivers behind the results and have deduced some policy implications for the situation-as-is.

The model-based analysis shows that the nuclear phase-out has a visible effect on the wholesale electricity prices. On the other hand, uncertainty in some input assumptions, such as the development of the gas price or energy efficiency, has a stronger effect than the timing of the nuclear phase-out. This implies that exogenous drivers and assumptions determine the electricity prices to a much greater extent than the phase-out itself. From comparison with other studies, we can conclude that different assumptions lead to a variety of developments of the electricity price which implies that the future development of electricity prices in Germany is highly unpredictable. For the period between 2015 and 2030, three out of five models show an increase in electricity prices while two show a decrease. We make the point that crucial assumptions at that time, for example concerning increasing CO_2 prices, have developed differently. This partly counteracts the negative effect of the nuclear phase-out on electricity prices, but on the other hand challenges the mitigation of CO_2 emissions.

The sensitivity analysis has revealed that some assumptions have a substantial influence on the model output, i.e. the electricity price. Whereas some of these assumptions, for example the expansion of renewables or developments regarding energy efficiency, can be addressed by policy measures, some others, for example the gas price, are independent of national policies. This implies that policy-makers need to consider scenarios that analyze the whole range of possible future developments. For this task, a structured model comparison with harmonized input assumptions is required. Robust pathways that are valid under a range of assumptions and across a range of models could be identified from such an analysis.

The modeling studies presented have tried to isolate the effect of the nuclear phase-out by reflecting other important drivers through exogenous assumptions. Two years after the decision to phase-out nuclear it turns out that some assumptions valid at that time have changed and that the nuclear phase-out cannot be assessed in isolation from the broader context. This context incorporates other developments such as the European CO_2 price or the development of renewable capacities. Some of these aspects point towards a European solution (Fischer and Geden, 2011). The EU ETS should be considered as crucial element for a German mitigation strategy and more effort should be put on re-strengthening this instrument. With a well-functioning EU ETS, CO_2 is avoided where emission reduction is cheapest, thus enabling cost reduction of mitigation in Germany and all other European countries. The further development of the EU emissions trading system is extremely important for future climate and energy policy, although it might be difficult to implement a scheme with a high enough carbon price and one that is able to cover all emissions. With this in mind, an early agreement on a European GHG reduction target for 2030 should be an urgent issue on the policy maker's agenda. The security of supply also needs to be considered in a European perspective to avoid lock-ins into national mechanisms considered necessary to ensure adequate capacity. It goes without saying that this requires European coordination beyond the current extent.

As initially indicated, we concentrated solely on the effect of the nuclear phase-out on electricity prices for industry and on CO_2 emissions. Most modeling studies failed to investigate some of the most relevant factors in the current context, for example the decrease of CO_2 prices, the rapid increase of renewables and the aspect of security of supply. But the sensitivity analysis and the policy implications that we deduced from that indicates that the different interacting instruments of renewable supporting schemes, emission pricing and capacity mechanisms for ensuring the security of supply emerge as the future challenges that have to be tackled today. However these are the challenges of the entire "Energiewende", i.e. the transformation towards a "road into the age of renewables". The influence of the nuclear phase-out on this strategy seems to be only one of several challenges—and probably a small one at that.

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Chapter 4

EE Förderinstrumente & Risiken: Eine ökonomische Aufarbeitung der Debatte zur EEG Reform*

Michael Pahle
Oliver Tietjen
Fabian Joas
Brigitte Knopf

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POTSDAM-INSTITUT FÜR KLIMAFOLGENFORSCHUNG

PIK

EE Förderinstrumente & Risiken: Eine ökonomische Aufarbeitung der Debatte zur EEG Reform

Diskussionspapier, März 2014

Dr. Michael Pahle*
Oliver Tietjen
Fabian Joas
Dr. Brigitte Knopf

*Kontakt: michael.pahle@pik-potsdam.de

1. Einleitung

Die neue Bundesregierung hat sich zum Ziel gesetzt, das Gesetz zur Förderung der EE noch in diesem Jahr grundlegend zu reformieren und dafür am 10. Februar einen Gesetzentwurf vorgelegt. Weil sich eine solche Maßnahme schon seit längerem abzeichnete, sind dafür in den letzten zwei Jahren eine Reihe von Vorschlägen für die Ausgestaltung eines entsprechenden Förderinstruments veröffentlich worden, von denen Tabelle 1 eine Auswahl zeigt. Allen Studien ist gemeinsam, dass Kosten bzw. Effizienz als Designkriterium für die Ausgestaltung des Förderinstruments eine besondere Rolle spielen. Dies liegt nicht zuletzt daran, dass die gestiegenen Förderkosten des EEG als ein wesentlicher Grund genannt werden, um die Förderung zu reformieren. Auch wenn in vielen Studien eine Reihe von weiteren Kriterien zum Einsatz kommt, sind die Kosten politisch von besonderer Relevanz.

Autoren / Auftraggeber	**Studie**
Agora Energiewende (2013)	*Ein radikal vereinfachtes EEG 2.0 und ein umfassender Marktdesign-Prozess*
BDI (2013)	*Energiewende ganzheitlich denken*
BDEW (2013)	*Vorschläge für eine grundlegende Reform des EEG*
Enervis & BET (2013) [im Auftrag des VKU]	*Ein zukunftsfähiges Energiemarktdesign für Deutschland*
Frondel et al. (2012) [RWI; im Auftrag der NISM]	*Marktwirtschaftliche Energiewende: Ein Wettbewerbsrahmen für die Stromversorgung mit alternativen Technologien*
Frontier Economics (2012) [im Auftrag von EnBW]	*Die Zukunft des EEG – Handlungsoptionen und Reformansätze*
Haucap & Kühling (2012) [im Auftrag des SMWA]	*Marktintegration der Stromerzeugung aus erneuerbaren Energien*
Jacobs et al. (2013) [IASS]	*Eckpunkte für die Gestaltung der Energiewende*
Kopp et al. (2013) [arrhenius, Ecofys, MVV & Takon]	*Wege in ein wettbewerbliches Strommarktdesign für erneuerbare Energien*
Leprich et al. (2013) [IZES, Universität Würzburg & BET; im Auftrag der BW Stiftung]	*Stromsystem-Design: Das EEG 2.0 und Eckpfeiler eines zukünftigen Regenerativwirtschaftsgesetzes*
Löschel et al. (2013) [ZEW]	*Den Strommarkt an die Wirklichkeit anpassen: Skizze einer neuen Marktordnung*
Monopolkommission (2013)	*Energie 2013: Wettbewerb in Zeiten der Energiewende*
SR Umwelt (2013)	*Den Strommarkt der Zukunft gestalten*
SR Wirtschaft (2013)	*Energiepolitik: Warten auf die dringend notwendigen Weichenstellungen. Kapitel 10 des Jahresgutachten 2013/14*

Tabelle 1: Vorschläge zur EEG Reform bzw. zum Strommarktdesign

Im Hinblick auf die Kosten ist ein Aspekt von zentraler Bedeutung: die mit der Wahl des Förderinstruments verbundenen Risiken bzw. deren Verteilung zwischen Investoren und Konsumenten. Dies zeigt sich vor allem am Beispiel der handelbaren Grünstromzertifikate (Quote). Befürworter dieses Instruments verweisen darauf, dass Investoren durch die damit verbundene Übernahme von Risiken Anreize zu effizienterem Handeln haben. Gegner dieses Instruments hingegen verweisen auf die anfallenden Kosten durch vergleichsweise hohe Risikoprämien. Dieses Beispiel zeigt, dass Risiko – in Form von „Vermeiden“ und „Übernehmen“ – gleichzeitig als Argument für und gegen ein und dasselbe Förderinstrument angebracht wird. Diese unterschiedlichen Standpunkte ziehen unterschiedliche Forderungen nach der Allokation des Risikos mit sich, die letztendlich den Kern der Debatte um die Reform des EE Förderinstruments darstellen.

Doch obwohl Risiken eine wichtige Rolle spielen werden sie in den Vorschlägen – wenn überhaupt – meist nur oberflächlich behandelt. Dabei gibt es eine Reihe von wichtigen Fragen, die in diesem Zusammenhang immer wieder auftauchen: Was bedeutet Risiko überhaupt und in welchem Zusammenhang steht es mit Unsicherheit? Können Risiken reduziert bzw. komplett vermieden werden? Welche Risiken sind überhaupt mit der Förderung der EE verbunden und wie werden sie durch unterschiedliche Instrumente auf Investoren und Konsumenten verteilt? Und in welchem Zusammenhang stehen Marktintegration und Risiken?

Dieses Papier beleuchtet diese Fragen aus ökonomischer Sicht und ordnet die Ergebnisse abschließend politisch ein. Dabei werden an wesentlichen Stellen Argumente und Positionen aus ausgewählten Vorschlägen aufgegriffen, um davon ausgehend den jeweiligen Sachverhalt zu erörtern bzw. um diese Argumente zu beleuchten. Das Ziel dieses Papiers ist damit, die Debatte um die EE Förderinstrumente im Hinblick auf die mit Bezug zu Risiken vorgebrachten Argumente aus ökonomischer Sicht aufzuarbeiten; eine unmittelbare Bewertung der Instrumente erfolgt nicht.

Das Papier ist wie folgt aufgebaut: Abschnitt 2 beginnt mit einer grundlegenden Betrachtung des Risikos für die Kosten der Stromversorgung aus gesellschaftlicher Sicht. Es wird dargestellt, worin dieses Risiko besteht, wie es ggf. reduziert werden kann und ob es in dieser Hinsicht eine Unterscheidung zwischen öffentlichen und privaten Investitionen geben sollte. Auf dieser Basis wird erläutert, dass die Reduzierung von Risiken für EE Investoren durch bestimmte Förderinstrumente lediglich zu einer Verschiebung dieser Risiken auf andere Investoren bzw. Stromkunden und damit unterschiedlichen Risikoallokationen führt, das gesellschaftliche Gesamtrisiko dabei allerdings erhalten bleibt. In Abschnitt 3 werden die Risikoallokationen unterschiedlicher Förderinstrumente genauer betrachtet und erläutert, welche konkreten Risiken bestehen und wie sich diese ggf. durch die Steuerung eines Instruments reduzieren lassen. In Abschnitt 4 werden die unterschiedlichen Risiken der verschiedenen Förderinstrumente für EE Investoren genauer beschrieben. Es wird dargestellt, dass die Marktintegration der EE gleichbedeutend mit der Übernahme von Risiken ist, deren letztendlich erwünschter Effekt eine Verhaltensänderung ist, die das Eigeninteresse der Investoren im Markt in unternehmerische Initiative zum gesellschaftlichen Wohl übersetzt (dynamische Effizienz). Dabei wird auch diskutiert, welche Auswirkungen das Tragen von Risiken auf die Struktur der Akteure bzw. Investoren hat. In Abschnitt 5 werden die obigen Befunde zusammengefasst und vor diesem Hintergrund die aktuellen Eckpunkte der Bundesregierung zur EEG Reform eingeordnet und diskutiert.

2. Gesellschaftliches Kostenrisiko & Risikokosten der EE Förderung

Im Hinblick auf die Risiken der EE Förderung stellt sich zuallererst die Frage, welches konkrete Risiko aus gesellschaftlicher Sicht überhaupt von Belang ist und wodurch es entsteht. Aus ökonomischen Sicht wird im Fall gegebener politischer Ziele in der Regel die Kosteneffektivität als Evaluationskriterium herangezogen, also zu welchen Kosten dieses Ziel jetzt und in Zukunft erreicht werden kann. Dabei muss jedoch berücksichtigt werden, dass die Erzeugung von EE Strom mit der sonstigen Stromversorgung interagiert. Aus diesem Grund sind volkswirtschaftlich gesehen nicht allein die Förderkosten für EE Strom relevant, sondern die gesamten Kosten der Stromversorgung bei einem gegebenen Ziel für den EE Stromanteil.

Ganz allgemein – und vorerst unabhängig von den EE – besteht hinsichtlich dieser Kosten der Stromversorgung dahingehend ein Risiko, dass aus heutiger Sicht Unsicherheiten darüber bestehen, mit welchem Technologiemix zukünftig die geringstmöglichen Gesamtkosten zu erreichen sind. Denn wesentliche Kostenfaktoren wie zum Beispiel Anlagen- und Brennstoffpreise verändern sich im Lauf der Zeit und sind langfristig nur schwer vorhersagbar[1]. Daher ist das Tätigen von Investitionen bzw. der Ausbau des Kraftwerkparks mit einem Kostenrisiko verbunden, das in Anlehnung an die Risikodefinition von Kast & Lapied (2006:2) wie folgt definiert werden kann: Heutige (sichere) Investitionen in Erzeugungskapazitäten transformieren sich in eine Verteilung von zukünftigen Stromversorgungskosten. Von Bedeutung dabei ist, dass sich nach der gängigen Definition von Knight (1921) Risiko nur auf den Teil der Unsicherheit bezieht, der sich über konkrete Wahrscheinlichkeiten quantifizieren lässt. Das bedeutet, dass Risiko eine prinzipiell kalkulierbare Größe ist und sich wie in Abbildung 1 schematisch dargestellt aus einer Wahrscheinlichkeitsverteilung ableitet. Die blaue Linie entspricht der Wahrscheinlichkeitsverteilung der zukünftigen Kosten (C); die rote vertikale Linie kennzeichnet den Mittelwert und die rote horizontale Linie die Standardabweichung, die häufig als Maß für das Risiko herangezogen wird.

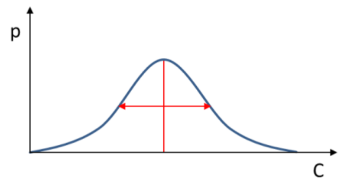

Abbildung 1: Schematische Darstellung des Risikos zukünftiger Kosten

Angesichts dieser Situation stellt sich die Frage, ob und wie das Kostenrisiko gegebenenfalls reduziert werden kann. Ansätze und Verfahren dafür liefert die Portfoliotheorie, die Investitionsverhalten und -strategien an Kapitalmärkten untersucht; eine kurze Darstellung der Grundlagen findet sich zum Beispiel bei Awerbuch & Berger (2003). Die auf Basis dieser Theorie ermittelten effizienten Portfolien kennzeichnen sich dadurch, dass sie die erwarteten Kosten für ein gegebenes Risiko minimieren bzw. für gegebene erwartete Kosten das Risiko minimieren. In anderen Worten: ein effizientes Portfolio nimmt kein unnötiges Risiko in Kauf (Awerbuch & Berger 2003:4). In der Menge aller möglichen Portfolios bilden die effizienten Portfolios den sogenannten „effizienten Rand" (*risk efficent frontier*), der in Abbildung 2 als blaue Kurve entlang der (effizienten) Portfolien A-B-C schematisch für die gesellschaftliche Kostenper-

[1] Analog zum Kostenrisiko besteht auch ein Nutzenrisiko, das allerdings hier nicht betrachtet wird.

spektive[2] dargestellt ist. Die Menge aller möglichen Portfolien liegt „rechts" dieser Kurve und ist beispielhaft durch das (nicht-effiziente) Portfolio D dargestellt.

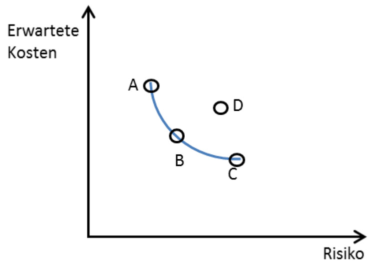

Abbildung 2: Schematischer effizienter Rand (gesellschaftliche Perspektive)

Kernidee der Portfoliotheorie ist, dass das Risiko von Investitionen durch Diversifizierung reduziert werden kann. Diversifizierung beruht auf dem Umstand, dass die Varianz der zukünftigen Kosten – also das Risiko – eines Portfolios geringer ist als die Summe der einzelnen Varianzen aller Anlagen innerhalb des Portfolios, sofern deren Risiken nicht vollständig miteinander korreliert sind (*portfolio effect*). Übertragen auf die Stromversorgung bedeutet dies, dass sich das Kostenrisiko durch eine geeignete Diversifizierung des Technologiemixes bzw. der entsprechenden Investitionen reduzieren lässt. Beispielsweise kann es bei unsicheren Brennstoffpreisen weniger riskant sein, ein Kohlekraftwerk und ein Gaskraftwerk zu bauen als nur ein Kraftwerk (Gas oder Kohle) mit der gleichen Gesamtkapazität, da das Preisrisiko beider Brennstoffe nicht vollständig miteinander korreliert ist. Diese Theorie wird im Stromsektor seit den 70er Jahren sowohl aus gesellschaftlicher als auch privatwirtschaftlicher Perspektive angewendet; eine Übersicht über bisherige Arbeiten und weitere Anwendungen finden sich bei Roques et al. (2008) und Lynch et al. (2013).

Die Reduzierung des Risikos durch Diversifizierung bedeutet allerdings gleichzeitig, dass sich der Erwartungswert der Kosten der Stromversorgung erhöht. Das ergibt sich aus dem Verlauf des effizienten Rands: je geringer das gegebene Risiko, desto höher die erwartete Kosten des Portfolios. Ein gegenüber zukünftigen Kostenrisiken besser abgesicherter Technologiemix führt also zu höheren erwarteten Kosten der Stromversorgung und entsprechend zu höheren Strompreisen. Dieser Effekt ist in Abbildung 3 dargestellt.

[2] Bei privaten Investoren ist der Bezugspunkt der Ertrag und nicht die Kosten. In diesem Fall ist der effiziente Rand konkav und nicht konvex.

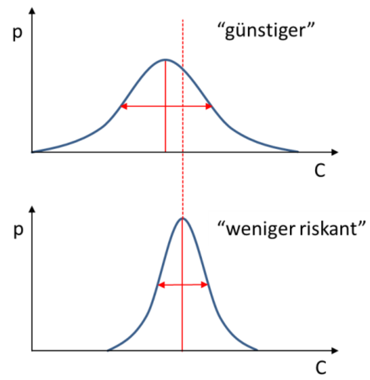

Abbildung 3: Schematische Darstellung der erwarteten Kosten & Risiken zweier Portfolien

Wie entscheidet sich nun die Wahl zwischen einem eher riskanten (aber erwartet günstigerem) und einem eher weniger riskantem (aber erwartet teurerem) Portfolio? In dieser Hinsicht maßgeblich ist die Risikoaversion der Gesellschaft bzw. der Investoren, die diese Entscheidung treffen. Risikoneutrale Investoren sind indifferent gegenüber Risiko und entscheiden sich für das „günstigere“ Portfolio, wohingegen sich risikoaverse Investoren für das „weniger riskante“ Portfolio entscheiden. Entscheidend dafür ist, in welcher Form die Stromversorgung organisiert ist bzw. durch welche Akteure die Gesellschaft Investitionen tätigt. In einem liberalisierten Markt sind die dezentralen Risikoaversionen der privaten Akteure ausschlaggebend, in einem regulierten Markt hingegen die „zentrale Risikoaversion“ des Regulierers bzw. Staates. Die Frage, ob und wie sich die Risikoaversion in beiden Fällen unterscheidet bzw. unterscheiden sollte wird weiter unten diskutiert. Davon abgesehen gilt auf individueller Ebene, dass Menschen in der Regel umso risikoaverser sind, je höher der Wert der Investition ist (*risk averse at the margin*) (Harrison 2010:39)[3]. Die grundsätzliche Risikobereitschaft bzw. -wahrnehmung wird dabei vermutlich durch kulturelle und genetisch Faktoren bedingt (Barnea, Cronqvist, et al. 2010).

Wenn das Risiko einer Investition die Risikobereitschaft eines Investors überschreitet stehen drei mögliche Kontrakte zum Transfer von Risiko (*risky contracts*) zur Verfügung, die entweder auf Finanzmärkten oder bilateral gehandelt werden (Kast & Lapied 2006:2): (a) Risikoteilung (*risk sharing*) zwischen mehreren Akteuren bzgl. der Investitionen und Erträge, (b) Aufnahme von Fremdkapital mit entsprechender Übertragung des Risikos, und (c) Versicherung. In den beiden letzten Fällen verlangt die Gegenseite (Kapitalgeber bzw. Versicherer) eine zusätzliche Risiko- bzw. Versicherungsprämie, die der Differenz zwischen erwartetem Ertrag und dem sogenannten Sicherheitsäquivalent (*certainty equivalent*) entspricht. Diese Prämien erhöhen als sogenannte Risikokosten (*cost of risk*) zwar die Kosten einer Investition, führen allerdings gleichzeitig zu einer effizienten Risikoallokation: Jeder Akteur trägt genau das Risiko, das er bereit ist zu tragen. Im Hinblick auf die Stromversorgung bedeutet dies, dass sich die Wahl des Risiko-Kosten-Verhältnis des Technologiemixes bzw. Portfolios als Konsequenz der sich über die Märkte (Strommarkt und Finanzmarkt) einstellenden Risikoallokation ergibt.

[3] Dies trifft insbesondere auf „einseitiges“ Risiko zu; beispielsweise werden beim Lottospiel geringer Beträge in Hoffnung auf mögliche hohe Gewinne gesetzt, während mögliche hohe Verluste durch Versicherungen abgesichert werden (Friedman & Savage 1948).

Was bedeuten diese Ausführungen nun im Hinblick auf die Debatte um das Förderinstrument für EE? Numerische Analysen wie beispielsweise von Kitzing (2014) für Windenergie in Dänemark bestätigen, dass Instrumente mit höheren Marktrisiken für Investoren auch höhere Risikoprämien und damit Vergütungssätze erfordern. In dieser Hinsicht wird wie oben beschrieben häufig argumentiert, dass vor allem die Quote wegen vergleichsweiser hoher Risikoprämien letztendlich „zu teuer" sei. Wie allerdings erläutert stellen diese Prämien keine zusätzlichen bzw. „nicht notwendigen" Kosten dar, weil sie prinzipiell zu einer effizienten Allokation des Risikos und damit einem im Verhältnis von Risiko und Kosten effizienten Technologiemix führen. Daher gilt für den Fall der Förderung durch das EEG, wo aufgrund der festgelegten Vergütung keine oder nur sehr geringe Risikoprämien fällig werden, dass das Risiko nicht „verschwindet", sondern lediglich von EE Investoren auf Investoren in Konventionelle und Stromverbraucher übertragen wird. Dies ist ein entscheidender Aspekte, der in der Debatte vor allem bei der Kritik an der Quote häufig außer Acht gelassen wird; siehe dazu auch die Ausführungen der Monopolkommission (2013:148).

Aus Sicht von Bofinger (2013) bestehen an dieser Schlussfolgerung jedoch Zweifel, weil das Tragen des Risikos durch den Verbraucher letztendlich mit geringeren Kosten verbunden sei. Ausgangspunkt seiner Kritik ist die mit der Monopolkommission übereinstimmende Feststellung von Frontier Economics (2012), dass es aus gesellschaftlicher Sicht irrelevant sei, ob die Risiken von Investoren oder Stromverbrauchern getragen werden. Er kritisiert dies wie folgt: „*Diese Argumentation übersieht […], dass man Risiken in einer Volkswirtschaft durch Diversifikation reduzieren kann. Genau hierin besteht der entscheidende Vorteil der Preissteuerung. Die EEG-Umlage beläuft sich derzeit auf rund 0,5 % der Ausgaben eines durchschnittlichen Privathaushalts. Selbst eine unerwartete Verdopplung der Kosten der Preissteuerung würde für die meisten Haushalte somit keine merkliche Belastung bedeuten. Die Risiken der Preissteuerung werden also aufgrund ihres sehr geringen Anteils an den Verbrauchsausgaben nahezu perfekt diversifiziert.*" (Bofinger 2013:30).

Die Details dieses Arguments erläutert Bofinger zwar nicht, aber im Kern handelt es sich dabei um das sogenannte Arrow-Lind Theorem (Arrow & Lind 1970)[4]. Es lässt sich nach Baumstark & Collier (2013) wie folgt zusammenfassen: „*When an investment project yields socio-economic net benefits that are uncertain but independent of the systematic risk of the economy, these benefits should be discounted at the risk free rate if they are disseminated among a large population of stakeholders. This may be the case of a public project whose benefits are distributed within the large population of taxpayers*". Seine beiden Kernaussagen sind die folgenden (vgl. Jensen & Bailey 1972:4): Erstens, aufgrund der angenommenen Unabhängigkeit vom systematischen Risiko stellt das Projekt eine Versicherung gegenüber der gesamten makroökonomischen Entwicklung dar (Risikodiversifizierung). Zweitens, durch die Verteilung des Risikos auf eine sehr große Zahl von Steuerzahlern fällt der anteilige Betrag relativ gering aus. Unter Annahme sinkender Risikoaversion bzw. marginalen Risikokosten einzelner Individuen bei sinkenden Risiken (siehe oben) wäre die individuelle Risikoprämie damit quasi null (Reduzierung der Risikokosten durch Risikoteilung), was in Abbildung 4 verdeutlicht ist.

[4] Weiterhin sprich Bofinger von einer Risikodiversifizierung, meint allerdings in dem von ihm beschriebenen Argument eine Risikoteilung (siehe oben). Diversifizierung ist jedoch auch ein Bestandteil des Theorems.

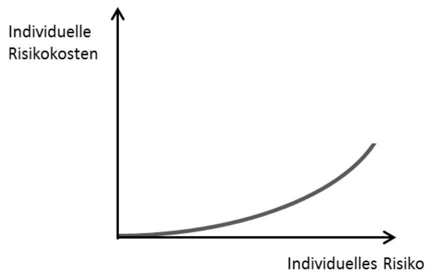

Abbildung 4: Individuelle Risikokosten (nach Baumstark & Gollier 2013)

Beiden Aussagen unterliegen jedoch relativ spezifische Annahmen, die nicht ohne weiteres auf jedes in der Praxis durchgeführte öffentliche Projekt übertragen werden können. In dieser Hinsicht ist das Arrow Lind Theorem vielfach kritisiert bzw. weiter differenziert worden, z.B. ursprünglich von Jensen & Bailey (1972) und in den letzten Jahren von Kast & Lapied (2006), Harrison (2010) und Baumstark & Gollier (2013). Dies betrifft einerseits die Unabhängigkeit des Risikos vom gesamten makroökonomischen Risiko (*systematic risk*): Man kann nicht davon ausgehen, dass öffentliche Projekte tendenziell eine geringere Korrelation haben als private Projekte[5]. Da sich das „gesellschaftliche Portfolio" aus der Summe aller privaten und öffentlichen Portfolien zusammensetzt, besteht also hier kein systematischer Unterschied. Dementsprechend findet auch keine Diversifizierung bzw. Reduzierung des Risikos statt[6]. Im Hinblick auf die Risikoteilung gibt es zwei wesentliche Gegenargumente: Erstens, anders als die Kosten sind die Nutzen öffentlicher Projekte in der Regel nicht wie von Arrow und Lind angenommen gleich verteilt. Zweitens, Finanzmärkte können die Risiken insgesamt effizienter als der Staat verteilen. Effizient bedeutet dabei, dass jeder Einzelne durch individuelle Beteiligungen an mehr oder weniger riskanten Anlagen bzw. Investitionen an diesen Märkten selbst entscheiden kann, wie viel Risiko er eingehen möchte. Das Risiko wird also insgesamt von den Akteuren und Individuen getragen, die bereit sind es zu tragen bzw. für die es mit den geringsten Kosten einhergeht. Zumindest aus theoretischer Sicht sind damit die gesamtgesellschaftlichen Risikokosten minimal bzw. das Risiko effizient verteilt (siehe oben)[7].

Anders als von Bofinger postuliert reduziert das EEG bzw. eine Preissteuerung mit Übertragung der Risiken auf die Stromverbraucher daher weder das gesellschaftliche Gesamtrisiko noch dessen Kosten. Zwar unterscheiden sich die Risikoprämien bei den Förderinstrumenten – aber nur, weil sie die tatsächlich vorhandenen Risiken bzw. deren Kosten wiederspiegeln bzw. in unterschiedlichem Maß auf die EE Investoren übertragen. Insbesondere ist daher eine Kritik der Quote auf dieser Basis irreführend, denn „*this bang for the buck measure neglects the impacts on actors other than investors in renewables and those who pay subsidies*" (Schmalensee 2012:50). Diese Auswirkungen bzw. die Risikoallokationen der unterschiedlichen Förderinstrumente werden im nächsten Abschnitt genauer betrachtet.

[5] Jensen & Bailey (1972) nennen als Beispiel Infrastrukturen wie Straßen und Strom, deren gesellschaftlicher Wert mit dem wirtschaftlichen Output steigt bzw. fällt, deren Risiken also korreliert sind.
[6] Darüber hinaus bestehen angesichts einer Reihe von historischen Beispielen Zweifel, ob der Staat bei öffentlichen Investitionen überhaupt aktiv das Risiko steuert (Harrison 2010:40).
[7] In der Praxis gilt dies in vollem Umfang allerdings nur dann, wenn „*perfect markets for the fractional claims on the return on assets*" existieren (Jensen & Bailey 1972:12).

3. Risikoallokation bei unterschiedlichen EE Förderinstrumenten

Im Folgenden werden die Risikoallokation der gängigen Instrumente – also welche Akteure bei welchem Förderinstrument welches Risiko tragen – in einem stilisierten quasistatischen Modellrahmen untersucht, wobei aus formalen Gründen nur Risiken für Investoren betrachtet werden[8]. Die Analyse unterscheidet vereinfachend nicht zwischen Erzeugung und Investitionen (Kapazität) und geht davon aus, dass nur über die Grenzkosten der EE Unsicherheit besteht. Die durch Wetterunsicherheiten bedingten Unsicherheiten der Erzeugung von fluktuierenden EE werden vorerst nicht betrachtet, aber im Anschluss diskutiert. Weiterhin wird nur eine generische EE Technologie betrachtet und idealisierte Märkte bzw. Förderinstrumente angenommen[9]. Der Ablauf der Entscheidungen innerhalb des Modells ist wie folgt: Im ersten Schritt legt ein Regulator die Förderhöhe des Instruments so fest, dass gemäß den erwarteten Kosten ein bestimmtes EE Mengenziel erreicht wird. Im zweiten Schritt löst sich die Unsicherheit auf und das jeweilige Marktgleichgewicht zwischen erneuerbarer und konventioneller Erzeugung stellt sich ein. Da diese Analyse eine Reihe von vereinfachenden Annahmen trifft wird abschließend diskutiert, in welchem Umfang die Ergebnisse auf die konkrete deutsche Situation übertragbar sind und was dies für den Unterschied bzgl. des regulatorischen Risikos bedeutet.

Im Fall einer fixen Einspeisevergütung wie in Abbildung 5 dargestellt legt der Regulator eine Vergütung fest, durch die sich die EE vollständig finanzieren. Die Menge an erzeugten EE Strom (q_{EE}) ist von links nach rechts dargestellt und ergibt sich damit ausschließlich über die Grenzkosten der EE und die Höhe der Einspeisevergütung (EV). Die Menge an erzeugtem konventionellem Strom (q_{KV}) ist von rechts nach links dargestellt und ergibt sich aus der Differenz von Gesamtnachfrage (Q) und erzeugtem EE Strom. Der Strompreis entspricht den Grenzkosten der konventionellen Stromerzeugung. Der Regulator legt wie beschrieben die Einspeisevergütung (EV) so fest, dass sich bei den erwarteten Grenzkosten die durch das Ausbauziel vorgegebene Menge an EE einstellt. Weichen die tatsächlichen Kosten allerdings nach unten oder oben ab, so ergeben sich unterschiedliche EE Mengen, die nur durch die Kosten der EE bestimmt sind, weil der Strompreis nicht Teil der Erlöse ist. Diese Spreizung stellt ein EE Mengenrisiko (ΔQ_{EE}) dar, das sich auf den Anteil an konventioneller Erzeugung bzw. den Strompreis überträgt, und somit ein Strompreisrisiko (Δp) für Investitionen in Konventionelle darstellt.

[8] Das Risiko für Konsumenten setzt sich aus zwei zusammenhängenden Komponenten zusammen (Strompreisrisiko, Vergütungsrisiko). Die relative Höhe dieses Risiko kann nicht ohne weiteres grafisch bestimmt werden.
[9] Eine ähnliche, aber weniger umfangreiche Analyse findet sich bei Schmalensee (2012).

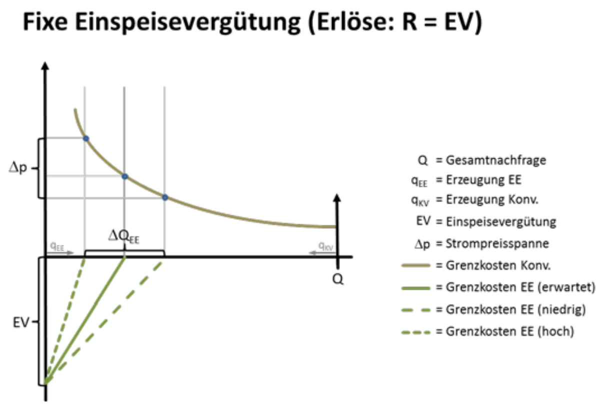

Abbildung 5: Fixe Einspeisevergütung

Im Fall einer Förderung mittels einer Quote wie in Abbildung 6 dargestellt setzt der Regulator lediglich die Menge, die immer „sicher“ erreicht wird, da EE Investoren genau in diesem Umfang die Differenz zwischen Kosten und Strompreis durch den Verkauf von Zertifikaten ausgleichen können. Für EE Investoren besteht jedoch hinsichtlich des Zertifikatspreises ein Vergütungsrisiko, das sich unmittelbar aus der Unsicherheit über die aggregierte EE Kostenkurve ergibt. Durch die konstante EE Menge allerdings besteht kein EE Mengenrisiko (ΔQ_{EE}) und somit auch kein zusätzliches Strompreisrisiko (Δp) für Investitionen in Konventionelle.

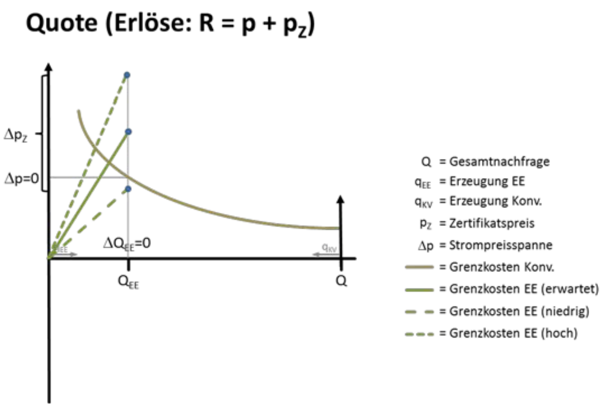

Abbildung 6: Quote

Im Fall einer Förderung mittels einer fixen Marktprämie wie in Abbildung 7 dargestellt stellt sich die Situation komplexer dar. In diesem Fördersystem übernehmen Investoren zwar ein Preisrisiko, tragen allerdings kein Vergütungsrisiko, weil ihnen eine fixe Prämie garantiert wird. Das Tragen des Preisrisikos führt dazu, dass sie die Änderung des Strompreises durch die EE Erzeugung mit einkalkulieren und sie entsprechend anpassen. Stellt sich beispielsweise heraus, dass die Kosten der EE niedriger sind als erwartet, so erhöhen sie ihre Erzeugung soweit, bis die Summe aus Strompreis und Prämie gleich den Grenzkosten der EE ist – jedoch weniger stark als bei der fixen Vergütung, weil sie das dadurch resultierende Absinken des Preises berücksichtigen. Durch diese „gegensteuernde“ Anpassung der Menge reduziert sich im Vergleich zur fixen Einspeisevergütung das EE Mengenrisiko (ΔQ_{EE}) und damit das Strompreisrisiko (Δp) für Investitionen in Konventionelle.

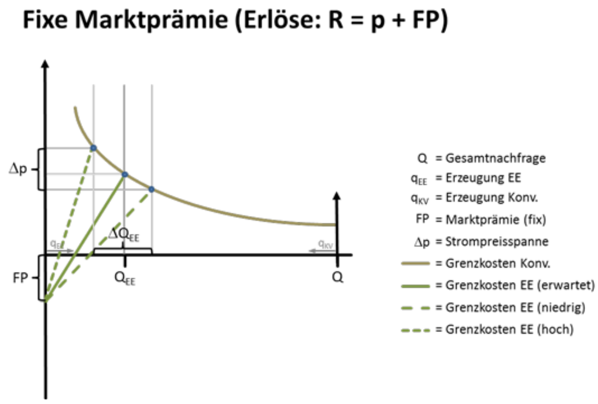

Abbildung 7: Fixe Marktprämie

Wird die fixe Marktprämie regulatorisch festgelegt, so hat auch eine eventuelle Kostenunsicherheit der Konventionellen Auswirkungen auf die entsprechenden Risiken. Dieser Fall ist in Abbildung 8 dargestellt: Das potentielle Mengenrisiko der EE (ΔQ_{EE}) wird größer, weil im Fall hoher Kosten für die EE und niedriger Kosten für die Konventionellen (Punkt A) noch weniger bzw. im umgekehrten Fall (Punkt D) noch mehr EE Strom produziert wird. Das potentielle Strompreisrisiko (Δp) steigt ebenfalls, weil im Fall hoher Kosten für die EE und hoher Kosten für die Konventionellen (Punkt B) noch mehr bzw. im umgekehrten Fall (Punkt C) noch weniger EE Strom produziert wird. Die letztendliche Ursache dieser Effekte ist, dass der Regulator bei der Festlegung der Marktprämie den späteren Strompreis berücksichtigen muss, über den allerdings durch die Kostenunsicherheit der Konventionellen ebenfalls Unsicherheit besteht. Wie sich dadurch das Gesamtrisiko für Konventionelle in diesem Fall im Vergleich zu einer Einspeisevergütung verändert, kann allerdings in dieser einfachen Analyse nicht ermittelt werden.

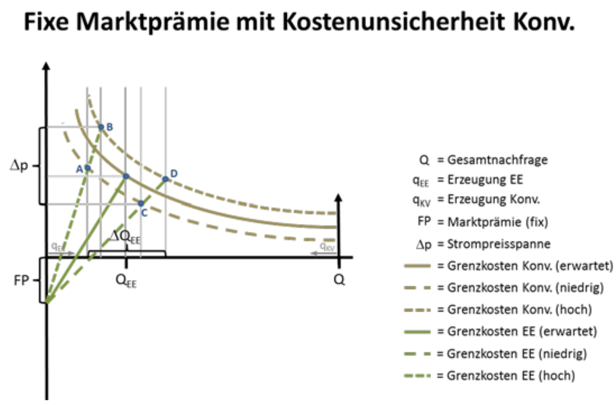

Abbildung 8: Fixe Marktprämie mit zusätzlichem Strompreisrisiko

[10]

Diese höheren Risiken lassen sich jedoch auch vermeiden, wenn die Prämie nicht regulatorisch, sondern über eine Auktionierung festgelegt wird. Der Grund dafür ist, dass es sich bei einer Auktionierung ebenfalls um eine Form der Mengensteuerung handelt, sofern festgelegte Mengen bzw. Kapazitäten auktioniert werden. Der prinzipielle Vergütungsmechanismus ist damit – zumindest in dem hier verwendeten Modellrahmen – identisch mit einer Quote, auch wenn die Höhe der Vergütung grundsätzlich über einen anderen Marktmechanismus festgelegt wird. Dementsprechend sind auch die EE Mengenrisiken und die Vergütungsspannen (auktionierte Prämien bzw. Zertifikatspreise) bei beiden Instrumenten identisch (vgl. Abbildung 6).

Die Identität zwischen beiden Instrumenten löst sich jedoch auf, wenn man explizit zwischen Investition und Erzeugung unterscheidet. Denn mit einer auktionierten fixen Marktprämie wird in der Regel der Zubau von Kapazitäten gesteuert, wohingegen eine Quote die tatsächliche Erzeugung im Prinzip „punktgenau" steuern kann. Dabei muss jedoch berücksichtigt werden, dass im Fall von dargebotsabhängigen EE wie Wind und Sonne wetterbedingte Unsicherheiten der Erzeugung bestehen, die sich auch durch eine Quote nicht genau steuern lassen. Werden beispielsweise zum großen Anteil Windenergieanlagen gefördert, so ist die gesamte EE Menge in einem Schwachwindjahr relativ gering und in einem Starkwindjahr relativ hoch. Die Erfüllung der Mengenziele kann zwar bilanziell durch Zurücklegen und Vorwegnehmen (*banking & borrowing*) der Zertifikate erreicht werden, die Volatilität der EE Erzeugung hingegen bleibt davon unberührt. Langfristig spielt diese Volatilität zwar nur eine geringe Rolle, da sich extreme Wetterlagen über die Jahre ausgleichen und Betreiber durch den Bau bzw. das Abschalten von Anlagen auf ein längerfristiges Über- bzw. Unterangebot von Zertifikaten reagieren. Kurz- bis mittelfristig allerdings besteht auch bei einer Quote ein (wetterbedingtes) Mengenrisiko und ein damit verbundenes Strompreisrisiko.

Zusammenfassend zeigt sich im Rahmen dieser theoretischen Analysen, dass die Reduzierung der Investitionsrisiken für EE durch die Wahl eines entsprechenden Förderinstruments nicht nur mit einer Übertragung des Risikos auf die Konsumenten, sondern auch mit einer Erhöhung des Investitionsrisikos für Konventionelle einhergeht. Der letztendliche Grund dafür ist die Form der Steuerung durch Preise oder Mengen (vgl. Menanteau, Finon, et al. 2003) bzw. die Einbeziehung des Strommarktes in die Förderung. Bei Unsicherheiten über die Kosten führt eine Steuerung durch Preise (Vergütung) grundsätzlich zu Unsicherheiten über die erzeugte Menge an EE Strom. Muss der EE Strom vermarktet werden (Marktprämie), so wirkt der Strompreis als Korrektiv, da höhere EE Mengen deren Marktwert senken. Wird der EE Strom hingegen nicht vermarktet (Einspeisevergütung), so übersetzt sich die Kostenunsicherheit vollständig in eine Mengenunsicherheit und ein dementsprechendes Investitionsrisiko. Bei einer Mengensteuerung und gleichzeitiger Vermarktung des EE Stroms (Quote) tritt – zumindest langfristig – keine Mengenunsicherheit auf.

Dass es in der Tat zu beachtlichen EE Mengenrisiken durch Kostenunsicherheiten im Fall einer fixen Einspeisevergütung kommen kann zeigt das Beispiel der PV Förderung durch das EEG in den Jahren 2010 bis 2012. In diesem Zeitraum wurden entgegen den ursprünglichen Plänen nach NREAP jährlich jeweils rund 7 GW neue Kapazität zugebaut. Ursache dafür waren vor allem die in dieser Zeit unerwartet stark sinkenden Kosten von PV und die relativ langen Reaktionszeiten für grundlegende Anpassungen der Förderungen, die nur im Rahmen einer EEG Novelle möglich waren. Zwar hat der unmittelbare Effekt auf die Kosten der EE Förderung einen Eingang in die Debatte gefunden, der indirekte Effekt des damit verbundenen Risikos für Konventionelle allerdings fand weit weniger Beachtung. Genauer gesagt: Investoren in Konventionelle konnten in diesen Jahren ihren Marktanalysen lediglich den nicht verbindlichen Ausbau der PV gemäß NREAP zugrunde legen, der jedoch tatsächlich weit übertroffen wurde. Anekdotischer Evidenz zufolge hätte eine Kenntnis des tatsächlichen Ausbaus zum damaligen Zeitpunkt eine ungünstigere Bewertung von Investitionen in Gaskraftwerke zur Folge gehabt.

Die historischen Probleme des EEG beim Ausbau der PV sind jedoch keine grundlegenden Unzulänglichkeiten dieses Instruments und können in einem gewissen Umfang korrigiert werden. Denn das tatsächliche Ausmaß der steuerungsbedingten Unsicherheit der EE Erzeugung bestimmt sich durch zwei wesentliche Faktoren: (a) die Höhe der Unsicherheit über die zukünftigen Kosten der EE und (b) die Schnelligkeit und Flexibilität mit der der Regulator in der Lage ist, auf unerwartete Kostenentwicklungen zu reagieren. Im Hinblick auf (a) ist das Risiko umso größer, je dynamischer bzw. volatiler die Märkte für EE Technologien sind. Bei relativ beständigen Investitionskosten ist die Notwendigkeit von Anpassungen der Vergütungen also relativ gering. Im Hinblick auf (b) ist das Risiko umso größer, je länger die Reaktionszeiten des steuernden politischen bzw. administrativen Prozesses sind. Ist der Regulator also in der Lage, auf Kostenschocks der EE relativ kurzfristig durch Anpassungen der Vergütungen zu reagieren, so fällt die Über- bzw. Untersteuerung vergleichsweise gering aus.

Daher ist es grundsätzlich auch mit einer fixen Einspeisevergütung möglich, zumindest den Kapazitätsausbau vergleichsweise akkurat zu steuern. Die wesentliche Voraussetzung dafür ist eine schnelle Anpassung durch den Regulator in Verbindung mit möglichst konkreten Mengenzielen so wie in Form des „atmenden Deckel“ für die PV, der mit dem EEG 2012 implementiert wurde; siehe dazu auch die Ausführungen von Leprich et al. (2013:44). Vor diesem Hintergrund sind auch die im Gesetzesentwurf zur EEG Reform vorgeschlagenen „verlässlichen Ausbaukorridore“ für die übrigen Technologien ein wichtiger Schritt – und eine durch den PV Ausbau der Jahre 2010-2012 teuer erkaufte Lektion im Hinblick auf die instrumentelle Ausgestaltung der Förderung durch eine fixe Einspeisevergütung.

4. Investitionsrisiken & Effizienzanreize bei unterschiedlichen EE Förderin-strumenten

Die unterschiedlichen Risikoallokationen geben Aufschluss darüber, wie die bestehenden Risiken verteilt sind, aber nicht welche Risiken EE Investoren aus ökonomischer Sicht tragen sollten. Der erste Schritt zur Klärung dieser Frage ist die Identifizierung der mit den Instrumenten verbundenen Investitionsrisiken. Diesbezüglich unterscheiden sich die Instrumente dahingehend, ob Investoren das Strompreisrisiko und ggf. ein zusätzliches Vergütungsrisiko tragen müssen (siehe Tabelle 2)[10]. Bei einer fixen Einspeisevergütung werden Investoren keinem Risiko ausgesetzt. Bei der gleitenden Marktprämie tragen Investoren lediglich ein relatives Strompreisrisiko, d.h. ein Risiko für Abweichungen vom durchschnittlichen Börsenpreis (steuerbare EE) bzw. dem durchschnittlichen Marktwert der Technologie (fluktuierende EE). Da sich die Vergütung aus der Differenz zwischen durchschnittlichem Strompreis bzw. Marktwert und Einspeisevergütung ergibt (*contract-for-difference*), tragen sie somit kein separates Vergütungsrisiko. Bei einer fixen, regulatorisch festgelegten Marktprämie tragen Investoren das volle Strompreisrisiko, aber weiterhin kein Vergütungsrisiko. Bei einer fixen, per Auktionierung festgelegten Marktprämie tragen Investoren das Strompreisrisiko und ein „upfront" Vergütungsrisiko, das darin besteht, bei der Auktion keinen Zuschlag zu erhalten. Bei einer Quote tragen Investoren das Strompreisrisiko und ein dynamisches Vergütungsrisiko, das darin besteht, dass sich über die Laufzeit der Investition die Höhe des Zertifikatspreises ändert.

	Strompreisrisiko	**Vergütungsrisiko**
Fixe Einspeisevergütung (regulatorisch)	-	-
Gleitende Marktprämie (regulatorisch)	✓/- („relativ", nur für Abweichung vom Durchschnitt)	-
Fixe Marktprämie* (regulatorisch)	✓	-
Fixe Marktprämie* (auktioniert)	✓	✓ (Projektzuschlag)
Quote (Markt)	✓	✓ (Laufzeit)

*Hier wird nicht zwischen einer Prämie auf Leistung und einer Prämie auf Erzeugung unterschieden, die sich nur durch das Tagen des Mengenrisikos (Prämie auf Erzeugung) unterscheiden.

Tabelle 2: Wesentliche Investitionsrisiken unterschiedlicher EE Förderinstrumente

Da es sich bei beiden Risiken um Marktrisiken handelt ist das Tragen dieser Risiken gleichbedeutend mit einer marktbasierten Förderung. Dabei bezieht sich „markt-" sowohl auf den Strommarkt als auch auf einen eventuellen „Vergütungsmarkt" (vgl. Klessmann, Nabe, et al. 2008:3646). Im Hinblick auf die strommarktbasierte Förderung wird auch oft von der „Marktintegration der EE" gesprochen, die begriff-

[10] Darüber hinaus gibt es noch eine Reihe von weiteren Preisrisiken, technischen Risiken und finanziellen Risiken sowohl auf der Kosten- als auch Ertragsseite; siehe Tabelle 3.1 in Gross et al. (2007). Diese werden hier nicht näher betrachtet.

lich jedoch ungenau bzw. mehrdeutig ist[11]. Zielführender ist es, die Marktintegration der EE beispielsweise als Unterwerfung unter das allgemeine Marktpreisrisiko Gawel & Purkus (Gawel & Purkus 2013:43) bzw. das Agieren an den gleichen Märkten wie die Konventionellen und das Tragen des entsprechenden Marktpreisrisikos zu verstehen (2013:126). Dies gilt in ähnlicher Weise auch für das Vergütungsrisiko bzw. die vergütungsmarktbasierte Förderung. Dort steht allerdings nicht die Integration in einen bestehenden Markt zur Disposition, sondern die Schaffung eines neuen „Markts für Vergütung" für den Grünanteil des produzierten Stroms (Auktionierung bzw. Zertifikatsmarkt).

Die besondere ökonomische Bedeutung des Tragens von Marktrisiken liegt darin, dass dadurch Anreize für langfristig effiziente Investitionsentscheidungen unter Unsicherheit erzeugt werden. Beim Bau einer neuen EE Anlage müssen Investoren drei Entscheidungen treffen: (1) die Wahl der allgemeinen Erzeugungstechnologie, (2) die Wahl des spezifischen Anlagentyps innerhalb dieser Technologie, und (3) die Wahl des Standorts der Anlage. Bei einer marktbasierten Förderung kombinieren Investoren diese voneinander abhängigen Wahlentscheidungen so, dass der über die finanzielle Laufzeit einer Anlage erwartete Ertrag möglichst hoch bzw. die Kosten möglichst gering sind. Entscheidend ist, dass sie dabei notwendigerweise die zukünftige Entwicklung der jeweiligen Märkte bzw. Preise in ihre Entscheidung einbeziehen müssen. Weil diese Entwicklungen unsicher sind, besteht dabei ein entsprechendes Investitionsrisiko. Müssen Investoren dieses Risiko tragen, bedeutet dies, dass sie für negative Abweichungen von den erwarteten Erträgen bzw. Kosten aufkommen müssen bzw. von positiven Abweichungen profitieren. Sie haben somit einen Anreiz, die Investitionsentscheidungen bestmöglich vorausblickend und unter Abwägung der Unsicherheiten zu treffen[12]. Nach den Grundsätzen der ökonomischen Theorie führen diese Investitionsentscheidungen in der Summe zu einem langfristig effizienten Ausbau der EE, der die im Markt bestehenden Unsicherheiten so gut wie möglich berücksichtigt.

Die konkreten mit dem Tragen des Strompreisrisikos verbundenen Anreize betreffen grundsätzliche alle drei oben beschriebenen Wahlmöglichkeiten. Bei einer technologiespezifischen Förderung wie im aktuellen Förderregime wird jedoch der Effekt des Strompreisrisikos auf die Technologiewahl nivelliert; es bleiben also lediglich die Wirkungen auf Anlagentyp- und Standortwahl. Maßgeblich für die Investitionen ist in dieser Hinsicht (a) die standortabhängige Ressourcenverfügbarkeit (erwartete Erzeugung) sowie (b) die standort- und anlagentypabhängige Kovarianz zwischen Einspeisung und Marktpreis (erwarteter Marktwert). Numerische Analysen unterstreichen, dass durch eine entsprechende marktbasierte Förderung die Kovarianz zwischen Winderzeugung und Residuallast zunimmt (Schmidt et al. 2013:269), was einer Erhöhung des Marktwerts der Anlage bzw. effizienteren Stromerzeugung aus Systemsicht gleichkommt.

[11] Beispielsweise verstehen Leprich et al. (2013:2) darunter relativ allgemein die stärkere Teilnahme der EE an bestehenden Märkten und eine besseren Koordination mit der konventionellen Erzeugung. Gelegentlich wird wie von der Agora Energiewende (2013:11) darunter sogar das Entfallen jeglicher Förderung verstanden, was allerdings durch „vollständige Marktintegration" (Enervis & BET 2013:126) bzw. „Wettbewerbsfähigkeit" (BDEW 2013:25) zutreffender beschrieben werden kann.

[12] Sie haben darüber hinaus auch Anreize, diese Unsicherheit durch Innovationen zu reduzieren. In diesem Sinn ist Risiko auch ein „energetisierendes Prinzip" (Giddens 1999).

Die konkreten mit dem Tragen des Vergütungsrisikos verbundenen Anreize hängen hingegen von den spezifischen Vergütungsrisiken des Instruments ab. Wie in Tabelle 2 dargestellt kann eine solche Förderung durch eine Quote oder durch eine fixe auktionierte Marktprämie implementiert werden, mit denen jeweils unterschiedliche Vergütungsrisiken bzw. Unsicherheitsfaktoren verbunden sind (vgl. Frontier Economics 2012:77; Bofinger 2013:31-34).

Bei einer Auktionierung besteht lediglich Unsicherheit über das aggregierte Angebot zum Zeitpunkt der Auktion. Die beste „Entscheidung" von Investoren unter dieser Unsicherheit ist, die Kosten einer Anlage im Vorfeld soweit wie möglich zu reduzieren, um den Zuschlag zu bekommen. Letztendlich handelt es sich also nur um einen statischen wettbewerblichen Effekt. Damit ist allerdings insofern ein Risiko verbunden, als dass im Fall eines Zuschlags die tatsächlichen Kosten eines Projekts das ursprüngliche Gebot überschreiten können (*winners's curse*). Diese Situation ergab sich beispielsweise bei den Auktionierungen in Großbritannien in den 1990er Jahren (NFFO) und in China Anfang der 2000er Jahre (Batlle, Pérez-Arriaga, et al. 2012). Aktuell erfolgt der Einsatz dieses Instruments zum Beispiel in Brasilien, wo seit 2009 mehrere Auktionen von langfristigen Stromlieferverträgen (PPA) durchgeführt worden sind. Das dort verwendete Auktionsdesigns kann allerdings noch nicht umfassend bewertet werden (Cozzi 2012), nicht zuletzt weil der Verpflichtungszeitraum zum Bau von geförderten Anlagen drei bis fünf Jahre beträgt. Einige allgemeine Erfahrungen liegen allerdings schon vor (vgl. Rego 2013).

Bei der Quote hingegen kommen zwei langfristige Unsicherheitsfaktoren zum Tragen: (a) die politische Unsicherheit des Förderrahmens bedingt zum Beispiel durch mögliche nachträgliche Anpassungen der Förderung an den tatsächlichen EE Zubau[13] und (b) die Unsicherheit über die zukünftigen Kostenentwicklungen der EE Technologien, die sich beide in einem Zertifikatspreisrisiko widerspiegeln. Der potenzielle Effizienzvorteil im Hinblick auf (b) bestehen darin, dass Investoren auch nach dem Bau einer Anlage Anreize zur weiteren Kostenreduzierung haben (Menanteau, Finon, et al. 2003:810), was zum Beispiel durch die Senkung der Betriebskosten (z.B. Pacht) oder eine Modernisierung der Technik („Repowering") möglich ist. Im Hinblick auf (a) besteht für Investoren die generelle Schwierigkeit, allgemeine politische Unsicherheit in ein kalkulierbares Risiko zu übersetzen. Je höher also die politische Unsicherheit, desto weniger wahrscheinlich sind effiziente Investitionen. Im Umkehrschluss leitet sich daraus ab, dass bei der Quote ein langfristig stabiler regulatorischer Rahmen essentiell ist[14].

Vor diesem Hintergrund stellt sich im Rahmen der Debatte um das Förderinstrument die Frage, wie in den unterschiedlichen Vorschlägen für bzw. gegen das Tragen von Risiken argumentiert wird und wie diese Argumente zu bewerten sind. Wie oben dargestellt ist dieser Aspekt zentral, was zum Beispiel auch in der Gegenüberstellung der Argumente für eine gleitende Marktprämie und eine fixe Marktprämie durch den BDEW (2013) deutlich wird, die sich beiderseitig auf „Marktrisiken" und „Risikoübernahmen" konzentrieren. Zur genaueren Analyse der Argumente ist es hilfreich, vorab die einzelnen Studien im Hinblick auf ihre diesbezüglichen Empfehlungen einzuordnen (siehe Tabelle 3). In mehreren Studien

[13] Das bedeutet nicht, dass für Investoren bei der auktionierten fixen Marktprämie keine politische Unsicherheit besteht, denn auch der Bestandsschutz bzw. die Verträge können prinzipiell aufgehoben werden.
[14] Die tatsächliche Stabilität des regulatorischen Rahmens zeigt sich natürlich erst im Nachhinein. Daher ist für das politische Risiko vielmehr die Glaubwürdigkeit dieses Rahmens entscheidend.

werden aus politischen Gründen mehrere Reformschritte unterschieden; in diesen Fällen wird nur der langfristige Vorschlag berücksichtigt.

<table>
<tr><th rowspan="2">Risiken / Vorschlag</th><th>Keins bzw. relativer Strompreis</th><th>Strompreis</th><th>Strompreis + Vergütung (Zuschlag)</th><th>Strompreis + Vergütung (Laufzeit)</th></tr>
<tr><td colspan="4">Zunehmendes Investitionsrisiko -></td></tr>
<tr><td>Agora Energiewende (2013)</td><td>X
(kurzfristiger Fokus auf 2014-2017)</td><td></td><td></td><td></td></tr>
<tr><td>Jacobs et al. (2013)</td><td>X</td><td></td><td></td><td></td></tr>
<tr><td>SR Umwelt (2013)</td><td>X
(gleitende MP)</td><td></td><td></td><td></td></tr>
<tr><td>Leprich et al. (2013)</td><td>X
(Option A)</td><td></td><td>X
(Option B)</td><td></td></tr>
<tr><td>BDEW (2013)</td><td></td><td></td><td>X
(Zielmodell)</td><td></td></tr>
<tr><td>BDI (2013)</td><td></td><td colspan="2">X*
(Auktionierung zu prüfen)</td><td></td></tr>
<tr><td>Enervis & BET (2013)</td><td></td><td></td><td>X</td><td></td></tr>
<tr><td>Frontier Economics (2012)</td><td></td><td colspan="2">X*</td><td></td></tr>
<tr><td>Kopp et al. (2013)</td><td></td><td></td><td>X
(Zieldesign)</td><td></td></tr>
<tr><td>Löschel et al. (2013)</td><td></td><td colspan="2">X*</td><td></td></tr>
<tr><td>Frondel et al. (2012)</td><td></td><td></td><td></td><td>X</td></tr>
<tr><td>Haucap & Kühling (2012)</td><td></td><td></td><td></td><td>X</td></tr>
<tr><td>Monopolkommission (2013)</td><td></td><td></td><td></td><td>X</td></tr>
<tr><td>SR Wirtschaft (2013)</td><td></td><td></td><td></td><td>X</td></tr>
<tr><td colspan="5">*Festlegung der Prämie (regulatorisch bzw. wettbewerblich) nicht spezifiziert</td></tr>
</table>

Tabelle 3: Übersicht der zu tragenden Risiken in den Vorschlägen zur EEG Reform

Im Hinblick auf das Strompreisrisiko sind die genannten ökonomischen Gründe gegen das Tragen dieses Risikos wenig überzeugend. Wie die Übersicht zeigt gibt es insgesamt vier Vorschläge, die vorsehen, dass EE Investoren weiterhin kein bzw. nur ein einseitiges Strompreisrisiko tragen sollten. Die Agora Energiewende begründet dies nicht explizit sondern weist lediglich daraufhin, dass eine Integration der EE aufgrund der für eine Refinanzierung zu niedrigen Strompreise überhaupt nicht möglich wäre (2013:11). Wie oben erläutert liegt dem allerdings ein bestimmtes Verständnis von Marktintegration zugrunde („Vollständige Marktintegration“ ohne weitere Förderung), dass weit über das Tragen des Strompreisrisikos hinausgeht. Jacobs et al. (2013:7) verweisen darauf, dass das Tragen des Strompreisrisikos (a) die Risikoprämien und damit die Förderkosten erhöhe und (b) bei fluktuierenden EE nicht „produktiv“ sei, da dargebotsabhängige Erzeugung nur begrenzt auf Marktpreise reagiere. Im Hinblick auf (a) stellt die Erhöhung der Förderkosten jedoch kein Gegenargument dar, sondern wie erläutert lediglich eine Abwägung zwischen Risikokosten in Form von Risikoprämien und dem Kostenrisiko durch die anfallenden Mehrkosten im Falle geringerer Rentabilität der EE. Im Hinblick auf (b) wird übersehen, dass die effizienzsteigernde Wirkung des Risikos vor allem bei der Investitionsentscheidung entsteht und nicht bei der

Produktion. Der SRU (2013:105) verweist ebenfalls auf die höheren Risikoprämien und argumentiert darüber hinaus, dass Investoren in der Konsequenz mit „Investitionszurückhaltung“ reagieren würden. Warum letzteres generell der Fall sein sollte bleibt jedoch unklar. Das elaborierteste Argument findet sich bei Leprich et al. (2013:44) und betrifft die Diversifizierung des Risikos durch Umlage auf die Stromverbraucher – an seiner Gültigkeit bzw. der Anwendbarkeit des zugrundeliegenden Arrow-Lind Theorems bestehen jedoch gewisse Zweifel (siehe Abschnitt 2). Auch andere im Rahmen der weiteren Debatte vorgebrachte ökonomische Argumente sind wenig überzeugend bzw. begründet: Gawel & Purkus (2013:59) zum Beispiel sehen das Tragen des Strompreisrisikos als nicht sinnvoll an, „solange keine Netzparität erreicht ist und Unsicherheit besteht, ob das gegenwärtige Strommarktdesign überhaupt zukunftsfähig ist“. Warum dies überhaupt ein Argument darstellen sollte führen die Autoren allerdings nicht aus.

Im Hinblick auf das Vergütungsrisiko konzentriert sich die Debatte auf die Frage, in welchem Ausmaß es getragen werden sollte. Eine wichtige Feststellung ist, dass die Vorschläge, die das Tragen des Strompreisrisikos vorsehen, auch – zumindest perspektivisch – das Tragen des Vergütungsrisikos in Form einer Auktionierung vorsehen. Diese „Trennlinie“ zu den Vorschlägen ohne Risiko legt nahe, dass es eine gewisse Grundüberzeugung zu geben scheint, ob marktliche Elemente in der Förderung sinnvoll sind oder nicht. Innerhalb der ersten Gruppe haben die Befürworter einer Quote einen gewissen Sonderstatus, nicht zuletzt weil sie in der Regel keine Reformzwischenstufen vorsehen und darüber hinaus für eine technologieneutrale Förderung plädieren. Der entscheidende Aspekt im Hinblick auf das Vergütungsrisiko ist also nicht ob es überhaupt getragen werden sollte, sondern nur in welchem Ausmaß.

Die in diesem Zusammenhang vorgebrachten ökonomischen Gründe sind in der Regel differenzierter und stichhaltiger. Vorschläge, die sich kritisch mit der Quote auseinandersetzen, betrachten sehr unterschiedliche Aspekte: die Notwendigkeit der Stabilität des Förderregimes (Kopp, Engelhorn, et al. 2013:4; Frontier Economics 2012:74), die Preisvolatilität (Löschel, Flues, Pothen, et al. 2013:11) bzw. Liquidität (Kopp, Engelhorn, et al. 2013:4) des Zertifikatsmarkts sowie eventuelle Fragen von Marktmacht (SRU 2013:94). Doch die Kritik ist zum Teil auch methodisch problematisch: Der SRU (2013:93) weißt beispielsweise auf die im internationalen Vergleich höheren Förderkosten der Quote bei gleichzeitig geringere Effektivität hin; an der Grundlage eines solchen Vergleichs bestehen jedoch erhebliche Zweifel. Ebenso wird relativ einseitig mit der Höhe der Risikoprämien argumentiert (2013:93)[15], obwohl sich diese wie erläutert im Hinblick auf das Kostenrisiko der Förderung relativieren. Darüber hinaus werden ganz allgemein Zweifel geäußert, ob den hohen Investitionsrisiken auch entsprechende Effizienzgewinne gegenüberstehen; siehe z.B. Kopp et al. (2013:4). Begründet werden diese Zweifel jedoch in der Regel nicht. Insgesamt werden die möglichen positiven Wirkungen des beständigen Kostendrucks bei vielen Kritikern kaum gewürdigt, auch wenn aus empirischer Sicht unklar bleibt, ob sie sich tatsächlich einstellen würden.

Die Debatte um das Förderinstrument bzw. die Risiken wird jedoch nicht allein mit ökonomischen Argumenten geführt. Es gibt auch ein politisches Argument, das allgemein gegen das Tragen von Risiken vorgebracht wird. Es beruht auf der Annahme, dass zur Umsetzung der Energiewende eine breite Ak-

[15] Siehe dazu auch Dieckmann et al. (2012).

teursstruktur auch mit kleinen bzw. privaten Investoren notwendig sei, weil durch die entsprechende ökonomische Teilhabe die notwendige Akzeptanz geschaffen werde. Jacobs et al. sprechen hier vom „Gemeinschaftswerk Energiewende" und einer entsprechenden Finanzierung (2013:7), der SRU weißt auf (a) die Gefährdung der Akzeptanz durch eine verminderte Zahl an Investoren und Betreibern und (b) ein mögliches Ausbleiben von Investitionen hin (2013:94) und Leprich et al. sehen die Stärkung der Akzeptanz durch Partizipation an den Verdienstmöglichkeiten als erforderlich an (2013:80). Die „Benachteiligung" kleiner Investoren bei entsprechenden Förderinstrumenten beschreiben Mitchell et al. (2006:31): *„As many renewable generators are small generators, they tend to be relatively risk averse due to a less diverse fuel portfolio and a limited ability to finance projects through the balance sheet. They are therefore likely to be disadvantaged by high-risk markets*". Man muss daher davon ausgehen, dass Investitionsrisiken dazu führen, dass sich insbesondere Privatpersonen bzw. Einzeleigentümer, die zurzeit im Besitz von rund einem Viertel der EEG-geförderten Anlagen sind (trend:research & Universität Lüneburg 2013), nicht mehr am Ausbau der EE beteiligen können bzw. werden. Dementsprechend setzen die obigen Vorschläge die Maßgabe, dass EE Investoren keine oder nur sehr geringe Risiken tragen sollten[16].

Im Hinblick auf die Akzeptanz wird jedoch auch die Annahme vertreten, dass die Unterstützung für die Energiewende entscheidend von ihrer Kostenentwicklung bestimmt sein wird; siehe z.B. Appelrath et al. (2012:4). In diesem Fall würden die potenziell realisierbaren Effizienzgewinne bzw. die wettbewerbliche Bestimmung der Vergütung grundsätzlich für das Tragen von Risiken sprechen. Die tatsächliche Bilanz lässt sich allerdings nur schwer quantifizieren und kann lediglich an Beispielen veranschaulicht werden. Eines davon sind die Pachtkosten von Flächen für den Betrieb von EE Anlagen. Deutsche WindGuard (2013) beziffert den durchschnittlichen Anteil der Pachtkosten an den Stromgestehungskosten einer WEA mittlerer Standortqualität auf rund 7% (0,5 ct/kWh). Laut einem einschlägigen Medienbericht betragen die absoluten Kosten in der Spitze an besonders windreichen Standorten bis zu 100.000 EUR pro Jahr und Windrad bei relativ geringem Flächenbedarf (Handelsblatt Online 2013). Solche Renten seitens der Landbesitzer erhöhen in der Summe die Förderkosten und senken damit ggf. die Akzeptanz. Eine wettbewerbsorientierte Förderung bzw. das Tragen von Risiken könnte hier also gegenläufig wirken[17].

Welche Rolle die Risikoprämien in dieser Hinsicht spielen ist allerdings weniger eindeutig als oft dargestellt. Grundsätzlich erhöhen die Risikoprämien die Förderkosten, wobei nicht notwendigerweise davon auszugehen ist, dass die wettbewerbliche Festlegung der Vergütung diesen Aufschlag nicht mehr als kompensiert; siehe dazu die Diskussion der Ergebnisse im Vergleich mit anderen Studien bei Kitzing (2014:9). Nichtsdestotrotz stellen die Risikoprämien zusätzliche Kosten dar, die die gesamten Förderkosten erhöhen. Doch wie oben dargestellt bedeuten höhere Risikokosten auch ein niedrigeres Kostenrisiko für die Förderung. In dieser Hinsicht ist die entscheidende Frage, ob die Akzeptanz lediglich mit der ab-

[16] Bei Leprich et al. (2013) wird in dieser Hinsicht zwischen zwei Optionen unterschieden. Die obige Argumentation bezieht sich dabei lediglich auf Option A (Bürgermodell).

[17] Im konkreten Fall der Pachtkosten muss man allerdings berücksichtigen, dass die zögerliche Ausweisung neuer Flächen ein limitierender Faktor ist, der nicht unmittelbar durch Wettbewerb selbst behoben werden kann. Dieser würde jedoch für mehr Transparenz sorgen und könnte damit den Prozess vermutlich beschleunigen.

soluten Höhe der Förderkosten zusammen hängt oder ob auch unerwartete Schwankungen dabei von Bedeutung sind. Wäre letzteres der Fall, so müssten die Risikoprämien gesondert bilanziert werden.

Über die Frage der Akzeptanz hinaus wirft das Tragen bzw. Nicht-Tragen von Risiken noch einen weiteren Aspekt auf, der die Debatte auf eher subtile Weise durchzieht: Verantwortung. Diesbezüglich besteht ein breiter Konsens, dass die EE mehr Systemverantwortung durch das Erbringen von Systemdienstleistungen wie z.B. Netzstabilisierung übernehmen müssen. Entsprechende Regelungen werden bereits seit dem EEG 2009 umgesetzt. Der BDEW (2013:13) weist allerdings treffend darauf hin, dass diese Verantwortung eine technische ist, d.h. im übertragenen Sinn von den Anlagen und nicht etwa von den Investoren übernommen wird. Eine Verantwortung für Investoren bzw. Erzeuger hingegen würde bedeuten, dass sie sich die folgende Frage stellen müssten: „Was richtet die von mir erzeugte Kilowattstunde Strom im System an?" (Matthes 2012:11). Verantwortung bzw. Verantwortlichkeit kommt somit ins Spiel, wenn Einzelne die Konsequenzen der Auswirkungen ihrer Entscheidungen auf das Gesamtsystem tragen müssen. Wenn diese Entscheidungen wie im Fall von Investitionen zudem langfristig sind und unter Unsicherheit erfolgen, dann bedeutet Verantwortung notwendigerweise auch das Tragen von Risiken (vgl. Giddens 1999:8). Doch für was genau übernehmen EE Investoren die Verantwortung?

Grundsätzlich übernimmt jeder Investor durch das Tragen der Risiken lediglich die Verantwortung für die eigene Investition bzw. deren Profitabilität. Wie oben dargestellt führt dies dazu, dass ein Investor seine Anlage so auslegt, dass sie unter den gegebenen Unsicherheiten Strom zukünftig zu möglichst hohen Preisen produziert. Hohe Preise bedeuten jedoch gleichzeitig, dass es im Gesamtsystem eine große Nachfrage gibt und der Strom somit dann erzeugt wird, wenn er gebraucht wird. So übernimmt der Investor neben der Verantwortung für die eigene Investition auch indirekt eine Verantwortung für die bedarfsgerechte Stromerzeugung aus Sicht des Gesamtsystems, die wie oben dargestellt nur dadurch entsteht, dass er die Konsequenzen seiner Entscheidung tragen muss. Bei einer Förderung ohne das Tragen von Risiken ist eben dies nicht der Fall, weil dort das Prinzip „Invest, produce & forget" gilt und Investoren die Konsequenzen ihrer (Investitions-)Entscheidungen nicht oder nur sehr eingeschränkt tragen müssen. Das Nicht-Tragen von Risiken befreit also EE Investoren von der Übernahme der Verantwortung für eine bedarfsgerechte Stromerzeugung.

Insgesamt gesehen ist die Akteursbreite damit keine Frage von „ganz oder gar nicht", sondern vielmehr eine Abwägung, die im Kontext der Gesamtentwicklung des Ausbaus getroffen werden muss. Die Markteinführung der Windenergie beispielsweise wurde anders als zum Beispiel in Spanien zum Großteil von Privatpersonen bzw. unabhängigen Projektentwicklern getragen, während sich die großen Energieunternehmen dieser Entwicklung aus verschiedenen Gründen nicht daran beteiligten (vgl. Stenzel & Frenzel 2008). Mittlerweile haben die wesentlichen EE Technologien jedoch Marktreife erreicht und ihr Anteil an der Gesamterzeugung beträgt rund 25%. Damit sind einerseits Geschäftsmodelle für Investition und Betrieb solcher Anlagen etabliert, die die Marktbarrieren für Investoren senken. Zudem sind neue Geschäftsmodelle für die Vermarktung von Kleinanlagen entstanden. Privatpersonen haben damit die Möglichkeit, sich auch im Fall einer marktbasierten Förderung an der Energiewende ökonomisch zu beteiligen, wenn auch nicht notwendigerweise über die PV Anlage auf dem eigenen Dach.

Darüber hinaus wird bei steigendem Marktanteil der EE das Gesamtsystem zunehmend koordinations– bzw. steuerungsintensiver, nicht zuletzt weil die Zahl der Anlagen bzw. deren unterschiedliche ökonomischen Bedingungen rapide wachsen. Das hat zur Folge, dass bei einer nicht-marktbasierten Förderung auch die regulatorische Komplexität bzw. die entsprechenden Anforderungen zunehmen, wodurch sich tendenziell die Ineffizienzen und damit die Kosten erhöhen; siehe dazu auch Klessmann et al. (2008:3659). In dieser Hinsicht illustrativ sind etwa die vom SRU angedachten Kilowattstundenkontigente zur spezifischen Förderung unterschiedlicher EE Anlagen. Laut Vorschlag wäre deren Berechnung beispielsweise auf Basis der standortspezifischen Sonneneinstrahlung für PV bzw. der überstrichenen Rotorfläche für Wind möglich (SRU 2013:101). Doch selbst wenn diese Informationen für jede einzelne Anlage verfügbar wären bleibt völlig unklar, wie damit konkret Anreize geschaffen werden können, um EE Anlagen effizient auszulegen und zu betreiben. Dieses Beispiel unterstreicht, dass mit zunehmendem Marktanteil der EE die „Durchregulierung eines sehr koordinationsintensiven Systems kaum funktionieren wird“ (Matthes 2013:2) und eine marktbasierte Förderung immer dringlicher wird. Entsprechend wird es sich nicht vermeiden lassen, dass das dafür notwendige Tragen von Risiken die Akteursbreite reduzieren wird.

Insgesamt gesehen spricht also Vieles dafür, dass ein Übergang zu einer marktbasierten Förderung zur Erreichung des „Strommarktdesigns der Zukunft“ notwendig ist. Streitbar ist allerdings der Zeitpunkt des Übergangs – aber aus mindestens zwei Gründen wäre die Politik gut damit beraten, diesen eher früher und gezielt als später und nur reagierend einzuleiten: Erstens, die Bereitschaft der Gesellschaft, die zunehmenden Kosten zu tragen, scheint sich zunehmend auf der Kippe zu befinden. In einer repräsentativen Befragung vom Herbst 2013[18] stimmten beispielsweise nur 55% der Befragten zu, dass die damals anstehende Erhöhung der EEG Umlage von 5 ct/kWh auf 6 ct/kWh angemessen (50%) oder noch zu niedrig (5%) sei. Eine einzelne Befragung ist zwar kein definitiver Gradmesser, aber zumindest ein Indikator für die aktuelle Situation. Zweitens, mit der Erlangung der Marktreife von PV und Wind hat der Ausbau der EE eine Phase erreicht, in der man eigentlich nicht mehr von einer Förderung sprechen kann. Verschiedentlich wird daher wie zum Beispiel bei Kopp et al. (2013), dem SRU (2013) oder Leprich et al. (2013) nicht mehr von einem Förderinstrument, sondern von einem Finanzierungsinstrument gesprochen. Wenn aber nur noch „Anlagen finanziert“ und nicht mehr „Technologien gefördert“ werden läuft die Energiewende Gefahr, im Hinblick auf eines ihrer wesentlichen Ziele – der Weiterentwicklung von EE Technologien wie als Ziel im EEG formuliert – in einen statischen Zustand zu verfallen. Das Tragen von Risiken ist in dieser Hinsicht sicher kein Allheilmittel, aber zumindest eine Triebkraft für Innovation und Fortschritt, um die Entwicklung der EE und ihre systemische Einbindung weiter zu voranzutreiben.

[18] http://unendlich-viel-energie.de/media/image/3838.aee_akzeptanzumfrage2013_eeg_umlage_72dpi.jpg

5. Diskussion & Schlussfolgerung

In diesem Papier wurden verschiedene Aspekte im Hinblick auf die Rolle von Risiko bei der Förderung der EE erläutert und diskutiert. Es wurde insbesondere klargestellt, dass (a) sich das gesellschaftliche Kostenrisiko nicht durch die Wahl eines Förderinstruments reduzieren lässt und (b) das Tragen von Investitionsrisiken auch bei fluktuierenden EE nicht „unproduktiv", sondern langfristig effizient ist, sofern die zugrundeliegenden Märkte funktionsfähig sind. Es wurde ebenfalls dargestellt, dass das Tragen von Risiken im Konflikt mit der Erhaltung einer großen Akteursbreite beim Ausbau der EE steht, da kleinere Akteure diese Risiken tendenziell nicht tragen wollen oder können. Aufgrund der steigenden Kosten der Förderung und den steigenden regulatorischen Anforderungen bei einer nicht-markbasierten Steuerung bei zunehmenden EE Anteilen liegt es jedoch nahe, dass EE Investoren in zunehmendem Umfang Risiken tragen sollten.

Vor diesem Hintergrund gibt der aktuelle Gesetzentwurf für die EEG Reform eine vergleichsweise klare Vorgabe in die entsprechende Richtung. Zwar gelten die unmittelbaren Maßnahmen vornehmlich der Kontrolle der absoluten Förderkosten und nur die verpflichtende Direktvermarktung mittels gleitender Marktprämie für Neuanlagen erhöht geringfügig die Effizienz. Doch eine marktbasierte Förderung in Form von technologiespezifischen Ausschreibungen (Auktionierung) soll in einem Pilotprojekt vorbereitet und ab 2017 bzw. 2020 (Wind Offshore) umfassend eingesetzt werden. Wenn eine entsprechende umfassende Förderung durch Ausschreibungen zumindest für Wind Onshore und PV tatsächlich bis zum Ende der Legislaturperiode eingeführt werden würde, wäre dies angesichts der Herausforderungen der Energiewende ein wichtiger Schritt und eine große politisch Leistung.

Längerfristig stellt sich allerdings unabhängig vom Instrument die Frage stellen, ob eine dauerhafte Förderung der EE notwendig bzw. sinnvoll ist. Der Koalitionsvertrag von CDU, CSU und SPD stellt diesbezüglich klar, dass die EE perspektivisch ohne Förderung am Markt bestehen sollen. Ob dies allerdings im Rahmen der aktuellen Ausbauziele möglich ist bzw. ab wann genau die EE ohne Förderung auskommen sollen bleibt unklar. In dieser Hinsicht wird zukünftig sicherlich auch der gesellschaftliche Nutzen des EE Ausbaus ein zunehmend wichtigeres Thema werden. Hier stellt sich allem voran die Frage, welche Ziele die Politik bzw. Gesellschaft dadurch erreichen möchte.

Aus Sicht des Klimaschutzes als einem wesentlichen Ziel der Energiewende spricht Einiges dafür, EE Technologien zumindest bis hin zur Erreichung der allgemeinen Marktreife zu entwickeln. Die Vermeidung von THG Emission ist allerdings noch mit einer Reihe von anderen Technologien möglich, die schon bekannt und erprobt oder vielleicht noch gänzlich unbekannt sind. Ein langfristig stabiler und angemessen hoher Preis auf CO_2 zusammen mit einer Intensivierung der F&E Förderung könnte allen diesen Technologien eine Chance zur Entwicklung geben, sofern sich dafür im jeweiligen Fall die gesellschaftliche Unterstützung findet. Und er könnte ebenso dafür sorgen, dass die EE ohne weitere Förderung und nur durch Berücksichtigung der externen Kosten einen hohen bis sehr hohen Anteil in der Stromerzeugung erreichen. Wenn die Politik nicht schon frühzeitig die Weichen für einen Übergang von einem EE-Förderregime zu einem CO_2-Vermeidungsregime stellt, stellt dies vielleicht sogar das größte Risiko für das Gelingen der Energiewende dar.

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Chapter 5

The (Ir)relevance of Transaction Costs in Climate Policy Instrument Choice: an Analysis of the EU and the US*

Fabian Joas
Christian Flachsland

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V The (Ir)relevance of Transaction Costs in Climate Policy Instrument Choice: An analysis of the EU and the US

Authors: Fabian Joas and Christian Flachsland

Abstract

This article assesses the relevance of *ex post* transaction costs in the choice of climate policy instruments in the EU (focusing mainly on the example of Germany) and the US. It reviews all publicly available empirical *ex post* transaction cost studies of climate policy instruments broken down by the main private and public sector cost factors and offers hypotheses on how these factors may scale depending on instrument design and other contextual factors. The key finding from the evaluated schemes is that it is possible to reject the hypothesis that asymmetries in *ex post* transaction costs across instruments are large and, thus, play a pivotal role in climate policy instrument choice. Both total and relative *ex post* transaction costs can be considered low. This conjecture differs from the experience in other areas of environmental policy instruments where high total transaction costs are considered to be important factors in the overall assessment of optimal environmental policy choice. Against this background, the main claim of this article is that in climate policy instrument choice, *ex post* transaction cost considerations play a minor role in large countries that feature similar institutional characteristics as the EU and the US. Rather, the focus should be on the efficiency properties of instruments for incentivizing abatement, as well as equity and political economy considerations (and other societally relevant objectives). In order to inform transaction cost considerations in climate policy instrument choice in countries that adopt new climate policies, more data would be desirable in order to enable more robust estimates of design- and context-specific transaction-cost scaling factors.

Policy relevance:

The findings of this study can help inform policy makers who plan to set up novel climate policy instruments. The results indicate that *ex post* transaction costs play a minor role for large countries that feature similar institutional characteristics as the EU and the US. For instrument design the focus should rather be on efficiency properties of instruments in incentivizing abatement, as well as equity and political economy considerations (and other societally relevant objectives).

Keywords:

Carbon tax; climate policy instruments; emissions trading schemes; EU Emissions Trading Scheme; OECD; transaction costs

1. Introduction

A significant body of literature has evolved in recent years that analyses the optimal design of climate policy instruments for correcting market failures, such as the external costs of emitting harmful GHGs or research and development (R&D) underinvestment due to technology spill-overs (e.g. Fischer & Newell, 2008; Goulder & Parry, 2008; IPCC, 2007). As demonstrated by Stavins (1995) and Coggan, Whitten, and Bennett (2010), the design, implementation, and enforcement of such policy instruments involve transaction costs (TCs) that might affect optimal policy choice. In other words, the ranking of policy instruments regarding the economic cost-effectiveness criterion might change when TCs are included in the analysis (Ofei-Mensah & Bennett, 2013). Transaction costs are defined as 'the *ex ante* costs of establishing environmental policy in all of its aspects, and the *ex post* costs of administering, monitoring and enforcing the policy once established' (Krutilla & Krause, 2010). This article provides an assessment of the relevance of *ex post* TCs in the choice of climate policy instruments, such as permit trading, taxes, and standards, by reviewing and comparing the available data on their transaction-cost performances. This is done by reviewing all publicly available empirical *ex post* TC studies of climate policy instruments broken down by the main private- and public-sector cost factors. In order to inform TC considerations in climate policy instrument choice in countries that adopt or change their instruments, hypotheses are offered on how they can be expected to scale depending on various instrument designs or regulatory context factors, such as the number of regulated entities or the level of abatement. Different design options (e.g. the point of regulation and the design of trading schemes) and their influence on TCs are discussed. Where quantitative data are not available, qualitative considerations and hypothetical plausibility deductions supplement the analysis. *Ex ante* TCs are not considered because very little empirical data are available, even though these costs may be important factors influencing the implementation of climate change policies. The key finding from the evaluated schemes is that it is possible to reject the hypothesis that asymmetries in *ex post* TCs across instruments are large and thus play a pivotal role in climate policy instrument choice. Both total and relative *ex post* TCs incurred by the public and private sectors can be considered low. In Germany, for instance, they range from € 28 to € 81 million[1] annually for different instruments on which relatively robust empirical evidence is available. This represents between 6 and 18 Euro cent (€ct) per regulated ton of CO2 in 2011, or less than 2% of the certificate price in the European Union Emission Trading System (EU ETS) in 2011 (€ 10), or less than 1% of German net renewable electricity subsidies in 2011 (€ 12 billion) (Frontier Economics, 2012).

This article is structured as follows. Section 2 reviews the literature on TCs in climate policy instrument choice. Section 3 introduces the TC definition and the methodical approach of this study. Section 4 offers the results and a discussion on TCs for (1) trading schemes, (2) taxing schemes, (3) a comparison of different points of regulation for tax and trading schemes, (4) technology standards, and (5) performance standards. Section 5 concludes.

2. Literature review

Stavins (1995) was the first to demonstrate analytically that in the context of environmental policy instruments, the TCs of trading permits can significantly affect the efficiency of an ETS. He finds that if TCs drive a significant cost wedge between a firm's option to abate internally or to trade permits on the market, this can significantly reduce the efficiency gains of harmonizing marginal abatement costs (MACs) across regulated entities. This hypothesis has been confirmed empirically for several environmental ETSs in the US. Kerr and Mare (1998) found that the TCs of permit trading reduced cost-

[1] Throughout this article, all € values have been adjusted for inflation to the year 2011.

effectiveness by around 10–20% in the US lead phase-down scheme. Gangadharan (2000) showed that the presence of trading TCs reduced the probability of trading by about 32% in California's Regional Clean Air Incentives Market (RECLAIM) scheme. Hahn and Hester (1989) demonstrated that high TCs decreased trading activity in the Fox River scheme in Wisconsin. In this context, it must be noted that TCs have two distinctly different effects. First, TCs cause direct costs (such as the costs of monitoring, reporting and verification (MRV) of emissions, brokerage, and trading) that can be readily measured and are the subject of this study. Second, TCs can also distort optimal abatement and lead to welfare losses (Stavins, 1995). The latter effect is discussed in the following, but its quantification is not the subject of this study.

Empirical studies of TCs in the environmental policy literature remain patchy, because most authors have limited their TC definitions and analyses to the narrow neoclassical definition – the cost of using the market mechanism – that has usually been operationalized as the brokerage costs of trading permits. This narrow definition has two problems. First, it covers only a small portion of total TCs. Second, it does not allow for a comparison of TCs with other policy instruments where no trading takes place, such as taxes or standards. Against this background, McCann, Colby, Easter, Kasterine, and Kuperan (2005) and Krutilla and Krause (2010) developed a more inclusive taxonomy (see Section 3) that provides a useful framework to analyse the environmental policy instruments comparatively. This broader perspective has been adopted by several empirical studies in recent years, which revealed that in trading schemes, brokerage costs are small compared to other TC components, such as the costs of MRV (Brockmann, Heindl, Löschel, Lutz, & Schumacher, 2012; Jaraite, Convery, & Di Maria, 2010; Lo¨schel, Brockmann, Heindl, Lutz, & Schumacher, 2011; Löschel, Kiehl, Lo, Koschel, & Koesler, 2010; VBW, 2011).

Three other recent studies have investigated the relative TC performances of different climate policy instruments. Betz, Sanderson, and Ancev (2010) compared the total costs (abatement costs plus TCs) of achieving a certain reduction target by means of uniform firm coverage under an ETS to a scheme where small emitters opted out of the ETS and, instead, were covered under a performance standard. They found that with modest emissions reduction targets, shifting from uniform to partial coverage led to overall cost savings. Yet, if the level of ambition for CO2 abatement increased, overall savings decreased due to the relatively lower abatement efficiency of the performance standard.

Ofei-Mensah and Bennett (2013) compared three climate policy instruments in the Australian transport energy sector: two standards providing enhanced consumer information (the Fuel Label Program and the voluntary Fuel Efficiency Program) and a hypothetical Tradable Permit and Fee System. They identified strong asymmetries in TCs per tCO2e abated between the standards (about \$2.5/tCO2e abated) and the Tradable Permit and Fee System (about \$7.2/tCO2e). However, this conclusion critically hinged on their chosen cost metric of cost-per-ton abated and the assumption that the trading system would yield only 6.7MtCO2e total cumulated emissions reductions over a 15-year period. If more cumulative abatement occurred in this time span – e.g. 67 MtCO2e – the TCs of trading according to this metric would drop (in the example, to \$0.72/tCO2e abated). This shows that the chosen metric is critical for a comparison with other policy instruments, in this case because TCs depend on the assumed abatement level.

A recent synthesis article by Mundaca et al. (2013a) describes TCs as 'an important factor in public policy' in the context of climate policy instruments. The article reviews TCs in the context of energy efficiency technologies, renewable energy technologies, offset carbon markets, and the EU ETS. However, the TCs are not presented in a consistent metric across the instruments, which makes it difficult to draw broader conclusions. Clearly, TCs have been high or even exorbitant for some projects of the Kyoto mechanisms (Antinori & Sathaye, 2007; Michaelowa & Jotzo, 2005).

This article complements the existing literature by reviewing and comparing all publicly available empirical studies on climate instrument TCs. The aim is to discern whether TCs critically affect the efficiency rankings of different climate policy instruments.

3. Definitions and approach

This study adopts the following TC definition: 'Transaction costs are the *ex ante* costs of establishing environmental policy in all of its aspects, and the *ex post* costs of administering, monitoring and enforcing the policy once established' (Krutilla & Krause, 2010; based on McCann et al., 2005). In other words, '[transaction costs are all costs of the policy] excluding abatement costs.' This definition covers all phases and aspects of costs that are needed to carry out a meaningful comparison across different policy instruments (see Table 1 for a general list of public sector TCs and Tables 2 and 3 in the following sections for a list of private- and public-sector TCs in the case of emissions trading, which further differentiates the general *ex post* TC components, as indicated in Table 1).

The focus of this article is on *ex post* TCs, because only very limited data exist on the *ex ante* stages for climate policy instruments (categories (i)–(iii) in Table 1). In the short term, if these *ex ante* costs are significant, they may influence a firm's decision and could lead to an investment hiatus, implying adverse impacts on cost-effectiveness. However, in the long run, *ex post* costs will usually be the dominant factor (Betz, 2010).

Other studies that have investigated the TCs of policy instruments apply concepts such as information costs, search costs, administrative costs, compliance costs, legal expenses, monitoring costs, and enforcement costs (Destatis, 2011; Kossoy & Guigon, 2012; LECG, 2003; Margaree Consultants Inc., 1998; McMahon, Chan, & Chaitkin, 2000; DR Roever & Partner KG 2006; Sandford, Godwin, & Hardwick, 1989; Smulders & Vollebergh, 2001; VBW, 2011). The definition adopted here allows for the integration of all these cost components.

Table 1. Transaction costs associated with public policies.

Transaction Costs
(i) Research and information
(ii) Enactment or litigation
(iii) Design and implementation
(iv) Support and administration
(v) Contracting
(vi) Monitoring/detection
(vii) Prosecution/enforcement

Source: McCann et al., 2005.

Table 2. Classification of private-sector *ex post* transaction costs in the EU ETS.

Private sector ex post Transaction Costs
(i) Assembling information on cost-effective abatement at the facility level
(ii) Monitoring, reporting and verification (MRV)
(iii) Application for free allocation (unless permits are auctioned)
(iv) Legal expenses
(v) Trading permits

Table 3. Classification of public sector *ex post* TCs in the EU ETS.

Public sector *ex post* Transaction Costs
(i) Compliance agency
(ii) Registry
(iii) Auctioning

As pointed out by Mundaca et al. (2013b) and Macher and Richman (2008), the existing empirical literature on TCs for policy instruments lacks a well-developed and comprehensive theoretical foundation. Although this article does not attempt to systematically fill this gap, it aims to contribute to the development of TC theory by introducing conceptual distinctions of how *ex post* TC dimensions for climate policy instruments can scale with respect to differing regulatory contexts and policy designs. The need for such a specification of the scaling of TCs arises when attempting to compare estimates of TCs across empirical cases. This is done in order to draw conclusions regarding the anticipated TCs when introduced in other regulatory contexts, that is, to inform the choices and set-ups of novel climate policy instruments.

Building on the empirical studies reviewed in this article, as well as conceptual considerations, we suggest distinguishing the following dimensions along which TC components of climate policy instruments can be scaled:

1. The number of regulated entities

Firms' MRV costs make up a large share of total TCs. The more entities being regulated, the higher the total private-sector TCs will tend to be.

2. The size of regulated entities

Small installations tend to have smaller total TCs than large installations. However, the TCs per tCO2 regulated tend to be smaller for large installations due to economies of scale.

3. The number of regulated appliances (in the case of an appliance standard)

For homogenous mass-produced goods, such as household appliances or vehicles, certification must be carried out for each model of appliance (e.g. fridge or dryer) that is offered in a certain market. Therefore, TCs scale based on the number of different models of appliances being regulated, but not on the total number of appliances sold.

4. The level of abatement

Identifying abatement options at the firm level and establishing an abatement cost curve is costly. Therefore, increasing levels of abatement should raise TCs.

5. The volume of market transactions (in the case of trading mechanisms)

The trade of TCs includes brokerage costs, which must be paid for each traded unit (e.g.CO2 certificate). Accordingly, the TCs vary with the number of traded certificates.

6. Other instrument or TC-specific factors

The magnitude of TCs from legal disputes, for example, partly depends on how firms estimate the costs of lawsuits versus the chances of winning the case. The more favorable this ratio, the more likely legal action will be. Other factors, such as the costs of lawsuits, corporate law, and legal norms, can also play a role in this specific cost factor.

7. Time

Time, as a TC-scaling factor, cuts across the basic TC categories and the previous scaling dimensions.

Cost factors, and the degree to which they are scalable, are likely to change over time. For example, due to learning-by-doing and technological change, absolute TCs may generally fall over time (e.g. trading costs in the US SO2 allowance market fell 98% over time) (Joskow & Schmalensee, 1998; LECG, 2003).

These dimensions can interact. Consider a limiting case. When, over time, the level of abatement becomes so ambitious that emissions approach zero, fewer entities will require regulation, and absolute trading volumes will fall. TCs will probably rise with respect to abatement cost information, but decline with respect to the other factors.

In addition, there are fixed costs during the inception of the policy instrument that occur only once (such as the administrative, informational, and capital costs involved in setting up novel compliance structures), as opposed to the annual running costs of a scheme over the long term (Jaraite et al., 2010). Finally, for clarity, it is useful to distinguish TC components and scaling factors at the firm- and aggregate- system level (indicating total TCs). This article focuses on the latter.

The methodical approach of this article is to assemble all publicly available *ex post* TC data on existing climate policy instruments and to use evidence from other policy instruments that were plausible analogies. The latter approach was taken only where TC data on climate policy instruments were scarce or unavailable (e.g. CO2 tax). Data were obtained from case studies, consultant reports, government reports, interviews, and our own calculations. Where possible, the data were broken down into the *ex post* cost components defined above. Overall, data were limited but available for the EU ETS, the US SO2 ETS, US RECLAIM, the UK excise duties on hydrocarbon fuels, and the US Residential Appliance Standard. When different studies reported different values for a scheme, we focused on the higher estimates to ensure that our aggregation was on the conservative (i.e. high-cost) side. However, by indicating ranges, we also display the low-cost estimates. For policy instruments where neither data nor useful analogies existed (e.g. technology standards for large point sources) the costs were assessed qualitatively.

The use of the metric for reporting TCs depends on the quality of data and the purpose that it is intended to serve. If the aim is to inform the comparison and choice of climate policy instruments in countries that consider adopting novel policies, there is no single metric that can convey all of the desired information in a satisfying manner. This is because, as argued above, cost components are scaled based on context- and policy-specific dimensions. Quantitative scaling factors cannot (yet) be reliably estimated based on the very few existing data points. This can be illustrated with regard to two prominent TC metrics used in the literature.

First, reporting TCs per regulated GHG units (such as € ct/tCO2e) is an elegant way of expressing TCs in a given ETS, relative to the visible price of an emissions allowance. It is most often used for comparing MRV costs across firms in order to identify MRV TC-scaling effects with respect to firm size (e.g. Jaraite et al., 2010; Löschel et al., 2011).We make use of this metric when discussing these dimensions, but using this metric more generally to compare TCs across policy instruments and regions could mask potentially significant context-specific factors, such as the mix of large and small regulated entities in a scheme.

Second, reporting TCs per unit of GHG abated only makes sense when considering cases with comparable abatement levels. Consider the following example. In the first trading period of the EU ETS (2005–2007), little abatement occurred (Ellerman, Convery, & Perthuis, 2010, p. 191), while the EU ETS incurred full TCs. Thus, TCs per abated emissions were relatively high. If the cap had been much tighter, TCs per abated tCO2 would have been much lower, without changing the absolute TCs, because these are likely to scale only to a limited extent with regard to abatement levels (see Section 4.1). This cost metric would be very high in one case and very low in another, while absolute TCs would have remained roughly constant. Without further qualification, such information is not very helpful and is potentially misleading for comparing costs across instruments and regions.

To sum up, if multiple data points on TC components in different contexts were available – and they might become available in the future – it could inform numeric estimates of the different scaling factors. This is currently not the case. This study copes with this challenge by reporting total TCs per country, using Germany and the US as examples. For specific (climate) policy instruments, the magnitudes of different cost components are reported in detail. Potential scaling factors, if these instruments were transferred to other contexts, are discussed. Furthermore, some sensitivity analyses of TCs with respect to programme design were conducted (i.e. upstream versus downstream points of regulation for the EU ETS). The main limitations of this approach are the same as for the other metrics, i.e. the results and policy instruments are not directly comparable to other countries due to differences in the coverage and levels of abatement that are induced. Bearing this caveat in mind, the existing data indicated that the total TCs of different instruments in Germany and the US are low compared to other macroeconomic figures. Finally, the relative costs of the different instruments fall within a range of similar orders of magnitude.

4. Instrument comparisons

Policy instruments for reducing GHG emissions can be divided into two groups: market- and non-market-based instruments. Market-based instruments address the market failure of the GHG externality by incorporating external costs. While the regulator sets the price (or quantity), the market determines the quantity (or price). Examples are permit-trading schemes (quantity instruments) and GHG taxes (price instruments) (IPCC, 2014). In the case of non-market-based instruments (i.e. standards), the regulator sets either a limit for maximum emissions (in absolute or relative terms) or prescribes a certain technology. Examples are vehicle performance standards (CO2 emissions per driven km) and technology standards (e.g. banning coal-fired power plants). This section analyses and discusses the available empirical TC data components for market- and non-market-based instruments for GHG mitigation. Section 4.3 compares different points of regulation (upstream or downstream) for GHG trading and taxation schemes. The discussion of each TC component for each instrument is complemented by a plausibility analysis of its potential scaling dynamics.

4.1 Emissions trading

Emissions trading is a quantity instrument, because the maximum amount of permissible emissions for the regulated entities is set by the regulator (Tietenberg, 2006). Emissions permits are distributed either by free allocation or auctioning and can be traded among polluting entities. Firms engage in abatement efforts and permit trading until the equilibrium permit price emerges. Under ideal conditions, the instrument is cost-effective because MACs are indicated by the market permit price and equalized across all participating firms.

The EU ETS is by far the largest application of emissions trading worldwide, and a number of TC studies of the EU ETS have been conducted, particularly in Germany and Ireland. They are usually based on questionnaires handed out to companies or expert estimations.

These studies exclusively focus on private-sector TCs. However, the analysis in this article adds public-sector costs. Due to the relatively good availability of data for both private and public TCs in Germany, we have used this country as a case study for EU ETS data and compared it with Irish data to show that private-sector figures seem to be robust. Public agency costs in Germany were considered to be on the higher end (on a TC-per-regulated-entities basis), compared to the rest of the EU (Transaction Costs of DEHSt, W. Seidel, personal communication, April 20, 2011, Berlin, DEHSt). We therefore used the German public-sector TCs as the basis for the calculation of the EU-wide public-sector TCs.

4.1.1. Private-sector costs

The EU ETS TC components for the private sector are displayed in Table 2.

The first component is 'assembling information on cost-effective abatement at the facility level'. Before firms can engage in abatement, they need to assemble information on their abatement cost schedule. This involves financial and technical analysis, as well as an analysis on how production and product quality will be affected (Hein & Blok, 1995). This requires additional personnel expenditures and advice from experts, including calculations and risk assessments for payback periods. It can be expected that these costs will rise with increasing abatement ambition because it becomes more difficult to find new abatement options once the easy abatement options have been exploited. However, with only € 0.9million in annual costs regulated to the EU ETS in Germany (Löschel et al., 2011), these costs are currently very small and are seen as negligible compared to other cost components. If these costs were significant, they might affect overall cost-effectiveness along the lines identified by Stavins (1995) by driving a wedge between the theoretically cost-effective allocation of abatement and the actually realized one in the presence of TCs.

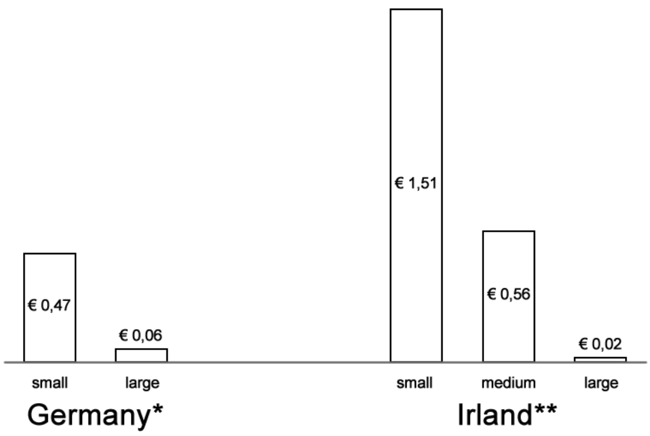


Figure 1 EU ETS annual MRV running costs for small and large installations in €/tCO2 regulated.

Sources: Jaraite et al. (2010) and Löschel et al. (2011).

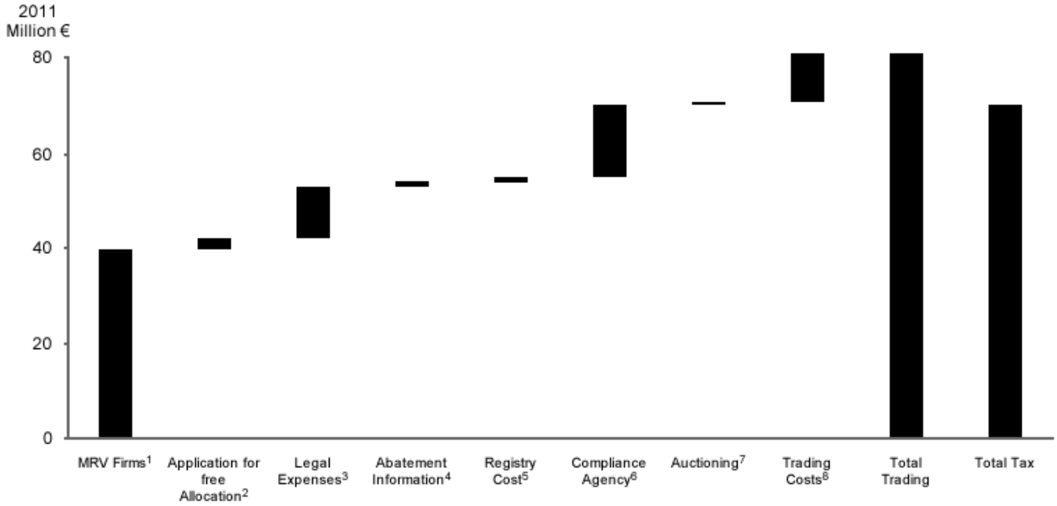
Notes: *median; **average costs.

The MRV of emissions is crucial to all market-based schemes because regulators require reliable emissions data, and firms have an incentive to under-report and over-emit. In the EU ETS, firmsmust report their emissions annually, then have these reports verified by an external verifier who must be accredited by a government agency (DEHSt, 2012). A firm's MRV costs can differ strongly with the size of regulated installations. This non-linearity in firms' MRV costs (see Figure 1) is due to economies of scale in the MRV process, which feature relatively high facility-level fixed costs that have been well documented by several studies (Betz, 2005; Frasch, 2007; Heindl, 2012; Jaraite et al., 2010; Löschel et al., 2010, 2011; Schleich & Betz, 2004). It has been argued that this may lead to a competitive disadvantage for small emitters (Jaraite et al., 2010). Heindl (2012) suggests that this effect may theoretically lead to a larger optimal firm size and might even induce increasing market power in the permit market. However, given the low orders of magnitude involved – a firm emitting 10,000 tCO2 per year at an average TC of € 0.76 would face annual costs of € 7,600 – it seems that the empirical effect will be practically irrelevant. Yet, TCs of € 1.51 per tCO2, as reported by Jaraite et al. (2010) for Ireland, may lead to disproportionate hardships for certain firms.

From 2009 to 2011, the average annual private-sector MRV costs in Germany were reported to be between € ct2/tCO2 (Löschel et al., 2011) and € ct9/tCO2 emitted (Destatis, 2011). In terms of absolute average-per-entity costs, this translates into roughly € 2,500 per annum (p.a.) for small installations (annual emissions below 25,000 tCO2) and roughly € 8,600 for large installations (annual emissions above 25,000 tCO2).[2] For Germany, total MRV TC estimates range from € 11 to € 40 million p.a. As illustrated in Figure 2, MRV constitutes the largest share of private-sector TCs (61–81% of total private costs; Destatis, 2011; Löschel et al., 2011; own calculation).

Aggregate MRV costs are scaled to the number of regulated facilities and the mix of large- and small sized entities (small/large emitters have lower/higher absolute, but higher/lower per unit GHG costs) (Frasch, 2007; Jaraite et al., 2010; Löschel et al., 2011). These costs are independent of the abatement level, because MRV processes have to be carried out for all emissions, independent of the level of abatement. It can be expected that MRV costs will fall over time due to the effects of learning and improved technology.

[2] This calculation is based on firms' MRV cost data, provided by Löschel et al. (2011). The high cost estimates (used in Figure 2) could not be used because no differentiation was made between the small and large firms in the studies by VBW (2011) and Destatis (2011).



	Total costs in 2011 million €
MRV Firms	11 - 40
Application for Allocation	2.4 – 2.6
Legal Expenses	10.7
Abatement Information	0.9
Registry Costs	0.8
Compliance Agency	15
Auctioning	0.13
Trading costs	11
Total Trading	51 - 81
Total Tax	41 - 71

Figure 2 Year 2011 EU ETS and hypothetical carbon tax TCs for different cost components for Germany based on data from the first and second trading periods in total costs.

Sources: 1, Destatis (2011); 2, Brockmann et al. (2012), Destatis (2011); 3, VBW (2011); 4, Löschel et al. (2011); 5, DEHSt (2011a); 6, DR Roever & Partner KG (2006), DEHSt (2011b), DEHSt (2008), CEC (2012); 7, EEX (2012), Point Carbon (2011); 8, Kossoy and Guigon et al. (2012), M. Weber, personal communication, September 10, 2012, Berlin, GreenStream Network Plc, EEX (2012).

If the numbers differed across the studies for the same cost components, the highest estimate was used in order to ensure robustness of the results.

Notes: Bar chart (left) provides cost components using conservative (higher) cost data. Table (right) provides cost ranges. CDM TCs are excluded to focus on the direct costs of the EU ETS.

Concerning the allocation of permits, firms covered by the EU ETS received the largest amount of certificates for free in the first two trading periods (2005–2012). In the third trading period (2013–2020), free certificates will be handed out based on firms' export shares and relative efficiency (benchmarking). Brockmann et al. (2012) found that for the third trading period, the median TC for the free allocation of certificates amounted to a one-time expenditure of € 25,000 for personnel and external costs per firm at the beginning of the trading period. Extrapolating to all covered firms and distributed over eight years, this amounts to roughly € 2.5 million annually for all firms in Germany. The dynamics of this cost component depends on the number of firms that qualify for free allocation and, therefore, on the eligibility criteria for obtaining a free certificate. The higher the number of eligible entities, the larger the aggregate TCs from this component will be.

Auctioning is the alternative to the free allocation of certificates. The costs charged by exchanges to carry out auctions on behalf of governments are about € ct0.3 per certificate (Point Carbon, 2011). A 10% share of auctioned permits in Germany in 2011 amounted to roughly € 0.13 million in TC, while a

50% share (as implemented from 2013 onwards) would amount to € 0.7 million in TCs per year. These costs are clearly scalable to the number of auctioned certificates. As in the case of trading, these costs may fall over time.

Because the rules for granting free certificates are not clearly defined, firms can exercise their rights to legally dispute allocations in court.[3] A survey by VBW (2011) found that these figures translated into € 5,400 in litigation per installation in Germany, or € 10.7 million overall p.a.[4] The scalability of this component is not obvious. However, it can be expected that legal action is scalable to the success rate in relation to the costs of litigation. However, other factors such as legal traditions, corporate law, and political acceptance of regulations by companies may also have an effect.

Permit trading is central to an ETS because it leads to equalization of MACs across all firms. In his seminal study on TCs, Stavins (1995) shows that TCs for permit trading, which he defines as the 'direct financial costs of brokerage services', can lead to the inefficient allocation of abatement across firms. From a cost-effectiveness perspective, trading costs drives a wedge between firms' MACs. TCs reduce beneficial permit exchanges and corresponding adjustments in the allocation of abatement, thus reducing the cost-effectiveness of the policy instrument (Stavins, 1995). In the EU ETS in 2011, the trading volume amounted to 9.7 billion certificates (Kossoy & Guigonet, 2012). Trading TCs ranged from € ct0.1/tCO2 to € ct10/tCO2, with costs apparently falling towards the lower end of this range over time (Convery & Redmond, 2007; EEX, 2012; J. Hacker, personal communication, January 24, 2012, Berlin, UMB; Kossoy & Guigonet, 2012; M. Weber, personal communication, September 10, 2012, Berlin, GreenStream Network Plc). In the EU ETS, the overall trading costs amounted to roughly € 46 million in 2011 and about € 11 million p.a. for Germany. These trading costs are small and there is no empirical indication that they discouraged trading (Jaraite˙ et al., 2010). Therefore, the impacts of negative cost-effectiveness – Stavins' central concern – are likely to be minor for the case of the EU ETS. Trading TCs is scalable to the volume of trading because brokerage costs arise for each transaction. In the EU ETS, it can be observed that the majority of trades are carried out by market intermediaries who are seeking arbitrage opportunities, and not by regulated firms (M. Weber, personal communication, September 10, 2012, Berlin, GreenStream Network Plc). It is therefore likely that price fluctuations (that give rise to profit opportunities for market intermediaries) determine trading levels rather than the amount of regulated GHGs or the amount of abated emissions, even though in a larger trading system, overall higher aggregate trading levels would be expected compared to smaller schemes. It can also be expected that trading costs will fall over time, as illustrated by the comparison with other environmental permit-trading schemes in the following.

4.1.2. Public-sector costs

Table 3 presents the EU ETS TC components for the public sector.

The compliance agency is the central authority that administers the ETS. It oversees the MRV process by conducting sample checks, allocates free certificates, appoints exchanges to auction certificates, provides information, and engages in litigation. The total annual costs for these tasks amounted to roughly € 15 million or roughly € 7,700 per regulated entity for Germany from 2005 to 2011 (CEC,

[3] In the first trading period, 806 appeals were lodged against 1600 allocation decisions and 604 appeals against cost decisions in Germany (UBA, 2009). There were 373 appeals against allocation decisions in the second trading period (UBA, 2009).

[4] It has been stated that the enthusiasm for legal disputes is a special German phenomenon (Seidel, personal communication, April 20, 2011 Berlin, DEHSt; VBW, 2011). Litigation costs in Spain and France were substantially lower at only € 960 and € 60 per installation or € 0.9 million and € 60,000 total p.a., respectively (VBW, 2011). No data are available for other instruments and other countries.

2012; DEHSt, 2008; DR Roever & Partner KG, 2006; Seidel, transaction costs of DEHSt, personal communication, April 20, 2011, Berlin, DEHSt).

The compliance agency for TCs is scalable based on several factors, of which the number of regulated entities is probably the most decisive. Furthermore, there are initial start-up costs, such as setting up administrative processes and communicating and coordinating these processes with the regulated entities. It is likely that the cost of the compliance agency is also scalable to the quality of its performance because rigorous and more frequent verification would be more costly than relaxed control. The per-entity costs may decline with the increasing number of regulated entities due to economies of scale. The public registry is the electronic database for reconciling certificate accounts and the emissions data of all regulated entities and is usually run by the compliance agency. The costs related to the registry are mainly software and servicing costs. In Germany, they averaged about € 0.76 million per year for the first and second trading period (DEHSt, 2011a).

This is largely a fixed component because the costs are determined by the licensing and maintenance costs of the software. However, this cost also contains a variable component because it is likely that the costs of the software are scalable to the number of accounts. Due to improved technology, such costs may fall over time. However, they could also rise due to higher regulation requirements and safeguards against fraud (European Voice, 2013).

4.1.3. Offsets for Kyoto mechanisms

In the EU ETS, firms can also use credits from the Kyoto offset mechanisms (the Clean Development Mechanism [CDM] and Joint Implementation [JI]) for compliance. These credits are usually cheaper (due to lower abatement costs) than the EU ETS allowances, but tend to feature higher TCs (due to costly project cycles). In the second trading period, 302 million Kyoto offset credits were used for compliance in Germany (CEC, 2014; DEHSt, CDM und JI in zweiter Handelsperiode, W. Seidel, personal communication via e-mail, 2014; Emissions-euets.com, 2014). Based on data from Krey (2005), Antinori and Sathaye (2007), and Michaelowa and Jotzo (2005), we found a range of TCs, from € 15 to € 32 million p.a., which resulted from the use of offset credits for Germany. However, it must be noted that these TCs do not affect the companies in the EU ETS directly because the TCs are already incorporated into the offset price, which is usually lower than the costs of the European Union allowances (EUAs). Nevertheless, these costs hamper the efficiency of the EU ETS link to the CDM via the distortive effect identified by Stavins (1995).

Due to the various cost components of theCDMprocess cycle, a separate analysis of the dynamics of these cost components should be subject to further research; however, this is outside the scope of this study. For the EU ETS, the total TCs incurred by the offset credits is clearly scalable to the number of credits used for compliance.

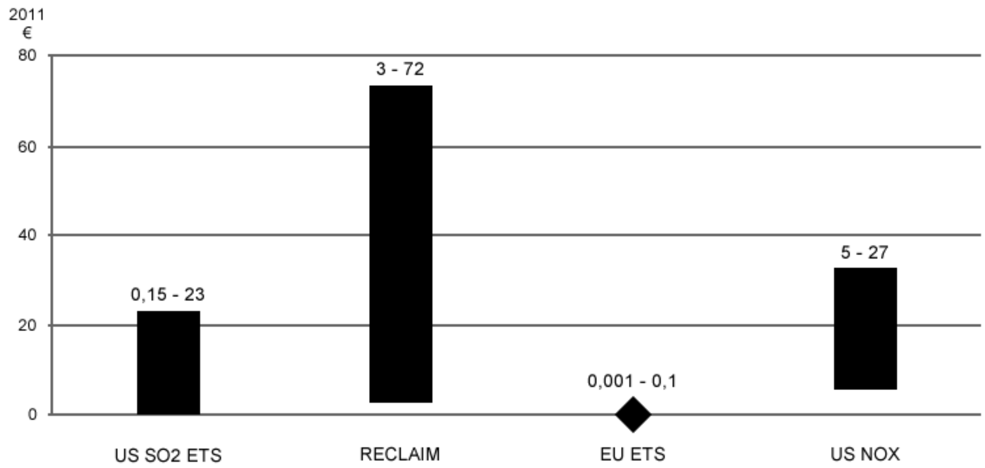


Figure 3 Ranges of ETS per unit (permit) of trading costs compared to the private sector.

Sources: Joskow and Schmalensee (1998), Margaree Consultants (1998), LECG (2003), EEX (2012), Convery and Redmond (2007), J. Hacker, personal communication, January 24, 2012, Berlin, UMB, M. Weber, personal communication, September 10, 2012, Berlin, GreenStream Network Plc.

4.1.4. Summary, discussion, and comparison with other environmental permit trading schemes

Figure 2 aggregates the *ex post* TC estimates for the EU ETS in Germany. The total annual costs in the one-year trading period from 2010 to 2011 amounted to € 81 million in Germany or € ct18/tCO2 regulated. Private-sector costs are 68–80% of total TCs, while public-sector costs are 20–32%.

Several studies have analysed the effects of trading costs on trading schemes targeting other environmental pollutants (Joskow & Schmalensee, 1998; LECG, 2003; Stavins, 1995). These schemes feature much higher trading costs, especially during inception. The RECLAIM scheme featured costs from € 3 to € 72 per traded unit (tNOx and tSOx), the US NOx budget trading scheme featured trading TCs from € 5 to € 27 per unit (LECG, 2003), and the US SO2 scheme is currently in the range of € 0.15, but started at around € 23 (Joskow & Schmalensee, 1998; LECG, 2003) (Figure 3). Due to the effects of learning by market participants and brokers, as well as improved technology, the costs have dropped by more than 98% over time.

The claim of inefficient abatement and resulting welfare losses due to the TCs of permit trading (Stavins, 1995) seems to be more relevant for these schemes (e.g. Gangadharan, 2000), especially at the time of their inception, than for the EU ETS where it seems sensible to assume that the relevance of this effect is negligible.

The comparison of public-sector TCs reveals that US environmental permit trading schemes are leaner than the EU ETS. While the EU ETS and the NOx budget ETS in the US have running costs of € 3,900 and € 7,700 per regulated entity, respectively, the US SO2 scheme is far less costly with only € 780 per regulated entity (DEHSt, 2008, 2011b; LECG, 2003; McLean, 1997; DR Roever & Partner KG, 2006). For the US SO2 scheme, the total firms' MRV costs amounted to approximately € 100 million and the trading costs were approximately € 3.5 million. Including the € 1.6 million from public-sector costs, this amounts to TCs of € 105 million (Joskow & Schmalensee, 1998; LECG, 2003; US Environmental

Protection Agency (EPA), 2001).[5]

All of these metrics suggest that the TCs of the EU ETS are not prohibitively high in absolute terms from a macro-economic perspective. In any case, when choosing a policy instrument, it is the relative costs of the instruments that matter. This point is addressed in the concluding remarks.

4.2 Tax

Emissions taxation is a price instrument, because the regulator sets the emissions tax, while the quantity of emissions is determined by firms' market behaviours. Much like a permit-trading scheme, a carbon tax can achieve the equalization of MACs across all regulated entities. Under standard assumptions of competitive markets, trading and taxation schemes are symmetric. Asymmetries in instrument performance have been discussed for conditions of uncertainty (Hepburn, 2006; Weitzman, 1974) or incentive structures for subnational jurisdictions in a federal system (Shobe & Burtraw, 2012). This study investigates how taxing and trading compare with TCs performance.

A comparison of TCs between the tax and trading schemes needs to be careful not to compare 'apples with oranges', as is sometimes done in public debates where real-world 'second best' schemes (such as the EU ETS) are compared with theoretical 'first best' taxation schemes. In particular, specifications regarding the point of regulation and rent distribution need to be treated in a conceptually equivalent manner. A downstream trading scheme with a large portion of grandfathered certificates (such as the EU ETS) should be compared with a downstream taxation scheme with an equivalent level of tax exemptions. Even though the incentives for abatement may be different, the two options (grandfathering and exemptions) should be regarded as analogous responses to identical political economy considerations.[6]

Firms' MRV costs as the major TC cost component would be the same in both tax and trading schemes for the firms that are subject to MRV, because data requirements for the MRV process are identical. Also, other private TC factors would be identical except for trading and auctioning costs, which do not accrue for taxes.

Drawing on data from the previous section, a downstream taxation scheme for Germany with tax exemptions equivalent to the free allocations in the EU ETS would thus result in TCs of approximately € 41 to € 71 million (see Figure 2). This is approximately € 10 million (the costs of trading and auctioning) less than the TCs of a trading scheme, which seems negligible from a macro-economic perspective.

A different approach to determining the TCs of a CO2 tax is to compare it to other taxes that require similar administrative efforts by the private and public sector. Because a CO2 tax would be designed to act as a levy on fuel according to its CO2 content, excise duties on hydrocarbon fuels are a good proxy. Data from a study on administrative and compliance costs of excises on hydrocarbon oils are available for the UK (Sandford et al., 1989, p. 155). The tax covers light oil, road vehicle fuel, fuel oil, and gas oil. The major findings from this study are that the majority of costs are the MRV costs of installations and the reading of meters (Sandford et al., 1989, p. 156). From 1986 to 1987, public-sector costs amounted to € 14.2 million and private-sector costs were E31.7 million for all of the UK.

[5] Firms' MRV costs are substantially higher for the US SO2 scheme than for the EU ETS. In 2001 there were 2100 regulated entities with average MRV costs of € 47,000 (or $50,000) (EPA, 2001). Initial capital costs were also large. Ellerman (2000) estimated them to be approximately $700,000 per generating unit (at 371MWe per unit).

[6] We assume that, due to political economy considerations (i.e. the rent distribution interests of firms), the taxing scheme would also be designed in a downstream manner.

The TCs for taxation schemes feature the same cost components (except for auctioning and trading) as an ETS. Thus, the same considerations apply concerning the scaling of these cost factors with respect to different context and design variables (see Section 4.1).

4.3 Carbon-pricing transaction costs: upstream versus downstream points of regulation

The point of regulation is the location in the fossil-fuel processing chain where the regulator carries out MRV and requires the submission of emissions permits. Options can be distinguished according to up, mid-, and downstream regulations. For upstream schemes, the point of regulation is during the exploitation or importation of fossil resources. In this case, all other downstream consumers would not be subject to MRV and trading, thus eliminating all TCs for downstream firms. The upstream carbon price can be expected to be devolved to the downstream level, as is standard procedure with vehicle fuel excise duties. This approach would eliminate the inefficiency of non-linear MRV costs for small companies, as discussed in Section 4.1 and illustrated in Figure 1. By contrast, midstream regulation is carried out at the processing or storage level, and downstream regulation is exercised at the firm (as in the EU ETS) or even the final consumption level (Flachsland, Brunner, Edenhofer, & Creutzig, 2011).

Table 4 Potential savings from switching to EU ETS upstream regulation in Germany

Downstream			**Upstream**			
	TC per t CO2 (€)	TC total (in million €)		TC per t CO2 (€)	TC total low (million €)	TC total high (million €)
Large firms	€ 0.02	€ 9	Producers and Importers	€ 0.01[a]	€ 2.7[b]	€ 10[c]
Small firms	€ 0.5	€ 3	Small firms		No costs	
Total		€ 12			€ 2.7	€ 10
Savings: **€ 2 - € 9,3 million**						

a) Very large installations have TCs of about € 0.01 (Löschel et al., 2011).
b) For the low estimate, we calculated the MRV costs for a large refinery (1.8 million tCO2 emissions; MRV costs of € 18,000 per year) and used this number as the average TC for the 150 importers and producers.
c) This calculation is based on the TC for large installations in Ireland (assuming that they have similar TCs as large installations in Germany). These costs amount to € 66,000 per year (Jaraite et al., 2010).

The TC savings that result from adopting an upstream scheme compared to a downstream scheme depend on two factors: (1) the difference in TCs per emitted tCO2 between small and large entities and (2) the ratio between small and large entities within a scheme.[7,8]

The calculations in Table 4 show that switching the point of regulation from downstream to upstream could result in savings ranging from € 2 to € 9 million p.a. for Germany. Small firms that currently

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[7] In this context, 'large entities' refers to the producers and importers of fossil fuels.
[8] There are 900 large installations (.25,000 tCO2) and 1100 small installations (25,000 tCO2) in Germany that make up almost 99% of emissions (Community Independent Transaction Log (CITL), 2013).

feature high relative TCs would benefit most from these savings. However, the savings are limited in absolute terms because most emissions (over 99%) in Germany come from large sources that already have small TCs. The scope for total TC reductions from a macro-economic perspective is limited. This may be different for other sectors that might be included in the EU ETS, in particular heating and transport. The cost savings roughly calculated here also need to be pitched against the full *ex ante* (opportunity) TCs of negotiating and implementing such a major regulatory change. However, the calculations suggest that a newly set up ETS should opt for upstream coverage from inception from an *ex post* TC perspective.

4.4 Technology standards

Technology standards are the most traditional instruments for environmental policy making. One major reason is that they are quite easy to design and monitor (Sterner, 2003, p. 80); i.e. *ex ante* and *ex post* TCs are often considered to be low. The drawback of this instrument is that an equalization of MACs across facilities is not possible. Strongly differing MACs among firms leads to low overall cost effectiveness of the instrument. This has led to a relative decline in the adoption of technology standards compared to market-based instruments in recent years (Aldy & Stavins, 2011).

From a TCs perspective, some forms of technology standards for point sources have the advantage of requiring very little MRV. Because, in many instances, it is not worth the effort to remove technologies once installed, sporadic monitoring is sufficient to enforce compliance, and public-sector efforts and data requirements are low (Hepburn, 2006). Other forms of technology standards, such as the requirement to inspect domestic heating systems for CO2 emissions in German MRV must be carried out regularly. Such forms of technology standards might therefore incur substantial MRV TCs; however, data are unavailable. Data for a standard for the regulation of large point sources – e.g. the planned CO2 standards for power plants in the US (US EPA, 2013) or the regulation of SO2 via scrubbers in Germany – are also unavailable. For the purpose of this study, no general quantitative estimates for MRV costs of technology standards for large point sources could be identified or could be plausibly determined by analogy. It seems safe to assume that they will be lower than those of any other policy instrument considered in this study.

4.5 Performance standards

A performance standard limits the amount of emissions for a certain unit of output (e.g. CO2 per ton of cement, CO2 per driven km, kWh per litre refrigerator capacity). In contrast to a technology standard, it has the advantage of allowing firms to choose from various emissions reduction options during the production process, rather than being obliged to fulfil specific technical requirements. It also has the advantage that the standard can be adapted to technological progress (e.g. Japan's Top Runner Program). Non-tradable performance standards have the disadvantage that harmonization of MACs across firms is impossible.

From a TC perspective, a performance standard for heterogeneous point sources of pollution entities (e.g. cement factories or steel mills) does not entail significant cost reductions. This is the case because, analogous to an ETS, all emissions have to be monitored and verified, and trading costs also arise (in the case of white certificate trading). The costs of monitoring are reduced if a performance standard is set for homogeneous non-point source pollution goods that are subject to mass production (e.g. vehicles or household appliances) and no regular inspection is required. Each model of an appliance (e.g. fridge or dryer) that is offered in a certain market must be certified only once. TCs for three different performance standard programmes are briefly discussed in the following paragraphs.

The US Appliance Standard covers a variety of appliances, such as refrigerators, space heaters, water heaters, and other electrical equipment. For compliance, the products must perform better than a maximum limit of energy consumption per unit of the relevant output. Standards setting, test procedures, certification, and enforcement are carried out by the US Department of Energy.

The calculation of annual TCs from different sources is summarized in Table 5. The total annual public sector TCs for the US Appliance Standard range from € 4.1 to € 17.4 million in 2011. These TCs are substantially lower than for the other climate policy instruments reviewed in this article, indicating that regulation via appliance standards is relatively cheap. This advantage needs to be considered against the abatement opportunities that are related to this instrument (which are likely to be limited) and the inferior overall cost-effectiveness of the technological standards. The reason for the lack of cost-effectiveness is incomplete MAC harmonization, the salience of which will increase with the rising stringency of the programme. This point is discussed further in Section 5.

Table 5 Annual public sector TCs for the US Appliance Standard in € (2011)

Total costs (million € $_{2011}$)	**Source**
4.1	Levin et al. (1994)
5	McMahon et al. (2000)
9.3	Meyers et al. (2003)
10.1	McMahon et al. (2000)
11.6	Meyers et al. (2003)
13.9	Gillingham et al. (2004)
17.4	Gillingham et al. (2004)

Note: The cost data are adjusted for inflation and converted into € (see note 1); therefore, it no longer matches the original data.

In general, the TCs of an appliance standard are likely to scale with respect to the number of different appliances covered, as MRV (i.e. certification) must be carried out for each model. There are also ongoing fixed TCs for governments and firms. If regular inspection of a device is required (e.g. home heating systems in Germany), the number of appliances, as well as the inspection procedure, will affect the total TCs for that instrument.

A hypothetical performance standard for large point sources in Germany, which would cover the sectors regulated under the EU ETS, would result in TCs of roughly € 41 to € 71 million p.a. The rationale behind this calculation is that the costs of MRV, registry, and the public agency will be roughly identical to those of an ETS or tax.

TCs for the EU Emission Vehicle Standard and the US Corporate Average Fuel Economy (CAFE) programme are likely to be low, but no data are available. The scaling properties for these TCs are likely to be analogous to an appliance standard. Each model (but not every single vehicle) has to be certified prior to sales, but regular inspection of each vehicle is not necessary. Furthermore, there are also ongoing fixed TCs for governments and firms.

5. Conclusions

Table 6 and Figure 4 summarize the reviewed TC data for different climate policy instruments. They show that *ex post* TCs of policy instruments in large industrialized countries are relatively low in macroeconomic terms. For example, the TCs for the EU ETS in Germany are less than 1% of the subsidies for renewable electricity in Germany, which was € 12 billion in 2011 (Frontier Economics, 2012). Furthermore, the comparison shows that TCs do not differ strongly across instruments. Compared to the potential orders of magnitude of macroeconomic inefficiencies from non-optimal policy instruments, especially in the longer run, the magnitude of TC differences (as indicated in Table 6) appear to be very small or negligible. For example, using a numerical dynamic general equilibrium model, Kalkuhl, Edenhofer, and Lessmann (2013) calculate that relying exclusively on a feed-in tariff instead of an optimal carbon tax can increase the costs of climate policy by 0.8% of total consumption in terms of balanced-growth equivalents (see also Fischer & Newell, 2008).

Table 6 Aggregated TCs for all instruments considered

Scheme	**Country**	**Pollutant**	**Total TC** (million € $_{2011}$)	**Regulation Method**
EU ETS (Downstream)	Germany	CO_2	51 - 81	Downstream; Point sources
EU ETS (Upstream) (hypot.)	Germany	CO_2	28 - 35	Upstream; Point sources
EU TAX (hypot.)	Germany	CO_2	41 - 71	Downstream; Point sources
UK TAX	UK	CO_2	46	Upstream; Point sources
EU Industrial Performance Standard (hypot.)	Germany	CO_2	41 - 71	Downstream; Point sources
US Appliance Standard	US	CO_2	4 - 17	Downstream; Non-point sources
CDM/JI used for EU ETS [a]	CDM/JI Host Countries / Germany	CO_2	15 – 33[a]	Certification; Point sources
US SO_2 ETS	US	SO_2	105	Downstream / CEMS; Point sources

Notes: Ranges are indicated where data from multiple sources were available. The column 'Regulation method' indicates how MRV is carried out.

a) TCs for offset credits used for compliance for the EU ETS in Germany. For data see Section 4.

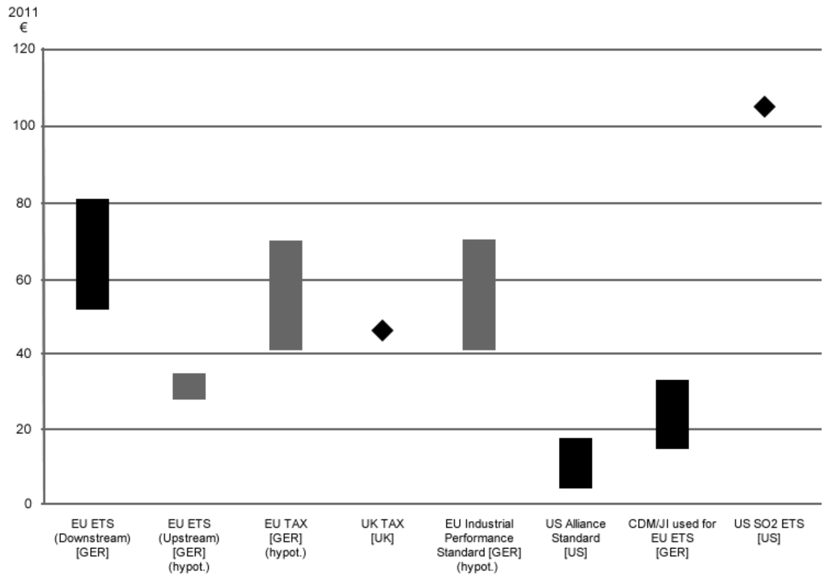

Figure 4 Aggregated total TCs for different climate policy instruments.

Notes: Ranges are indicated where data from multiple sources were available. Grey bars indicate that the calculations are based on hypothetical schemes. Black bars indicate that the data originated from empirical studies on schemes that were in operation. For data, see Section 4.

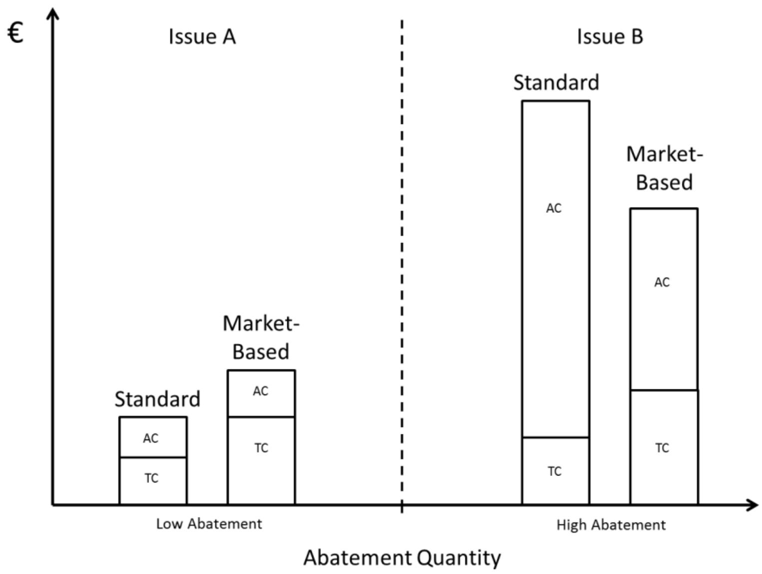

Figure 5 Optimal policy instrument choice for different issues (issue A, low level of abatement; issue B, high level of abatement) when both the cost-effectiveness, defined as total abatement costs (ACs), and TC properties of instruments are taken into account

Note: Total ACs are assumed to be lower for market-based instruments due to the equalization of MACs.

Figure 5 offers a framework to discuss TCs in relation to different abatement levels in order to discern whether TCs are relevant to the total cost-effectiveness ranking of climate policy instruments (for a similar line of argument, see Betz et al., 2010). It depicts two scenarios for the regulation of GHGs in one country[9] by comparing the abatement levels (low and high), the sums of the total system-level abatement costs, and total TCs of technology standards and market-based instruments.

Standards tend to have lower TCs than market-based instruments, but are inferior in terms of MAC harmonization across regulated entities. The magnitude of this adverse cost-effectiveness property will increase with the overall quantity of abatement, thus increasing the relative total abatement costs of the instrument with rising programme stringency. Hence, standards may be superior instruments at low levels of abatement (issue A), but for ambitious abatement programmes (issue B), market-based instruments can be expected to perform better due to lower total abatement costs. It can be argued that climate policy in large countries is generally a B-level policy issue because ambitious emissions reductions will be required in the long term.

Related to these considerations, the incorporation of TC considerations into policy instrument choice might principally also affect the optimal choice of the level of policy stringency in the context of an overall efficiency analysis (i.e. balancing the marginal costs (including TCs) and benefits of abatement using a specific instrument). However, given the small TC differences across climate policy instruments observed in this study, it seems that TCs are practically not relevant in such considerations, at least in regulatory contexts similar to the EU and the US, and instead the relative abatement cost performance as well as other societally relevant evaluation criteria are relevant to the optimal choice of climate policy instruments. However, several limitations to this finding have to be considered.

First, as discussed in Sections 3 and 4, TCs scale with respect to different country- and design-specific factors. For example, TCs may be substantially higher in other jurisdictions with different institutional structures, governance capacities, and market infrastructures. This may be true for other Organisation for Economic Co-operation and Development (OECD) countries, but especially for emerging economies and developing countries. Research on schemes such as the CDM and Reducing Emissions from Deforestation and Forest Degradation (REDD) have shown that TCs can be large and are therefore likely to distort optimal abatement (Antinori & Sathaye, 2007; Boettcher et al., 2009; Fichtner, Graehl,&Rentz, 2003; Michaelowa&Jotzo, 2005). The same may apply to jurisdictions with few abatement opportunities (such as cities). In such cases, the differences in TCs of different instruments may outweigh the advantages of MAC harmonization (indicating that the issue is A-level in the framework of Figure 5). Furthermore, in very small jurisdictions with little abatement, such as cities, differences in TCs may outweigh the advantages of MAC harmonization, which would also indicates A-level situations and related policy choice. To better inform the choice and set-up of novel climate policy instruments with respect to relative TCs, more empirical TC data from applications in different contexts would be required to be able to robustly estimate the magnitude of these scaling effects.

Second, the TCs in this study relate to average *ex post* costs over a longer time period. Short-term changes in regulation, such as new MRV requirements, may affect investment behaviour and may imply financial hardship for certain firms in the short term, which can create costs at the system level. Furthermore, other *ex ante* costs such as setting up administrative processes and communicating and coordinating these with regulated entities, but especially the societal costs of political bargaining, may be important factors that can limit the development of climate change policies. A comprehensive analysis of the interdependence of TCs and policy instruments would, therefore, need to put a stronger focus on *ex ante* TCs. The interplay between *ex ante* TCs, *ex post* TCs, and the cost-effectiveness of instruments should be subject to further research.

Third, it has been pointed out that economies of scale, resulting in different MRV costs for firms, may lead to a competitive disadvantage for small emitters, but the effect seems to be small in the case of the

[9] The numbers of regulated emissions and entities are assumed to be identical in both scenarios.

EU ETS (see Figure 1 and Section 4.1.1).

Fourth, TCs may alter the shape of a firm's marginal abatement supply curve and subsequently affect cost-effectiveness and efficiency. This may be the case if TCs for assembling information on cost-effective abatement at the facility level vary among different abatement options. The respective TCs for different abatement options at the firm level and their potential to distort programme cost-effectiveness should, therefore, be subject to further research.

Despite these caveats, current evidence indicates that, for large jurisdictions in OECD countries such as Germany and the US, *ex post* TC considerations play a minor role in climate policy instrument choices. In these contexts, the focus of policy-choice considerations should instead be on the cost effectiveness properties of the instruments for incentivizing abatement and other societally relevant objectives (e.g. equity or political economy considerations).

This conjecture differs from experiences in other areas of environmental policy, such as pollution trading in the Minnesota River basin and the US- led phase-out trading programme, where very high *ex post* TCs were observed and thus considered to be important in the overall assessment of optimal environmental policy choice.

Clearly, some caution is warranted given that the underlying data are somewhat meager and patchy outside of the EU ETS. Therefore, the results of this study should be viewed as preliminary until further evidence is provided. Such research should be based on more observations that are founded on clear and uniform reporting rules for TCs. The relevant question here is whether better data would alter the general findings of this study. As this discussion has attempted to demonstrate, it seems unlikely that, for large countries with similar institutional settings to the US and Germany, new data will change the picture dramatically and make *ex post* TCs a substantial factor for climate policy instrument choice from a macroeconomic perspective.

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Chapter 6

Synthesis, Discussion & Further Research

VI Synthesis, Discussion & Further Research

The main theme of this dissertation has been to analyze selected economic and political challenges[1] of the Energiewende in Germany's electricity sector.

Applied to the subject at hand, these are:

1. What are the goals (or problems) of the Energiewende (Chapter 2)?
2. What are the expected outcomes of certain policies (in this case different nuclear phase out dates) (Chapter 3)?
3. Which policy for EEG reform should be chosen to reach certain political goals (Chapter 4)?
4. What are observed ex-post policy outcomes concerning transaction costs for climate policy instruments (Chapter 5)?

This synthesis chapter is structured as follows: section 6.1 provides a synthesis of the central ideas as well as the main research questions and findings of the Chapters 2-5. Section 6.2 gives an overview over the methodological approaches used in each chapter and the lessons-learned in their application. Section 6.3 outlines ideas for further research. Section 6.4 concludes with thoughts on how to improve interaction at the science-policy interface.

6.1 Synthesis Summary of the Chapters

The following section provides a synthesis of the core chapters (2-5) of this dissertation by briefly summarizing the research questions and findings of each chapter:

Chapter 2, titled *Which goals are driving the Energiewende? Making sense of the German Energy Transformation* addressed research into the political goals of Germany's Energiewende based on 54 interviews with policy experts.

In particular the chapter aimed to answer the following questions:

- What are the goals that are commonly used to justify the Energiewende in the public discourse?
- How do German elite policy actors rank these goals? Do they leave goals out or add others?
- Are there goals that are often ranked higher than other goals?
- Is there a justification for intentionally leaving political goals vague?

The key finding is that a large majority of respondents named climate protection as the most important goal of the Energiewende. However, around 80% of all participants also pursue additional goals with the Energiewende, and around two thirds go as far as to agree that the Energiewende would make sense even if climate change did not exist. This seemingly

[1] Chapters 2 to 5 inform central questions of policy analysis, as defined by Dunn (2012: 5).

contradictory finding suggests that the goals and motivations behind the Energiewende are manifold and go far beyond just climate protection, as suggested by many prominent studies. It became clear that different actors pursue different goals with the Energiewende. Other important goals are, for example: the nuclear phase-out, import independence from fossil fuels, and job creation and regional added value in RES industries. The study also illustrated the discrepancy between the normative claim by economists that rational policy making is only possible if the goals are clear (e.g. Weimann, 2006: 10), and the instrumental usage of goals as described by Fischer (2006: 158): "politicians find it advantageous […] to leave the meanings [of goals] vague, permitting different groups to read into them what they want. The ambiguity of meanings is often the very thing that makes possible political compromise between groups with conflicting views."

Chapter 3, titled *Germany's nuclear phase-out: Sensitivities and impacts on electricity prices and CO_2 emissions,* was aimed at policy makers who must make decisions under high uncertainty.

The chapter aimed to answer the following questions:

- What options are available for replacing nuclear energy and how are they to be evaluated economically and environmentally?
- How would CO_2 emissions and the electricity prices (on the wholesale market and for end consumers) develop for different nuclear phase-out scenarios and with different replacement options?
- How is security of supply affected?
- How do the results change when individual model assumptions are varied?
- How do the results compare to other studies with similar research questions?

We found that in the short term, all nuclear power plants that were shut down according to the *moratorium on nuclear energy* can be replaced by making use of existing overcapacities as well as by reducing net electricity exports. In the medium term, a series of fossil fuel-fired power plants that are under construction can replace a large share of the nuclear fleet. To secure electricity supply in the long term, the options primarily deployed in our model include the building of new gas and/or hard coal power plants, the expansion of renewable energy and (centralized and decentralized) cogeneration capacity, the reduction of electricity demand by increasing energy efficiency and the import of electricity from other European countries. If nuclear power is replaced with fossil plants and no other mitigating actions are taken, the CO_2 emissions of the German electricity sector are likely to rise.

In the study we expected an increase of wholesale electricity prices following the shutdown of eight nuclear power plants since gas power plants were expected to set the marginal price in more hours of the year. This turned out to be a false prediction. In the model assumptions we had overestimated the CO_2 price and underestimated the large increases in RES production. In reality, the wholesale price decreased, and did not increase, as predicted by our model results.

Furthermore we found that the results in the model crucially hinge on some fundamental model assumptions. The most important is the development of fuel and CO_2 prices, which have a much larger influence on the price of electricity than the nuclear phase-out date itself.

When we compared our results to the results from other studies, we found substantial differences in the projections for the wholesale electricity price for different nuclear phase-out dates. The reasons for the differences can mainly be found in different model assumptions concerning fossil fuel prices, CO_2 prices, the demand for electricity in the future and the deployment path of renewable energies.

Chapter 4, titled *RES Support Schemes and Associated Risks: an Economic Analysis of the Debate of the EEG Reform in Germany* was designed to contribute to the debate over the reform of the EEG in summer 2014.

The chapter aimed to answer the following questions:

- What is the purpose of *risk* in the electricity sector and how does it relate to *uncertainty*?
- What particular risks are involved in the promotion of RES?
- How do different support schemes influence risk, and how does this influence the risk distribution between RES-investors and the society?
- Can increased risk for RES-investors increase the system friendliness of RES installments and thus their overall efficiency?
- How does the question of risk distribution relate to the achievement of political goals such as actor diversity?

The analysis shows that reducing the risk of RES investors shifts the risk to other investors (e.g. conventional power plants) and to electricity consumers. Yet the overall risk is not reduced. If increased efficiency of RES investment is the goal, RES investors should carry risk. This would increase efficiency of investment decisions, even though the costs for RES installments would increase in consequence due to higher risk premiums. However, increasing investor risk conflicts with the goal of maintaining a large variety of actors, as smaller players tend to be unable to manage larger risks. The issue of optimal risk distribution is therefore also a political (i.e. a distributional) question.

Chapter 5, titled *The (Ir)relevance of Transaction Costs in Climate Policy Instrument Choice: an Analysis of the EU and the US* is concerned with transaction costs of various GHG abatement policies focusing on the EU and the US. This study adds to the research regarding climate policy instruments by comparing the transaction costs of various climate policy instruments, such as emission trading versus an emission tax. The findings of this chapter can contribute to a more informed debate on this issue. This topic currently does not feature high on the political agenda. However, if more carbon pricing schemes are implemented internationally (as planned by many countries), the issue of optimal policy design (with the goal of minimal transaction costs) may play a larger role in the future. Thus, the political relevance of this chapter may still be ahead.

The chapter aimed to answer the following questions:

- Do transaction costs play an important role for climate policy instrument design?
- How do different climate policy instruments compare with respect to their transaction costs and how does this influence cost-effectiveness?

- How can transaction costs considerations be incorporated into climate policy instrument design?
- How do different cost components (e.g. monitoring costs) scale with certain variables such as the number of regulated entities or the level of abatement?

The key finding is that the hypothesis that ex-post transaction costs are large and thus play a pivotal role in climate policy instrument choice can be rejected for the evaluated instruments (among them the EU ETS). Both total and relative ex-post transaction costs incurred by the public and private sector can be considered low. The results indicate that ex-post transaction costs play a minor role for large countries that feature similar institutional characteristics as the EU and the US. In those countries, the focus should be on the efficiency properties of instruments for incentivizing abatement, as well as equity and political economy considerations (and other societally relevant goals). For countries with weak institutions, transaction costs may play a larger role. This should be subject to further research (see also section 6.3).

6.2 Review & Discussion of Methods and Methodological Lessons

This section reviews and discusses the different methods used in the five chapters of this dissertation and highlights methodological lessons learned. This dissertation can be classified as research in the field *of policy analysis* which is, according to Dunn (2012: 3), *methodologically eclectic*. The methods applied in this dissertation are qualitative as well as quantitative and stem from economics and social/political science. The section is structured along the chapters of this dissertation.

6.2.1 Chapter 2

Chapter 2 researches the *Goals of the Energiewende* applying social science methods. To answer the research question we carried out a two-pronged approach. In the first step, qualitative content analysis was applied to collect and conceptualize the goals of the Energiewende from oral and written statements in the public discourse. In a second step, 54 expert interviews were carried out to receive a personal Energiewende-related goal ranking. One methodological challenge in the interviews was to extract the personal preferences regarding the Energiewende goals from the respondents, as many interviewees tended to recite the goals stated in the public discourse irrespective of whether he or she believed that they were relevant.

Another challenge was drawing a line between *goals* and *means* during the interviews. This is conceptually difficult because the separation also depends on the normative stance of the interviewee. For instance, the *decentralization of electricity production* could be regarded a goal in itself, or as a means to *weaken powerful corporations in the electricity sector*. Weakening those corporations can, in turn, be a stand-alone goal in the spirit of skepticism towards large industry, or could be understood solely as a means to ensure efficient markets by ensuring that large corporations do not have pricing power. Having identified the various goals, it was crucial to explain and discuss the decision context (or frame) of the goals to the interviewees so that they could separate the goals and balance their importance against each other. A major methodical lesson is, therefore, that the differentiation between goals and means is always dependent on the decision context (in this case the Energiewende) (Eisenführ, 2003). This fact needs to be made clear to interviewees prior to interviews.

The task of separating and prioritizing goals also showed that many interviewees did not initially think of them of separate goals that could be weighed and traded against one another. Rather, many interviewees thought in terms of Energiewende-narratives, i.e. that various goals are necessarily linked and that prioritization among them is not possible or desirable.

6.2.2 Chapter 3

In Chapter 3, which deals with Germany's nuclear phase-out, mainly quantitative modeling methods were applied. To answer the question of possible developments of electricity prices and CO_2-emissions for different phase-out years, various scenarios were analyzed using the quantitative modeling tool MICOES (Mixed Integer Cost Optimization Energy System), a bottom-up electricity market model for power plant scheduling. MICOES applies mixed-integer optimization and incorporates short-term marginal cost, start-up and shutdown costs, as well as limited ramp rates. It uses a least-cost approach to optimize the hourly scheduling of the conventional fleet of power plants in the market. Additionally, the model results were tested for their robustness in sensitivity analyses, in which individual assumptions were varied. In this way, ranges of alternative scenarios were explored. Furthermore, a comparison of studies that attempted to answer similar questions (price and CO_2 developments for different nuclear phase-out dates) was carried out.

As mentioned earlier, the projections of the wholesale electricity price for different nuclear phase-out dates did not match the actual developments. The reason can be found in exogenous model assumptions that turned out to be quite far off (e.g. RES electricity production and CO_2-prices). The methodological lesson from this modeling exercise can be, again, that model results crucially depend on the input assumptions.

6.2.3 Chapter 4

Chapter 4 applies fundamental theoretical economic analysis and evaluates the risk distribution among different societal actors for certain policies using a general equilibrium framework. In a second step, a theoretical analysis was carried out indicating how the results from the economic analysis relate to different and conflicting political goals. The theoretical analysis proved to be useful in obtaining a fundamental understanding of the relationship between the risk for investors, the risk for society and the effects on costs (and risks) for RES and other market participants.

However, the lesson can be that for actual policy advice, the results of the theoretical analysis are only of limited use since assumptions were made that do not hold in reality (e.g. perfect capital markets and perfect information of all actors).

6.2.4 Chapter 5

In Chapter 5 a twofold approach was applied in order to compare transaction costs of various climate policies. First, a systematic review of all publicly available empirical ex-post transaction cost studies was carried out. Where quantitative data were not available, qualitative considerations and plausibility checks supplemented the analysis. Over the course of the research it became ever clearer that the concept of transaction costs for climate policy instruments lacked a well-developed and comprehensive theoretical foundation. Therefore, we made a first step in filling this gap by introducing conceptual distinctions of ex-post transaction costs dimensions. To apply the findings of this chapter to other countries and regions, it is crucial to identify which cost components decrease, increase, or remain constant as the scale of the system expands or decreases. Accordingly we hypothesized how the scaling of these dimensions can affect the choice of policy instruments in differing regulatory contexts.

The methodological lesson from this chapter is that a clear and agreed upon theoretical concept for transaction costs is needed before data is collected and compared. Given the extreme conceptual differences in the definitions of transaction costs in the past, this issue needs to be solved in the scientific community before detailed and comprehensive empirical cross-country comparisons of transaction costs are feasible.

6.3 Ideas for Further Research

This section shall provide an outlook on interesting questions for future research. The section is structured along the chapters of this dissertation.

6.3.1 Introduction (Chapter 1)

The introduction (Chapter 1) examines the history of the Energiewende applying Kingdon's *multiple streams framework* and also discusses different definitions of the term *Energiewende*. Both endeavors could be touched upon only superficially in this chapter and there leave ample room for further research.

First, a closer look at the definition of the term *Energiewende* is needed. Politicians, scientists and the media in Germany and also internationally widely use the term. However, very often different concepts and ideas are related to this term. In order to enable a well-founded discussion on the merits and problems of the *Energiewende* a widely accepted definition is necessary. Otherwise discussions over the *Energiewende* will remain superficial and create confusion rather than solutions.

Second, a deeper analysis of the Energiewende using Kingdon's *multiple streams framework* could be fruitful. The application in Chapter 1 was merely a scratch on the surface. However it gave a first indication that the seemingly erratic energy policy decisions in Germany over the past 30 years can be quite well explained with Kingdon's approach. If this high explanatory power also holds under closer scrutiny, the *multiple streams framework* could be established as a powerful tool for analysis of German energy policy.

Third, further research in the *politics stream* may bring interesting results. The chapters of this dissertation contribute to the *problem stream* (Chapter 2) and the *policy stream* (Chapters 3, 4 and 5). Analyzing the *politics stream* may give answers to the question why the Energiewende is taking place in Germany and not in other countries with comparable problems.

Fourth, going beyond Kingdon's analysis of the agenda setting process, it would be interesting to analyze the policy process after a problem has made it onto the political agenda. How did various interest groups, societal actors and political parties position themselves in relation to a certain policy? For this analysis the *multiple streams framework* is not helpful, and approaches such as Sabatier's *advocacy coalition framework* (Sabatier, 1987) may be more useful.

6.3.2 Chapter 2

The research in Chapter 2 regarding the political goals of Germany's Energiewende also raises numerous questions. The next logical (yet very challenging) step for further research would be to provide tools for policy makers which would help them to better understand what the achievement of certain goals would mean quantitatively (i.e. make related costs transparent). This would have to take account of all interdependencies and the various trade-offs between goals. Ideally, scientists could show how much it would cost to achieve certain goals. This would give answers to, for example, the question of how much more expensive it is to secure actor diversity in an RES-auction. Policymakers could then decide if they are willing to *pay this price* in order to secure a specific political goal. Edenhofer and Kowarsch (2015) suggest approaching this problem by carrying out assessments of alternative policy pathways and applying different methodologies.

Secondly, further interesting research would be to examine the arguments of the interviewees in order to assess their validity under scrutiny. This was deliberately avoided in the research underlying Chapter 2. Numerous claims will be (in the near to medium term) open to empirical evaluation, such as the claim that RES support will create German market leaders. An assessment of such claims would enable a better discussion on the validity of certain arguments.

Third, Germany's Energiewende discourse is often merely about policy instruments without a debate about the goals that should be achieved. This poses the question of why political goals play such a small role in the public discourse. It seems that the debate about policy instruments (means) is often a proxy-debate about ends, made unnecessarily complex and muddled. An example is the debate over emissions pricing versus direct support for RES. There is a heated ongoing debate over the pros and cons of these two instruments. Taking a closer look, this really seems to be a debate about the goals that are connected to these instruments rather than the instruments themselves. The hypothesis is that proponents of emission pricing consider *climate protection* as the only valid goal, whereas proponents of direct RES support put more weight on other goals such as *cost reductions in RES*, *regional added value* or *actor diversity*. It is, however, unclear why these different normative views (i.e. differing goals) are hidden behind the discussion of policy instruments (means).

Fourth, it would be interesting to evaluate to what extend the opinion of the interviewed experts corresponds to that of the public at large. In the pre-test for the expert interviews, the methodology was tested on non-expert subjects and proved to be a viable tool. Increasing the scope and the sample size of the questionnaire respondents may also lend more weight (and possibly another outcome) to the empirical claims made in this chapter.

Fifth, the *advocacy coalition framework* (Sabatier, 1987), could be utilized in the next step of analysis. It could be tested whether certain persons could, according to their answers in the questionnaire or the ensuing discussion, be allocated to various *advocacy coalitions*. Lastly, analyzing the interviewed persons with regard to their inclinations and attitudes would be interesting. For the research in Chapter 2, interviewees were asked explicitly to express their personal goals as opposed to those of the organizations they represent. Given the control question as to what the agreement between the interviewees personal and official position was, the majority estimated an overlap of 80-100%. This high overlap raises the question of whether persons with certain attitudes find matching organizations (or the other way around), or whether people adapt their personal views to those of their organizations, or even whether certain persons are able to commit their organization to their previously held private convictions.

6.3.3 Chapter 3

The results in Chapter 3 have once again shown how significantly model assumptions affect the results. In a next step, new model runs with updated assumptions could help to verify the results as well as the model. Additionally, further research could take other variables into account e.g. grids, new power plant installments and increased flexibility options.

6.3.4 Chapter 4

Chapter 4 describes a field of analysis in which the *theory of the second best* needs to be applied since the application of the *first best* solution (e.g. carbon pricing) is not possible (Lipsey & Lancaster, 1956). Direct RES support is an established policy instrument and the protection of legitimate interests demands that promised subsidies are paid. This forces German policymakers into a path-dependency, making adjustments of the existing scheme more likely than a complete overhaul of the funding scheme (e.g. to a system of R&D support in combination with a high price for CO_2). Therefore, further research on possible adjustments to the current funding landscape (i.e. the EEG) would be of high value to policy makers. One concrete question could be how the political goal that RES should be “better integrated into the electricity market” can be achieved (BMWi, 2016a). This entails the idea that RES investors should increasingly carry long-term price risks and receive an ever-decreasing amount of subsidies. Research on policy instruments or design features, which gradually rebalance the risk between RES investors, conventional power plant investors and the society, is in ample demand from political decision makers and is therefore an interesting field for further research.

Second, an assessment of international experiences with different funding schemes and resulting effects on risk distributions and consequences for risk premiums, efficiency of installments, and actor diversity would also be interesting further research. Preliminary work in this area was published by Pahle und Schweizerhof (2015).

Thirdly, it would be interesting to research how the arguments relating to risk allocation between investors and society change when Germany opens its RES funding scheme to foreign RES-plants as planned by the German government (BMWi, 2016b).

6.3.5 Chapter 5

Chapter 5 also raises intriguing questions for further research. First, the analysis could be extended to more policy instruments, sectors and especially countries and regions. This could enhance the empirical robustness of results and verify whether the findings also hold for countries with weaker institutional environments.

Second, ex-ante transaction costs could be added to the analysis. This means that the costs that occur prior to the implementation of a policy instrument (e.g. research, design and enactment) could be included in the analysis because they may play an important role in the overall assessment of transaction costs. This is, however, a challenging task, since the existing data required for such analysis is currently very scarce and chronically inconsistent. A precondition for such an analysis would therefore be an extensive effort to gather data on transaction costs applying a uniform definition.

Thirdly, the conceptual foundation of transaction costs of climate policy instruments should be strengthened. Chapter 5 makes an analytical attempt to establish which kind of costs (fixed or variable) has the largest impact on transaction costs. Further research is necessary to better understand the dynamics of transaction costs, especially with respect to the scalability of fixed versus variable components.

6.4 General Lessons and Concluding Remarks

Germany's Energiewende is a tremendously complex infrastructure and societal project that will likely become more rather than less complex in the foreseeable future. With a low- to moderate share of RES in the electricity sector, the system has remained fairly manageable. However, with strongly increasing shares of variable RES, major difficulties arise. New issues such as a revised electricity market design, demand side management, sector-coupling and grid extension will play an increasing role in the future and will add new layers of complexity to the endeavor. Possible disruptive technological developments (e.g. cheap electricity storage) have the potential to change fundamental assumptions such that long term plans (e.g. grid planning) may prove to be outdated whilst still being implemented.

Policymakers and bureaucrats, responsible for these decisions, often lack qualifications or the capacity to comprehend and oversee the technical and socio-economic interdependencies of this highly complex system, leading to mistakes and faulty regulatory frameworks. Germany's Minister of the Economy and Energy, Sigmar Gabriel openly admits that: "[energy policy] is a web, and whenever someone pulls on one end, something probably moves in places, which one did not intend to move" (Gabriel, 2015).

Since the complex workings of energy policy are, at this point, beyond the grasp of many decision makers, expert scientists take on a crucial role. By writing studies, expert statements, and actively engaging with society and policy makers, they are essential to explain causal relations, the functioning of policy instruments and the trade-offs between conflicting goals. This science-policy interaction could be improved if scientists whose research is related to current policy debates could develop a better understanding for the challenges and constraints policy makers face. They should be willing and able to incorporate political constraints (i.e. settings that cannot be changed in the short term) into their models and analysis by working on second-, third- or fourth best solutions. It seems that scientists (in this case mostly economists) often misinterpret political constraints as cumbersome restrictions standing in the way of straightforward welfare maximization. Instead, they should be regarded as an integral part of a democracy, where balancing interests between different societal groups is often more important to policy makers than pure economic welfare maximization. This demand must, however, be confined to scientists who are dealing with immediate policy advice. Those scientists who make suggestions against the background of longer time horizons and towards society at large are justified in ignoring immediate political constraints since such constrains are never set in stone and can change in the long run. In general scientists (or in this case economists) should, of course, continue to make politicians aware of social welfare losses, which may result out of the existing political constraints.

In this dissertation, I have on the one hand used economic analysis to assess policy instruments and on the other hand, political analysis to consider the political goals of Germany's Energiewende. I hope that my work will contribute to manage a successful transition towards a low-carbon (energy) economy. Should the Energiewende succeed, it may well serve as a role model for other countries all over the world. In this case, Germany's Energiewende may at last develop into an important building block in the fight against climate change.

6.5 References

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Statement of Contribution

Statement of Contribution

The four core chapters of this thesis are the result of collaborations between the author of this thesis, the two mentoring postdocs Dr. Michael Pahle, Prof. Dr. Christian Flachsland and the advisor of this thesis, Prof. Dr. Ottmar Edenhofer, sometimes involving additional colleagues as indicated below. The author of this thesis has made extensive contributions to the contents of all four papers, from conceptual design and technical development to writing. This section details the contributions of the author to the four papers and acknowledges major contributions of others.

Chapter 1 (Introduction)

The author was solely responsible for the idea and conceptual design of the introduction. Amani Joas provided support for the literature review on the history of the Energiewende.

Chapter 2

The author was responsible for the original idea, the conceptual design, the interviews and their evaluation as well as the writing of the article. Michael Pahle provided crucial contributions on conceptual design, especially methodological questions and in writing the article. Michael Pahle also participated in several interviews and also made large contributions in the review phase. Christian Flachsland made useful contributions to the conceptual design and contributed to the conclusions and policy implications section. The evaluation of the 175 speeches in the Bundestag, an essential preliminary step, was carried out by Amani Joas, who also based his master thesis on these results (Joas, 2013). Ottmar Edenhofer gave due support not least by establishing contacts to many of the interviewees.

Chapter 3

This paper was a collaborative work by the authors Brigitte Knopf, Michael Pahle, Hendrik Kondziella, Ottmar Edenhofer, Thomas Bruckner and the author. The paper was based on a study for the Friedrich-Ebert-Stiftung (Knopf et al., 2011) where the author was responsible for the Chapter on the possible effects of the nuclear phase out on EU energy and climate policy. The author contributed to the overall framing of the paper and carried out the literature review. He furthermore supported the lead author in writing the paper.

Chapter 4

The author partly conceived the original idea and introduced the aspect of combining economic and political analysis. The author evaluated a large share of the analyzed studies and contributed to the writing of the paper.

Chapter 5

The author was responsible for the original idea, the conceptual design, the data evaluation and the overall handling of the article. Christian Flachsland contributed to the writing of the article, the overall discussions and especially to theory development for transaction costs for climate policy instruments. Ottmar Edenhofer contributed in discussions to the article.

Tools & Resources

Tools and Resources

All texts were written with Microsoft Office Word 2010/15. The analytic and illustrative graphs have been created using Microsoft Office PowerPoint 2010/2015. The data collection and evaluation for Chapter 5 was carried out using Microsoft Office Excel 2010. For the data management of the transcribed interviews and for the evaluation of the goal rankings in Chapter 2 Office Excel 2013 was used.

This document was prepared using LATEX2, particularly the pdf pages package 3 to include Chapters 2 to 5 in their given layouts.