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The pathway towards decarbonisation 2050

A comparison of the behavior of Germany and the UK towards CO2 emission targets

Bachelor Thesis

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1. Introduction

The traditional ways of supplying energy worldwide, while being relatively cheap, represent a hazard for the environment and, in addition, are to be depleted eventually. Fossil fuels extracted from the ground, such as coal, oil and gas, remain the main sources for energy, have the highest demand and, since they contain high amounts of carbon, they are the main contributors to carbon dioxide (CO_2) emissions. In this regard, carbon dioxide is the trace gas with the highest impact (77%[1]) on the atmosphere's greenhouse effect with a direct anthropological influence. As such, a global challenge arises to fulfill the growing demand on energy in a responsible and environment-friendly way. The G7 nations (UK, France, Germany, Japan, Italy, US and Canada) pledged on May 2016 at the Ise-Shima Summit in Japan their intentions to end with inefficient fossil fuel subsidies by 2025 (The Guardian 05/2016). This goal is one of the numerous global efforts over the years to reduce the amount of greenhouse gas emissions from the atmosphere. In Europe, there exists binding legislation on decennial decarbonisation targets, in order to reach an 80% reduction below 1990 levels on greenhouse gas emissions until 2050.

The application of new energy and climate policy measures takes political will, but also financial resources. The reduction of carbon dioxide emissions needs investment and promotion of renewable energy and energy efficiency, but also a gradual termination of the traditional forms of energy supply. Since new technologies consider higher expenses from the government, the end consumers, particularly the ones with lower income, could be affected by deadweight losses and even fuel poverty[2]. However, one of the clear benefits of shifting towards renewable energies would be an increased security of supply, since a diversification of the energy mix for a country means less dependence on energy imports. This is especially relevant for countries of the European Union, since the energy supply disruption from Russia[3] in 2009 led to a massive cut on gas supplies for eighteen European countries and to a revamped EU Energy Security Strategy in 2014. A second benefit would be the growth in economic activity that comes from the investment in new industries, which create new jobs, and in innovation of renewable energy technologies, which can be used locally and also be sold to other countries. Finally, the decline of fossil fuels from the share of energy production and increase of renewables would substantially decrease the amount of carbon dioxide emissions.

Nevertheless, although there have been considerable efforts made to this end over the years, progress has been slow and has been criticized of being arbitrary at times, seemingly following a different agenda than the countries would like to claim. This rather erratic behavior is the main focus of the following research.

[1] World Resource Institute (2005)

[2] Fuel poverty is a term used to refer to a household that is unable to afford the lowest levels of energy at a reasonable cost.

[3] Russia is, currently, the main supplier of natural gas, crude oil and solid fuels for the European Union (Eurostat 2016a).

1.1 State of the Art

The European Commission decided to undertake an energy policy roadmap towards a competitive low carbon economy for the year 2050 in the second Strategic Energy Review in late 2008. This approach is grounded in the European sustainable growth agenda for Energy 2020 (European Commission 2011a). As a group, developed European countries are committed to reduce their GHG emissions by at least 80% by 2050 compared to 1990 levels. The roadmap established by the Commission points out that the accomplishment of the 2050 targets "will have to be met largely domestically", and sets out the decennial milestones of 40% by 2030 and 60% by 2040 as a cost-efficient pathway for the strategy (European Commission 2011b).

The need for this pathway is based on the unsustainable way energy is traditionally produced, transformed and consumed in the modern world. The Low Carbon Economy Roadmap for 2050 focuses on energy security, competitiveness and sustainability in this regard. Firstly, *security risks* are mainly related to energy supplies coming from imports. The high energy dependency of European countries on foreign imports (52.6% in 2010, 53.5% in 2014) from few exporting nations, which are politically unstable and tend to use this position as a geopolitical advantage in other international disputes (e.g. Russia, but also some OPEC countries), is a significant concern (Eurostat 2016b; European Commission 2011a, p. 6). Additionally, since fossil fuels are limited and gradually depleted with time, global competition arises for the production of new types of energy resources.

Secondly, the *competitiveness* aspect refers mainly to the risks of high energy costs and low investment in sustainable energy. A malfunctioning energy market could in this regard cause "fuel poverty" for households with lower income and move the incentive of investment in new high-priced energy sources away from Europe, putting its global competitiveness at risk. Investments in new energy sources are therefore needed in order to "guarantee a similar level of comfort to citizens at affordable prices [and] assure secure and competitive supplies of energy inputs to businesses and preserve the environment" (p. 7).

Finally, a focus in *sustainability* is an evident key aspect of reducing the negative anthropological development in the environment. Community sustainability is defined as "the long-term durability of a community as it negotiates changing practices and meanings across all the domains of culture, politics, economics and ecology" (James 2015, p. 24). Sustainability in the European and global community refers, in this regard, to the decrease of negative human influence in the environment and to set objectives in order to limit the rise in global temperature to 2°C. Almost 80% of GHG emissions come from carbon dioxide (CO_2), which is the main trace gas influenced by human activities. While it is a natural gas in the atmosphere, human influenced CO_2 emissions in the environment have dramatically altered the natural atmospheric carbon cycle since the industrial revolution, accelerating the GHG effect and, thus, creating global warming (Falkowski, et. al. 2000, p. 291). Therefore, not only the combustion of fossil fuels, which increases the amount of carbon dioxide, but also deforestation[4], which decreases the earth's natural ability to remove CO_2 from the atmosphere, are both activities that greatly affect GHG emissions. It is worth to mention, that Methane (CH_4), the second gas with the greatest impact on the GHG effect (15%)[5], is primarily produced by domesticated animals in agriculture and the management of garbage and human waste. The sources and measures regarding other gases on the GHG effect other than carbon dioxide are not the main focus of this research, however, their impact is considered in the analysis by means of carbon dioxide equivalency (CO_2e)[6].

The European Commission (2011a) points out in its impact assessment of the energy roadmap 2050 many underlying problems that hinder the pathway towards decarbonisation. Firstly, the *information asymmetry given by energy market prices* reflects on the end consumers and producers, giving a hidden cost to society in the form of adverse selection. This issue is reminiscent of a research by Tsvetanov & Segerson (2014), where consumers were misled into buying less energy-efficient products, because of its price, only to end up spending more in energy bills. Secondly, the *perception of the general public* requires proper incentives and time to cope with regulation changes on the traditional ways that energy is used regularly, e.g. heating households or transportation. Thirdly, there are significant *risks with technological developments* in the energy system, that come with long-term fixed costs on investments and uncertainty about the future of energy demand. Fourthly, since nearly all technological developments in the energy system are long-term investments, the *system is inert*, changes gradually and brings additional costs, making the shift towards new environmental-friendly development unpopular for the industry. Finally, there is *weak competition in the energy market*, because of the difficulty for third parties to access infrastructure, the allocation of new investments costs and the lack of a working regulatory framework (European Commission 2011a, pp. 7-8).

1.2 Scientific Relevance

The recent behavior of some European countries claiming a deep commitment to the reduction of carbon dioxide emissions open questions about their willingness to follow the path towards decarbonisation. For example, the UK decided to cut subsidies to householders installing rooftop solar panels by 65% shortly after agreeing to move towards low-carbon energy at the climate change conference in Paris in late 2015 (The Guardian 12/2015). In Germany, CO_2 emissions peaked in 2014 and there were concerns regarding a so called "coal comeback" following the decision to cut off nuclear power after the disaster from Fukushima (Jungjohann & Morris 2014). This kind of developments lead to uncertainties about the validity of agreements on climate change policies and raise questions about the developed countries' commitment on achieving even their short-term decarbonisation targets.

[4] Deforestation, however, has been slowly decreasing in the last decade (Federici et al. 2015).
[5] Data from the World Resource Institute (2005).
[6] Carbon dioxide equivalency is a measure that represents the amount of carbon dioxide that would have the same impact in global warming that any type of GHG (OECD 2013).

The most recent and closely related study to the topic of this research was published in 1993, a comparative Input-Output-Study for Germany and the UK on reducing their CO_2 emissions (Proops et al. 1993). It presented a quantitative analysis from an economic perspective of the interdependencies of different sectors in the national economy of the UK and Germany and how the economic structural change affects CO_2 emissions over the course of two decades. Nevertheless, while pointing out the limitations in achieving *political* implementation of emission targets, the authors emphasize the need from policy makers to act on their *will* rather than their *wish* to achieve their respective CO_2 emission targets, in other words the need for national political consensus on environmental policy-making (pp. 11-14). The focus of this research would try to address this specific aspect, which would be analyzed by using qualitative methods.

Several studies regarding regulatory reforms in the energy sector assess what can be done domestically to reach consensus on environmental policymaking. As Andrews (2005) points out, this has mainly to do with the prioritization of interests, that requires a balance between *environmental*, *energy security* and *economic* concerns. The decarbonisation of the economy is an important prerequisite for energy sustainability, which encloses other aspects than reducing carbon dioxide from the atmosphere. Renewable energy and energy efficiency are considered the "twin pillars" of sustainable energy and are both necessary to reduce and maintain CO_2 emissions (Prindle et al. 2007). Their effectiveness on reducing greater amounts of CO_2 emissions is researched in an extensive report on low-carbon energy of the Worldwatch Institute (Sawin & Moomaw 2009). Furthermore, studies like Gast et al. (2014) show that there is a high unpredictability in continuous energy provision of highly volatile renewable energy sources, such as wind and solar. These can be mitigated, but at an increase in energy costs, which show the interdependence of the variables pointed out by Andrews (p. 1336). Another report, from the InterAcademy Council in the Netherlands in 2007, highlights early that "competition for oil and natural gas supplies has the potential to become a source of growing geopolitical tension and economic vulnerability for many nations in the decades ahead", concerning energy security (IAC 2007, p. 152). This conclusion has been proven to be correct for European countries after the Russian-Ukrainian gas conflict affecting the EU in 2009.

However, while there is distinct research on the different aspects relevant to environmental policy there is only few done on the behavior and rationality behind it, namely how policy choices are determined and preferences established. Gsottbauer & van den Bergh (2011) point out that several authors have attempted to provide a foundation for the theory of environmental policy and only few recent research has been conducted to "explore specific behavioral anomalies in relation to environmental policy" (p. 284). The evaluation of the economic, environmental and security dimensions of environmental policymaking alone does not reveal a countries' ordering of its alternatives when it comes to its preferences. In this line of thought, Venkatachalam (2008) explains how polluting companies prefer to maintain the status quo and lobby against forms of emissions control. Nash (2006) evaluates how the framing of environmental policy affects public perception and behavior, and, thus, its effectiveness. These are only a handful of research done on environmental policy outlining the possible effects of externalities affecting a country's decision making process. There are, nevertheless, several studies on individual human rational agents engaging in erratic behavior due to common externalities, like information asymmetry.[7] In regard to establishing a distinct pattern in an agent's preference ordering, Hanemann (1994) emphasizes that the real problem "is not whether preferences are a construct but whether they are a stable construct" (p. 28).

1.3 Research Question

In the light of these papers, the analysis of behavioral deviations of rational agents in environmental policymaking is identified as a subject worthy of further research. Furthermore, there remains an open discussion regarding the behavior of national actors in regard to environmental policymaking and its correlation to long-term environmental targets. Therefore, the purpose of this paper would be to analyze the progress done towards long-term decarbonisation by comparing the behavior of Germany and the United Kingdom. Additionally, an assessment about the economic, environmental and security benefits of the progress will be made in order to evaluate the disposition of states to follow their adopted path in terms of their preferences. In this regard, the research will try to add more insight to the study of behavioral sciences by exploring the inconsistencies or deviations from rationality in the field of environmental policymaking.

The research will use gathered data relevant for the decision-making as rational subjects and policy-makers. To some extent, this paper will address the preferences of the countries considering their production of energy from fossil fuels and renewables, the diversification of their energy mix, their position towards nuclear power, their policies on energy efficiency and their dependency on energy imports.

The theory serving as framework for the research question of this paper is the rational choice theory. Based on its explanatory nature, the aim of this thesis will be to provide a plausible assessment of the behavior of Germany and the UK in their pursue of achieving their CO_2 emissions reduction targets. Therefore the research question elaborated in this thesis will be:

To what extent are Germany and the UK showing a consistent and favorable behavior while choosing energy policies that impact the progress towards their domestic decarbonisation targets of 2050?

In the case of Germany, despite criticism regarding their energy efficiency measures and rushed phase-out from nuclear power, the country is expected to have a solid transition strategy, which

[7] A paper on the welfare effects of energy efficiency standards applying the rational choice theory (Tsvetanov & Segerson 2014) examines how end-consumers are inclined to buy less energy-efficient products, because they are lower-priced, causing them however to pay higher electricity bills. This effect of "immediate payoff" results in higher costs for the consumer. This study highlights the need of having stricter energy efficiency standards, but, more importantly, points out that the rationality axiom might cause erratic behavior by trying to reduce costs while maximizing utility (pp. 260-261).

could lead to the accomplishment of their targets on the long-term after an intricate start. Regarding the UK, a swifter transition is foreseen, because despite having less environmentally safe policies and ever changing views on renewable energy, their overall progress on CO_2 emission targets compared to 1990 seems more feasible, at least in the short-term.

1.4 Structure of the thesis

The previous three sub-chapters and the current one are part of the introductory section of my thesis, where I have been describing the status quo of energy transition policies within the framework of the decarbonisation targets for 2050. Also, I have showcased the current debates in the field and pinpointed an open discussion about the rational behavior on policy choices of leading environmental actors, Germany and the UK, in the area of energy and their commitment towards achieving the 2050 targets.

In the previous sub-chapter I formulated my research question, highlighting my expectations for the results of the research and made references to the link between my research question and the chosen theory as a support for my observations.

In the following chapter I will be focusing on giving a short overview of the reasons why I have decided to use the rational choice theory as the theoretical framework. Most importantly, the three dimensions of utility maximization for the preferences of the rational actors, Germany and the UK, which create the framework for the assessment criteria in Chapter Three, will be presented.

The third chapter will give an insight about the methodological approach I have decided to use in this research. Furthermore, I will shortly introduce the criteria for the selection of national energy measures as well as the assessment criteria that will be applied when analyzing the policies and measures employed by the national governments. The qualitative content analysis and literature study will gather secondary data, mainly government's publications on environmental policy, as well as official statements and reports.

The fourth chapter will focus on the analysis of the policy measures selected by the criteria presented in Chapter Three and the application of the assessment criteria under the framework of the rational choice theory for the evaluation of the respective country's behavior. For this end, I will first briefly introduce the national environmental framework, looking at the main energy sources in the country, its policy goals and previous developments. Afterwards, I will be analyzing the relevant measures by considering the dimensions of the energy policy triangle, while conceptualizing the different policy outcomes under the framework of the rational choice theory. The effects and implications will eventually support or dismiss my assumptions regarding the achievement of the 2050 decarbonisation targets, presented in sub-chapter 1.3.

In the concluding chapter I will gather my observations from the two case studies and make an overall argumentation in regard to the respective behavior towards decarbonisation for 2050.

2. Theoretical Framework

The aim of this chapter is to provide a framework for the analysis of the case studies of Germany and the UK. This theoretical framework will help to make generalizations about relevant aspects of environmental policymaking and the way a country makes choices, taken as a rational individual rather than an aggregate of individuals. Furthermore, it will aid on supporting my findings, as well as reduce and constrain the deviations resulting from interpretations made by the reader. Finally, the limitations of such generalizations will be presented in order to allow a critical evaluation of the research methods and analysis.

2.1 Rational choice theory

The rational choice theory will be applied in order to approach the behavior of the two governments towards decarbonisation. The fundamental principle of this theory is that individuals shape their behavior in order to maximize their utility and minimize their costs, while taking into account the probability of success of the alternative. A rational individual is, thus, one who combines "his or her beliefs about the external environment and preferences about things in that environment in a consistent manner". Additionally, the aggregate group behavior depends from the individual choices of the members of a group of rational individuals (Shepsle 2010, pp. 13-35, 41-50).

In order to analyze if Germany and the UK are following a consistent behavior on their preferences on environmental policymaking, there needs to be a focus on the concept of rationality. For the purpose of analyzing their isolated behavior, their individual rather than their collective rationality needs to be considered. The basic assumption of individual rationality is that the rational agent has preferences among a number of available alternatives, and that they allow the individual to order these alternatives from their most to their least preferred (von Neumann and Morgenstern 1947).

In order to allow the ordering of alternatives in terms of preferences, two underlying axioms need to be satisfied: Transitivity and Completeness. Both are prerequisites for individual rationality. Preferences are said to be *complete*, if the alternatives are comparable between one another, so that the agent is able to choose one alternative over the other. *Transitive* are alternatives that are in a strict preference relation to one another, so that they can be ordered from the most to the least preferred (Eriksson 2011; Levin & Milgrom 2004; Shepsle 2010). Since the national governments are treated as rational agents, their preferences are assumed to be transitive and complete.

Following this line of thought, countries are expected to follow a specific criteria in order to assess environmental policies, from which a preference ordering will occur and the alternative that is the most preferred will be chosen over the other alternatives. Additionally, both countries are assumed to have a similar set of preferences: the reduction of their respective GHG emissions, which is made clear by their commitment setting decennial deadlines with clear cuts over the years until 2050. As such, the alternative chosen by the respective country is expected to be as aligned as possible with this preference. This will be explained further in the assessment criteria under subchapter 3.4.

Following their own criteria for addressing environmental policy, the subjects are expected to maximize the utility of their actions and minimize their costs under a set of beliefs that come from an external environment. A belief is a "probability statement relating the effectiveness of a specific action (or instrument) for achieving various outcomes" (Shepsle 2010, p. 30). Therefore, the variables that affect the choice of a preferred alternative from a set of alternatives for a rational individual are mainly *utility*, *costs* and *probability*. As such, these three dimensions, which influence a subject's *expected utility*, are relevant for the assessment of environmental policy in the analysis of the measures adopted by Germany and the UK towards decarbonisation.

Furthermore, national governments will be assumed to have a preference diversity, like any rational group (pp. 41-42), from which the preference to reduce CO_2 emissions will prevail over the other alternatives, e.g. national interests or policies. This assumption is additionally a requirement of the research question, since the variables to be observed in this research are both the measures adopted with a direct or indirect effect on CO_2 emissions, as well as the national interest to achieve a low carbon economy for 2050.

The rational choice approach is considered a form of methodological individualism, where the individual is taken as the basic unit of analysis (Brennan & Gillespie 2008). Therefore, this theory is usually applied to microeconomic models researching the behavior of individual human agents. However, the same assumptions can be made for collective entities e.g. national governments, as long as they are considered individual rational agents and under the premise of simplifying their collective preferences (Shepsle 2010, pp. 17-18).

While rational choice theory is widely applied to the analysis of microeconomic models, it also finds appliance in non-market goods, like in the field of political science (Shepsle 2010, pp. 13, 30, Becker 1978, p. 254). In terms of maximizing utility in social situations, rational individuals "are thought to be seeking some goal, pursuing some objective" in accord with their preferences (Shepsle 2010, p. 29). In the case of measures regarding the environment, Germany and the UK are expected to choose the ones that are in accord with their preferences, which are to fulfill their own decarbonisation targets, and hence, maximize their utility.

Furthermore, since the group behavior results from the aggregated behavior of the rational decision making individuals, the group preferences regarding the accomplishment of the emission reduction targets for 2050 is evidently dependent from the individual preferences of every single government in the group. For the purposes of this paper, however, this argument does not need further inspection, since every government commits to their own national decarbonisation targets in order to achieve a favorable expected global outcome regarding GHG emissions.

2.2 Expected Utility

Environmental policy selected by the country will be evaluated by its *significance* and *coherence* to the respective country's expected rational behavior and by whether it is favorable or detrimental to its preferences as a rational agent. The criteria to analyze the relevant measures of the governments with a preference for decarbonisation will be on the dimensions of utility, costs and probability. A rational individual will pick a preferred alternative from a set of alternatives, if he believes that the chosen alternative will maximize his *utility* (Levin & Milgrom 2004, p. 9). In order to make his decision, the agent considers the costs and probability that could undermine the appeal of a given alternative. The *costs* of an alternative are mainly those effects with any negative impact on the utility, that the rational individual may consider relevant for the decision making process (this includes opportunity costs). The *probability* aspect is that given by the individual to an alternative considering the believes he has about its likelihood. If the rational individual operates under the condition of risk, he will assign a probability to the particular outcome of the alternative's utility. In some instances the agent may lack information about the environment surrounding the alternative and operate under uncertainty, being unable to assign any likelihood to the alternative. In contrast, if the individual is certain of the outcome of the chosen alternative, he is operating under certainty and the probability dimension is not considered in the decision (Eriksson 2011, pp. 17-24). A rational individual making a decision under these conditions will always pick the alternative with the highest probability of getting the desired outcome. Thus, this behavior seeks to maximize his *expected utility* (Shepsle 2010, p. 33). In the present research, the national governments following rational behavior will be assumed to choose alternatives in environmental policymaking that reduce their domestic carbon dioxide emissions and hence, maximize their utility in respect to their decarbonisation goals.

In regard to the dimension of *probability*, it is assumed, that any measure adopted by national governments during the research timeframe was considered, taking into account a factor of certainty, risk or uncertainty among other alternatives. Since this research is using data from previous years (2010-2015), the effects that a measure had following its adoption may be evident in the present, but were not necessarily completely evident at the moment of choosing it. Therefore this specific criteria will be often examined isolated from utility and costs, dimensions that could be foreseen more easily.

2.3 Limits of Preferences and Rationality

The concept of preferences in individual rationality is a central aspect of the rational choice theory. However, subjects are found recurrently to deviate from the underlying properties of preferences under controlled conditions in some experiments, and thus, behaving irrationally even if they are rational individuals (Allais 1953; Machina 1987). This does not mean that the construct of preferences cannot accurately indicate a subject's behavior, but it is not necessarily a stable concept (Hanemann 1994). In this regard, Bayes' theorem applies rational learning by considering previous probabilities of alternatives to the likelihood of new alternatives, making the rational individual learn from past behavior (a way of updating probability by revising the individual's own beliefs) (Bayes 1764; Birnbaum 1962). This way, it can be inferred that by implementing new environmental policy a government has more accurate information with each subsequent application than the previous one. Both the phenomenon leading to erratic behavior, as well as the process of rational learning are particularly interesting for the focus of this research.

Another problem with using preferences as an exploration of rationality is their redundancy in explaining behavior, while being at the same time defined by it (Sen 1977, p. 326). Furthermore, Sen (1987) points out, that observing an agent maximizing his utility does not deliver "any independent evidence on what the person is [...] trying to achieve" (p. 73). Following this line of thought, Hodgson (2012) criticizes that it can never be demonstrated that an unidentified variable, like utility, is not being maximized and this, thus, makes the theory of expected utility unfalsifiable (p. 98). However, in the present research, the aim will be rather to observe the subject's deviations from a particular set preference (here, the reduction of CO_2 emissions) than to speculate what are the true preferences that an individual alternative is following or to inspect if some hidden utility has been maximized. This is, nevertheless, an important point to consider while assessing the possible reasons a country could have, if it is found to be engaging in erratic behavior.

In this regard, the concept of rationality is diffuse and finds multiple definitions in the literature (Sen 1987). Most criticized are the versions of rationality that conceptualize it as a function seeking the maximization of explicit, mainly economic rewards (Hodgson 2012). However, as aforementioned, concepts of rationality based on maximization of expected utility cannot be falsifiable, but entertain the same framing as expected values in economics (for example, like expected value of return), which make them worthy of further research. Furthermore, rational choice models are often found not to be helpful for decision makers, since their main purpose is to only point out the issues surrounding the decision itself and the deviations from individual rationality (Nau 1999, pp. 220-221). In other words, they give insight on how the decision was taken (the explanatory power), without going further to provide solutions in order to improve the decision making process.

2.4 Conclusion

This chapter has helped to establish a framework for the methods and the criteria that will be used to analyze environmental policy in Germany and the UK. The basic concepts of the rational choice theory in terms of preference ordering and maximization of expected utility in order to evaluate rational behavior have been laid out, and their relevance for the research question has been explained. Additionally, the limitations of the theory have been presented and contemplated. These key concepts will be the foundation stone for the analysis performed in the subsequent chapters.

3. Methodology

This chapter introduces the methodological approach used in this research, presents the process of data collection, and guides the analysis under the theoretical framework. First, the research design will deliver the structure for the analysis, giving and outline for the collection of data and its analysis. In this regard, the timeframe limitations for the literature search will be explained. Finally, the instruments to be employed for the analysis of the data will be introduced. The criteria for the selection of domestic policies and the assessment criteria that will be applied for the analysis of these environmental policies and measures employed by the national governments will be laid out.

3.1 Research Design

For this research a case study research design will be applied, since it provides a useful method for testing the rational choice theory on a particular situation. The term case study "usually connotes a study whose analytic objective is larger than the case under intensive research" (Gerring 2006, p. 707), in this way it aims to make the subject a representative example for a broader population of subjects. The case study can be defined as "an intensive study of a single unit for the purpose of understanding a larger class of (similar) units" (Gerring 2004, p. 342).

Case studies differentiate themselves from other research designs for being observational rather than experimental studies (Gerring 2007, p. 688). For this reason, multiple sources of data are evaluated in order to achieve a greater overview of the cases. Primary data shall be evaluated mainly from selected institutions involved in deep decarbonisation pathways and secondary data from reports of other authors and governmental organizations.

Following the *most similar* method of the case study research design, Seawright and Gerring (2008) explain that in its purest form, the pair of cases chosen is similar on all background conditions relevant to the outcome, i.e. all the other independent variables measured, with the exception of the one independent variable of interest X and, thus, its outcome Y, as well. The units to be observed on this paper are two national governments, Germany and the United Kingdom, which are very similar not only in terms of their economy, but also in their commitment towards the decarbonisation of the energy industry. The difference of interest between the two units on this subject may be between the measures and policies they adopt towards their desired outcome, that is, the decarbonisation of their respective economies.

3.2 Limitations

Considering a wider definition, a case study describes the monitoring of a "phenomenon during a certain period or, alternatively, [the collection of] information afterwards with respect to the development of the phenomenon during a certain period" (Swanborn 2010, p. 13). While there have been concerns regarding the greenhouse effect since the 19th century, these only started to be addressed in developed countries arguably since the 1970s. The focus on the reduction of greenhouse gas emissions, especially carbon dioxide, has only gained importance recently. The year 2010 is a relevant starting point for both Germany and the UK, as well as the years that followed. Germany's *Energiewende*, which found its roots in anti-nuclear movements of the 1970s, was announced in 2010 and it was followed by a nuclear phase-out transition in 2011 (BMWi 2010; BMWi 2012). With the 2008 Climate Change Act, the UK established the world's first legally binding climate change target, which was followed by a government's policy paper on greenhouse gas emissions from 2010 to 2015 and the UK's new nuclear strategy (DECC 2009; DECC 2013a).

The European low-carbon economy roadmap highlights the feasibility and affordability of the European community to achieve the established decarbonisation targets for 2050. The roadmap presents cost-efficient pathways to fulfill the emissions reduction target of 80% for 2050 by setting decennial goals for 2020 (20% emissions cut), 2030 (40% emissions cuts) and 2040 (60% emissions cuts).[8] In this regard, the starting wave of political mobilization towards a low-carbon energy future by 2050 appeared to be in 2008 with the second Strategic Energy Review.

However, in terms of political debates, agreements and policy development, the first national initiatives were observed in 2010: Germany formulated its low carbon energy policy, the *Energiewende*, two years after they had committed themselves to achieving the 2050 targets and binding legislation came only in late 2011 (Meeus et al. 2012). In the case of the UK, there is a similar turn of events, namely the legislative decision regarding the Energy Act in 2010, for which implementation steps followed through the next years (idem.)

Considering this, the literature search will focus on the time frame starting with 2010 until late 2015, following through the behavioral pattern of energy measures in Germany and the UK, monitoring their progress on decarbonisation policies and their achievements in regard to their domestic environmental targets.

Additionally, since the decennial milestones are mainly means to an end, it's therefore important for the purposes of this paper to point out that, while some reduction targets could have already been fulfilled by a government, this doesn't necessarily ensure the realization of the next one. For this reason, the presented analysis will give more consideration to measures with long-term effects aiming to achieve the 80% emissions reduction until 2050 than to short-term measures with more immediate, but not necessarily lasting effects on emissions.

3.3 Data collection

Due to the nature of the concepts handled in this research and the need of understanding the underlying reasons for possible behavioral deviations, as well as the environmental policymaking

[8] See: European Commission (2011a)

process of national governments, I will conduct a literature study. Following this line of thinking, I will carry out a qualitative content analysis of national policy documents, official national and international publications and reports, newspaper articles and expert opinions, as well as political statements of national actors and institutions.

Qualitative data collection methods allow inductive reasoning by developing insights and finding patterns in the data, as well as creating an outline to better understand phenomena and allow a holistic perspective, focusing on the relationship between the units of analysis (Miles & Huberman 1994, p. 274; Silverman 1998). This will provide the research with an objective view of the topic and give the possibility to pick out external factors, which might be avoided in an individual paper. Furthermore, as supporting data for this research, peer reviews of researchers and statistic analysis will be used, which will be compiled under my own discretion to better support the observed behavioral interpretation.

The reason for using this data for conducting a literature study rather than other types of data is its explicit relevance to the policymaking process of the governments. Miles & Huberman (1994) consider the underlying reasons for qualitative research to be description and hypothesis formulation (p. 4). Policy documents and national action plans are considered the direct outcome of the respective government's behavior towards environmental policy. The accompanying reports and expert opinions found in other publications are relevant for the analysis of this resulting behavior. The data collection process finishes when theoretical saturation for the respective case study is accomplished, i.e. there is no more relevant data needed and the relationships between the observed variables is built (Strauss & Corbin 1998).

3.4 Assessment criteria

The criteria employed for the selection of domestic measures is based on their direct or indirect impact on carbon dioxide emissions and their possible implications on the realization of decarbonisation targets of 2050. These implications will derive fundamentally from the speculation on long-term effects of expert opinions or secondary data. The assessment criteria for the maximization of expected utility following the theoretical framework is analyzed based on the classical *energy policy triangle*, which encloses three main policy objectives: environmental compatibility, economic viability and supply security. The national governments are assumed to have a preference ordering that favors the "environmental compatibility" component of a policy or measure above the other two dimensions in environmental and climate policymaking.

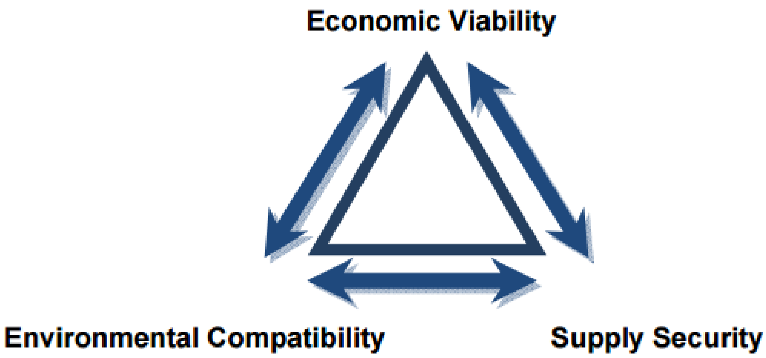

Figure 1 Energy Policy Triangle (ifo Institute 2012, p. 15)

Gsottbauer & van den Bergh (2011) point out that concerning economic decisions under rationality, "the standard criteria for policy instrument selection are economic efficiency, effectiveness and equity" (p. 286). However, in environmental policymaking these dimensions have little relevance for the decision making process of the national governments. In terms of its subgroup, climate policy, which covers the mitigation of GHG emissions and climate change adaptability (p. 289), is analyzed in regard to its impact following the criteria presented in the aforementioned energy policy triangle (ifo Institute 2012; Heffron 2015). Furthermore, the low carbon economy roadmap for 2050 of the European Union focuses, as mentioned in chapter one, on sustainability, competitiveness and security. These aspects follow the energy policy objectives of the energy policy triangle, because this is how both energy law and policy are conceived (Heffron 2015, p. 3). As a result, it is safe to assume that government of the European Union will take these policy objectives into account while adopting a measure in connection with climate policy, and thus for decarbonisation. A measure adopted this way is, therefore, perceived by the government, as a rational agent, to maximize its expected utility (axiom of preference ordering following individual rationality) with regards to its CO_2 reduction targets.

In this paper, **environmental compatibility** objectives seek that adopted measures target a direct or indirect reduction of CO_2 emissions. This policy objective is, as a result, the most relevant in terms of preference ordering for the maximization of expected utility. The national measures may, therefore, be related to renewable energy sources (RES), carbon capture and storage (CCS), nuclear power, fossil fuels and energy efficiency (EE). It is expected that a policy change favoring RES, CCS, energy efficiency mechanisms or nuclear power has a positive effect on the expected utility of the governments, while a change favoring fossil fuels has a negative impact. In regards to nuclear power, both Germany and the UK have reviewed their nuclear power programs following the Fukushima Daiichi nuclear disaster in 2011.[9] While Germany plans among other countries to gradually remove nuclear power from their respective nations, it is important to notice that nuclear power has a comparable value of emissions during its life-cycle (66 gCO_2e/kWh) to that

[9] See: DECC (2013a); BMWi (2012).

of renewable energy sources[10] (Table 1). Nevertheless, although a measure favoring nuclear power could hypothetically reduce CO_2 emissions and thrive in spite of other national interests, this conjecture would prove to be questionable given the framework of nuclear safety, particularly of Germany, and hence, be difficult to find consistent with its recent rational behavior. This problematic will be analyzed further in Chapter Four.

Technology	Capacity/configuration/fuel	Estimate (gCO_2e/kWh)
Wind	2.5 MW, offshore	9
Hydroelectric	3.1 MW, reservoir	10
Wind	1.5 MW, onshore	10
Biogas	Anaerobic digestion	11
Hydroelectric	300 kW, run-of-river	13
Solar thermal	80 MW, parabolic trough	13
Biomass	Forest wood Co-combustion with hard coal	14
Biomass	Forest wood steam turbine	22
Biomass	Short rotation forestry Co-combustion with hard coal	23
Biomass	FOREST WOOD reciprocating engine	27
Biomass	Waste wood steam turbine	31
Solar PV	Polycrystalline silicone	32
Biomass	Short rotation forestry steam turbine	35
Geothermal	80 MW, hot dry rock	38
Biomass	Short rotation forestry reciprocating engine	41
Nuclear	Various reactor types	66
Natural gas	Various combined cycle turbines	443
Fuel cell	Hydrogen from gas reforming	664
Diesel	Various generator and turbine types	778
Heavy oil	Various generator and turbine types	778
Coal	Various generator types with scrubbing	960
Coal	Various generator types without scrubbing	1050

Table 1 Lifecycle estimates for electricity generators (Sovacool 2008, p. 2950)

Security of supply is another policy objective to consider for energy policy indirectly targeting CO_2 reductions in the long term. The security of energy supply aims to oversee the competition over energy sources and takes into account the political instability of energy exporting nations, but also the prevention of natural disasters or accidents on supply infrastructure, like ensuring nuclear safety standards and controlling environmental hazards from the population (Pascual & Elkind 2009, p. 2; Trosman 2010). It is, therefore, also focused on reducing the dependency on energy imports, which come mostly from fossil fuels (Eurostat 2016a). As aforementioned, the EU relies over half of its energy needs upon imports and this dependency has been gradually increasing over the last decade. In this period the production of RES increased by 73.1%, while "the production levels for the other primary sources of energy generally fell over this period, [significantly] for crude oil (-52.0 %), natural gas (-42.9 %) and solid fuels (-25.5 %), with a more modest fall of 13.1 % for nuclear energy" (Eurostat 2016a). Therefore, the diversification of the energy mix with low carbon emitting energy resources is consistent with the objectives of security of supply (less dependency on energy imports) and, thus, a low carbon economy in the long term.

[10] Some more recent studies even compare the median gCO_2e/kWh of nuclear power to be 13 gCO_2e/kWh, comparable to onshore wind power (12 gCO_2e/kWh) and lower than other RES . See: Warner & Heath (2012), Moomaw et al. (2011).

Finally, the objective of **economic viability** is significant for the decision making process in this regard, as well. The energy transition from less capital-intensive energy sources, like coal, to the less cost-efficient, but environment-friendly renewable energy sources requires a transformation of infrastructure networks and a further liberalization of the energy market (European Commission 2011a, pp. 9-10). Additionally, energy efficiency plans focused on reducing energy consumption (particularly in households and transportation) are needed, if the capital requirements for new investments in the energy sector cannot be met. It is estimated that "the cost of energy per unit of GDP output could be about 20 to 30% lower" in a possible decarbonised scenario, due to the implementation of "energy efficiency levers and a [...] shift away from oil and gas in transport and buildings, with electric vehicles, fuel cells and heat pumps being both more efficient than current technologies and using lower-cost energy sources" (ECF 2010, p. 13).

3.4 Conclusion

This chapter has introduced the case study research design and presented the form of data collection by means of a literature study. This will provide a structure for the analysis of the environmental policies taken by the governments targeting decarbonisation under the rational choice approach. The timeframe from 2010 to 2015 under which the data collection takes place has been established and explained. Finally, the assessment criteria for analyzing climate policy is based on the energy policy triangle, which presents a so called "trilemma" for environmental policymakers. This intention of balancing the three dimensions of sustainability, economy and security is the critical aspect taken into account by the decision makers when implementing policy targeting emissions reduction. In the following chapter the analysis will take place, in which the data will be presented and analyzed by first addressing the relevant national policies and subsequently testing the subject's preferences using the energy policy triangle. This process will be done until the theoretical approach has been exhausted in the individual policy subsections laid out for the respective country. Furthermore, statistical data from official national documents and excerpts taken from reports as well as expert's and public opinion will aid on the validity of my own analysis.

4. Analysis

In the following analysis the individual case studies will be conducted separately. For each case study the national environmental framework will be introduced, in order to provide a clear overview of the preferences set for the respective country in terms of decarbonisation, as well as aid a reference for the assessment of its climate policies. Subsequently, the qualitative analysis of the data will take place assisted by statistical inferences done on emissions, which contain observations as well as own interpretations of the key figures. Each country's respective preferences will be analyzed separately based on its climate policies directed to nuclear power, fossil fuels and renewable energy sources, as well as energy efficiency measures. These preferences will be analyzed comparing the preference ordering resulting from the maximization of the country's expected utility, establishing in this way a link to the theoretical framework. Finally, an interim conclusion will provide an overall view of the analyzed country's behavior towards climate policy and decarbonisation.

4.1 Germany

4.1.1 Energy concept

On September 28th, 2010 the German government adopted the Energy concept commonly known in the literature as the German *Energiewende*. The document set a number of domestic goals leading to an affordable way of supplying energy and map the road for renewable energy by "designing and implementing a long-term overall strategy for the period up to the year 2050" (BMWi 2010, p. 3). The strategy introduced nine fields of action in detail, from which the key elements were the development of renewable energies as a cornerstone of energy supply, and energy efficiency as the key issue relating to achieving a swift transition.

Originally the strategy for nuclear power and fossil-fuel power plants was to further liberalize the electricity and gas markets and strengthen the competition. In order to achieve this, fossil fuel power plants (especially hard coal and lignite) would need to become highly efficient and CCS-ready to prevent high CO_2 emissions. As a result, the government pointed out the need for technological development in CCS technologies to further reduce the amount of CO_2 emitted from coal, and, additionally, terminate domestic hard coal subsidies in line with European and national guidelines (pp. 15-17). While shifting towards a dynamic energy mix, the short-term transition was focused on moving to nuclear power as a bridging technology by extending "the operating lives of nuclear power plants by an average of 12 years" (p. 14). As aforementioned, this transition would make sense for the decarbonisation goals, since nuclear power has an emissions value comparable to renewable energy sources and therefore would be beneficial as a short-term replacement for the electricity supply from fossil fuel sources (Table 1). However, the nuclear disaster of the Fukushima Daiichi nuclear power plant in Japan on March 11th, 2011 caused the German government to rethink its strategy on the prolongation of nuclear energy and declare instead a complete phase-out of all German nuclear power plants until the end of 2022, which supplied 27% of the country's electricity (Jorant 2011, p. 15). In regards to its strategy for renewable energy sources, the German government aimed to increase the cost-efficient expansion and use of renewable energies, especially of offshore and onshore wind energy, the further development of storage technologies and electricity grids, and promote the sustainable and efficient use of bioenergy. Regarding energy efficiency, the government aimed to tap its potential in private households and the public sector by providing end users with an improved transparency of the market and rising energy prices as an incentive to save energy. For industries, the government planned to grant energy-intensive companies an eco-tax relief for their contribution to energy savings (BMWi 2010, pp. 7-13). These strategies set in 2010 are aligned with the preference set of Germany for the reduction of carbon dioxide emissions and are, therefore, a solid base for analyzing relevant policies or measures of significance affecting their development.

In the following chapter the key figures related to decarbonisation and the utility of German environmental measures and policies from 2010 to 2015 will be analyzed.

4.1.2 Qualitative Analysis

Compared to 1990 levels Germany reduced its GHG emissions by 27% as of 2014, which is 13% points short of the original 2020 domestic target, but 7% points on top of the targets set by the European Commission. Germany will need to reduce on average GHG emissions by 3.5% each year in order to reach its long-term decarbonisation targets (Hillebrandt et al. 2015, p. 10-11). Between 2010 and 2014 there were two consecutive rises in GHG emissions in 2012 and 2013, which were followed by a significant drop of 43 CO_2eq million tonnes in 2014. However, it has been pointed out that an evident reason for this decrease is attributed to significant energy savings in households and the public sector (Figure 1).

In 2014, 37% of the decrease in CO_2eq came from household emissions compared to 2013. A report of the global trends in CO2 emissions (2015) show that 2014 was the warmest year globally since 1880, and there was, thus, "a large drop in demand for space heating (by 10%) in the European Union (EU-28) due to the warmest winter months on record contributed to plummeting gas consumption and the large drop (by 5%) in the EU's CO2 emissions" (Olivier et al. 2015, p. 10). Furthermore, 2015 saw an increase of only 10 Million tonnes in comparison with 2014, signalizing a stabilized development of emissions, but also due to a marginal increase in household emissions. In order to achieve the domestic energy target of 40% for 2020[11], Germany would have to decrease an average of at least 2.6% points (31.8 CO_2eq million tonnes) each year from 2015. From 2010 there has been a total decrease of 2.6% points (33 CO_2eq million tonnes) in five years. This shows that Germany will need to increase its efforts focusing

[11] The 2020 climate and energy package target of 20% set of binding legislation by the European Commission was already surpassed by Germany in 2010 (24.5%) (European Commission 2011a).

on measures related to transport and energy efficiency[12] both progressively for the EU binding 40% reduction target of 2030, and significantly, in order to achieve its domestic 40% reduction targets for 2020[13] (Jungjohann & Morris 2014, pp. 18-19).

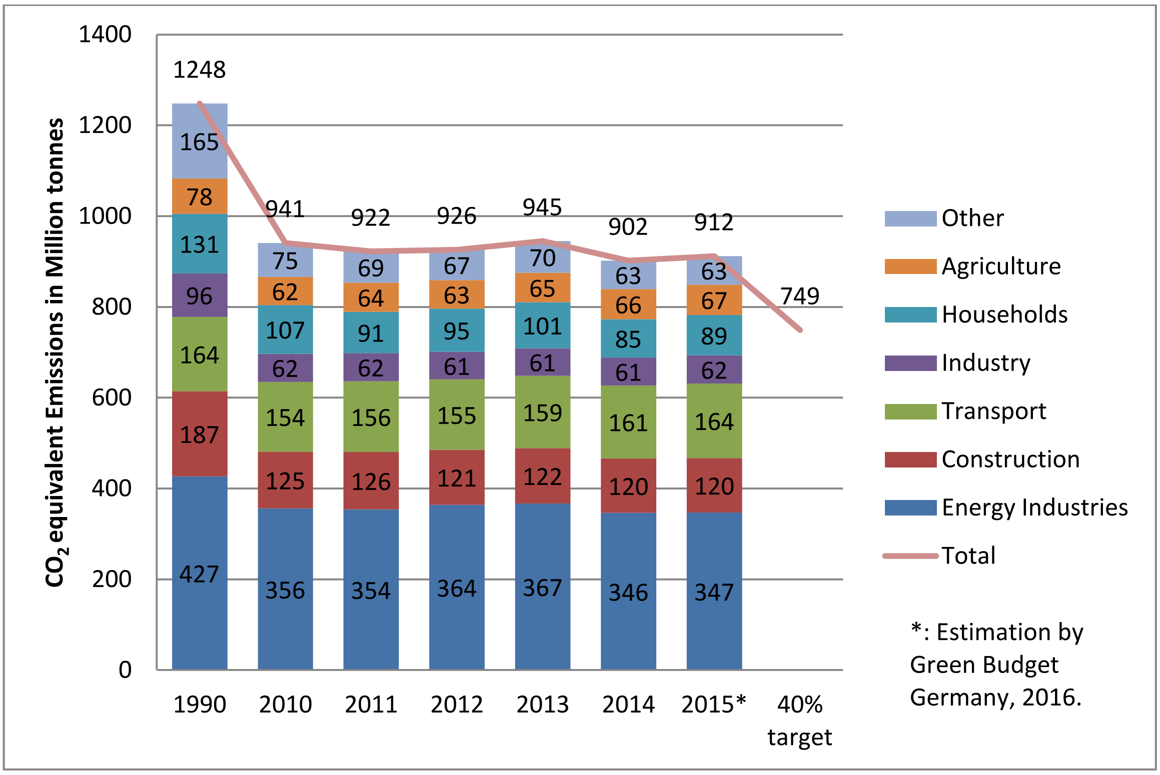

Figure 1 GHG emissions trend in Germany from 2010 to 2015 compared to 1990 levels (own chart, Data: UBA 2016, Green Budget Germany 2016).

Nuclear power

The disaster in Fukushima increased the popularity of anti-nuclear power movements and concerns about nuclear energy in Germany in 2011, which had been a recurrent political issue (Jorant 2011, p. 15). The Ethics Commission for a Safe Energy Supply (2011) produced a report on May 2011 issued by chancellor Angela Merkel highlighting the risks of using nuclear energy and recommending its withdrawal. As a result, Germany changed its strategy of using nuclear power as a bridging technology for the transition to renewable energies, and in the Spring of 2011 shut down the seven oldest nuclear power plants and the Krümmel nuclear plant permanently (BMWi 2012, p. 6). As of 2016, there remain eight operational nuclear plants in Germany (IAEA 2016). The effect of this measure on the decline of the share of nuclear power in

[12] "Germany aims to cut greenhouse gas emissions to 40 percent below 1990 levels by 2020. These targets are also in peril because progress in other areas of Germany's transition to a renewable and nuclear-free energy future has been slow - especially in transport and efficiency" (CLEW 12/2015).

[13] For the 2030 climate and energy framework GHG targets of 40% set by the European Commission this would mean a more realistic and affordable target decrease of 0.87% points (10.6 CO_2eq million tonnes) each year on average from 2015 (European Commission 2011a).

Germany's power production can be appreciated in Figure 2. Since 8 of the then 17 operational nuclear power plants were shut down in the Spring, the resulting reduction of power share can be noticed already for the year 2011. When considering the *environmental compatibility* of this measure, it can be argued that it is detrimental to the goals of reducing CO2 emissions, since the possible emissions that could be spared from fossil fuels would mean opportunity costs for the country. This observation is supported by the fact that emissions and the share of coal in power production increased from 2011 to 2013 (Figure 1 and 2). The Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (2016) regards this measure to be *economically viable* under the assumption that the investments and workplaces lost by the nuclear phase-out would go directly to renewable energy sources and energy efficiency[14].

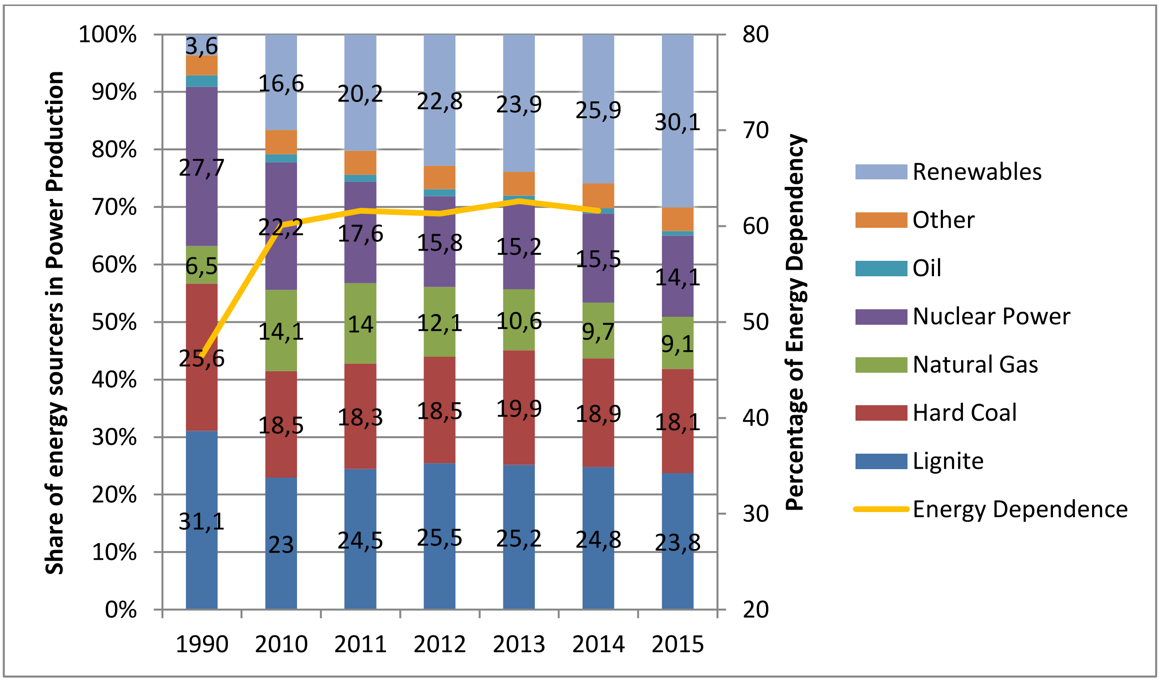

Figure 2 Share of energy sources in power production and energy dependency from 2010 to 2015 compared to 1990 in Germany (own chart, Data: Eurostat 2016b, AGEB 2016).

Since the decision to phase-out from nuclear power was primarily caused by the growing concerns on nuclear safety, it can be argued that the main focus of this measure was to ensure *security of supply*. The effectiveness of this measure guarantees that the country will spare security resources that were destined for nuclear safety in 2022. However, it is worth mentioning that diminishing nuclear power also affects the total amount of power produced by Germany, which will need to be compensated by other energy sources, preferably RES (Olivier et al. 2015, p. 44). A lack of responsiveness from the government while mitigating from nuclear power would cause an increase in energy dependency from imports (Hillebrandt et al. 2015, pp. 48-50). Nevertheless,

[14] The official statement estimates 38,000 jobs affected by the phase-out. It points out, however, that in 2004 already 157000 people worked in the field of renewable energies. The energy efficiency program of "Gebäudesanierung" would give 250000 jobs and require 10 billion Euro in investments (BMU 2006, p. 9)

there has not been a significant increase in energy dependency from 2011 to 2014 (Figure 2). This deviation in behavior is found, then, to maximize another dimension of the energy policy triangle, than the expected one, which would be the environmental compatibility of the policy. The development is reminiscent of new axiomatic explorations of behavior anomalies called 'non-expected' utility theories (Nau 1999). The observed phenomenon, coined as 'ambiguity aversion', reveals a preference of the rational subject to choose alternatives that don't involve risk (Machina 1987). It is arguable then, if Germany would be avoiding the rising legitimacy risks of continuing to use nuclear power as a bridging technology against the wishes of its population. However, it is worth noticing that Germany could as well be following some other set of preferences that the one assumed. This conjecture would, nevertheless, be unfalsifiable (Hodgson 2012).

Fossil fuels

In order to ensure a secure power supply, the German new energy policy in 2012 stated that investment in "flexible gas- and coal-fired power stations is essential [...], as fossil fuelled power plants must make up some of the shortfall arising from the phase-out of nuclear power" from the country's energy mix (BMWi 2012, p. 8). From 2011 to 2013, there was an increase in the share of power produced by coal (hard coal and lignite) of 2.3% points, while the share of natural gas decreased by 3.4% points. From 2013 to 2015 both the share of coal and gas decreased, making up for 51% of Germany's power produced (55.6% in 2010) (Figure 2). The amount of life-cycle greenhouse gases emitted by gas and coal belong to the higher end of CO_2 equivalents compared to other energy sources, ranging from 443 to 469 gCO_2e/kWh for natural gas, and from 1001 to 1050 gCO_2e/kWh for coal (Sovacool 2008, p. 2949-2950; Moomaw et al. 2011). Considering that the life-cycle GHG emissions from nuclear power range from 13 to 66 gCO_2e/kWh, replacing its share with these fossil fuels is evidently inefficient in terms of applying a swift CO_2 reduction policy and, thus, not *environmentally compatible* with the country's preferences. Nevertheless, as coal power decreased in 2014, so did the CO_2 emissions (Figure 1). While, as aforementioned, this development happened mainly due to energy savings by households and the public sector during the warm Winter, there was also an increase in the share of renewable energy power and nuclear power in comparison with 2013 that helped decrease the emissions from energy industries of that year (Figure 1 and 2). In 2015 the share of power from nuclear and renewable energy together increased by 2.8% points, while emissions increased by 10 Million tonnes, which shows that emissions in this year concern other factors.

One of the key strategies of the German energy concept for fossil fuels was to terminate all subsidies for hard coal (BMWi 2010, p. 17). The German federal state, the states North Rhine-Westphalia and Saarland decided in 2007 to terminate all subsidies to the sales of hard coal for the year 2018 (BMWi 2016a). An analysis of the environmental impact of energy subsidies indicates that a "subsidy phase-out leads to fuel switching [and] the net impact on emissions of greenhouse gases depends on whether the energy source affected is more or less carbon-intensive than the alternative" (OECD 2010, p. 25). It is plausible, therefore, that a gradual fade-out of the competitiveness of hard coal will lead to fuel consumption of either alternative fossil fuels or RES. However, although the government decided in 2014 to cut lignite production by 1.3 billion tonnes in the future, the state of North Rhine-Westphalia declared in the same year that lignite and hard coal mining has been secured at least until 2030 (NRW 4.2014). While this developments might have a positive impact on emissions, their late implementation may be detrimental to Germany's closer decennial targets. Furthermore, as the subsidies for hard coal will terminate in 2018, it is expected that the dependency on energy imports will rise to compensate for the loss in competition (Angerer et al. 2016, p. 109) and, thus, signify a threat to the national *security of supply*.

In this regard, the European Commission remarks that "imports and exports of energy products have an impact on CO2 emissions in the country where fossil fuels are burned: for example if coal is imported this leads to an increase in emissions, while if electricity is imported, it has no direct effect on emissions in the importing country, as these would be reported in the exporting country where it is produced" (European Commission 06/2015). Following this line of thought, since Germany's energy concept aims to decrease emissions from fossil fuels by decreasing their share in power production, and the country doesn't plan to end the mining of coal (hard coal and lignite) until at least 2030, it is questionable what will Germany do with the excess coal from mining operations in the future. From the year 2000 the exports of lignite have been gradually increasing, and from 2010 the exports of hard coal have stayed around the same level (Statistik der Kohlenwirtschaft 2016). Also, exports of electricity from lignite and hard coal reached a new record in 2013, which is responsible for the "crowding out of gas power stations not only domestically, but abroad as well" (own translation, Süddeutsche Zeitung 1.2014). These developments could imply, that while Germany could potentially decrease its CO_2 emissions from the burning of coal, reducing its share in power production domestically and increasing the energy dependency from imports[15], the extension of mining operations would possibly increase the exports of coal, thus, effectively moving the problem away from the country into coal importing countries while securing a strong source of income for the mining industry. This would make the measure *economically viable* for Germany.

In this regard, the erratic behavior of supporting the production of coal and using it to partially replace the electricity demand left by nuclear power could find its roots in the attempt of Germany to maintain the status quo of its energy industry. The 'status-quo bias' (Kahneman et al. 1991) is found to cause behavior anomalies, where there is an aversion of polluting companies to changes in environmental policy (Venkatachalam 2008). Venkatachalam warns that inefficient environmental policy reforms "come with additional cost and when these measures fail, the transaction costs already incurred become an economic waste" (p. 643).

[15] This development can be appreciated in Figure 2: While the share of coal (hard coal and lignite) has decreased in domestic power production since 1990, the energy dependency of imports has increased.

Renewable energy and energy efficiency

There have been numerous policies and measures on both energy efficiency and renewable energy sources from 2010 to 2015. As a result, the share of renewables in the German power production increased from 16.6% in 2010 to 30.1% in 2015 (AGEB 2016). In accordance with Directive 2009/28/EC on the promotion of the use of energy from renewable sources, the targets of Germany's National Renewable Energy Action Plan (NREAP) for 2020 are an 18% share of energy generated in gross final energy consumption, 15.5% of demand for heating and cooling, 37% of electricity demand and 13% of energy demand in transport met by renewable energy sources (NREAP 2010). In Germany, as of 2015, the share of energy generated by RES amounted to 30.1%, the demand for heating and cooling met by RES to 13.2%, the electricity demand met by electricity generated from RES to 32.6% and the demand in transport met by RES to 5.3%. This development shows a significant progress on renewable energy sources in comparison with the year 2010 and previous years (BMWi 2016b). It is, however, plausible that Germany doesn't meet all of its targets for 2020 on renewable energy sources (Energy Transition 6.2015). Nevertheless, there has been much investment for RES and national budget destined for both RES and energy efficiency increased substantially since 2014 (Table 2).

			in Million €			
	2010	2011	2012	2013	2014	2015
Investments in RES	27,300	23,800	20,300	15,700	18,800	14,600
Hard coal[16]	1,469 (79.5%)	1,473 (80.6%)	1,312 (78.3%)	1,229 (76.9%)	1,290 (44.6%)	1,201 (44.6%)
RES & EE[17]	170 (9.2%)	150 (8.2%)	151 (9.0%)	145 (9.1%)	1,380 (47.7%)	1,288 (47.9%)
Energy & Sustainability[18]	1,848	1,828	1,675	1,598	2,892	2,690

Table 2 - Investments in renewable energy sources in Germany and Budget of the German Federal Government for hard coal, renewables and energy efficiency from 2010 to 2015 (own table, BMWi Haushalt 2010-2015, Statista 2016).

Decisive for the development of RES policies in Germany is the Renewable Energy Sources Act (EEG). Since 2010 there have been two amendments of the act, in 2012 and 2014, with plentiful changes to policy implementation mechanisms and legislation on offshore and onshore wind

[16] Expenditures in hard coal were calculated by adding the sections "Kohlebeihilfen" and "Anpassungsgeld für Arbeitnehmer". The percentage is its share from the total budget for energy & sustainability.

[17] Expenditures in renewable energy and energy efficiency (RES & EE) were calculated by adding the sections "Energie Forschung", "Steigerung der Energieeffizienz", "Energetische Gebäudesanierung", "FuE Erneuerbare Energien" and "Einzelmaßnahmen erneuerbare Energien (MAP)". The percentage is its share from the total budget for energy & sustainability.

[18] The budget for energy & sustainability were taken from the sections "Energieforschung", "Rationelle Energieverwendung", "Steinkohlenbergbau" and "Wismut GmBH Sanierung".

power, hydropower, biomass and solar photovoltaic cells (RES Act 2014). As a result, the share of those RES in gross electricity production increased since 2010, especially wind and photovoltaic energy (BMWi 2016b). Furthermore, since 2011 the KfW development bank started supporting the financing of offshore wind energy projects, particularly of SMEs, on behalf of the German government and expanded financial aid to solar and hydropower (KfW 2016).

Among the numerous beneficial measures aiming to increase energy efficiency since 2010, the most significant ones were included in the third installment[19] of the National Energy Efficiency Action Plan (NEEAP) in Germany in 2014 (BMWi 2014). In the household sector the most important measure was the Energy-efficieny Construction Programme financed by the KfW on behalf of the Government, which preceded a KfW CO_2 building rehabilitation program from 2009. The program funds "homes [that] require innovative heating technology based on renewable energies and very good thermal insulation" in order to increase energy efficiency in buildings (Schlomann et al. 2015, p. 25). The increase in CO2 emissions from 2010 to 2013 pressed Germany to rise its budget for both developments in renewable energy sources and energy efficiency in this regard (Table 2). However, other subsidies for renewable energy sources, energy efficiency purposes, and for the 2009 and other KfW programmes, not included in the national budget, were continued from 2010 to 2015 and showed significant increases when compared to the previous years, as well (BMF 2011, 2013, 2016). Furthermore, Germany gives a significant portion of his budget for energy and sustainability to subsidy hard coal, a development that, as aforementioned, will end in 2018 (BMWi 2016a). With the termination of hard coal subsidies, a large amount of budget will become available for the financial aid of other areas in the energy sector.

Other minor development to increase energy efficiency in the transport sector was a levy on air traffic in 2011, which was increased in 2013 to consider the distance and time travelled to the destination (Destatis 2011). However, the application of mechanisms such as ecological taxes seems to have no correlation with the level of emissions (IEA 2013, p. 29). A semi-quantitative analysis on the impact of measures in the transport sector (2015) found that "with a number of 19 measures the transport sector has the lowest amount of measures for Germany. Nevertheless the EU-related measures mostly have a high impact. [For example] the Community Framework for the Ecological Tax Reform (fiscal) of which the measures are deemed to be high in both in the household and the transport sector" (Schlomann et al. 2015, pp. 36-37).

The analysis of the measures on energy efficiency and RES did not find any detrimental developments to the emissions of CO2 made by the German government between 2010 and 2015. Measures and policies applied in this manner were found to be in accord with the energy policy triangle dimensions of *economic viability*, *environmental compatibility* and *security of supply*. Rational behavior in this regard seems to be entirely consistent with the preference ordering

[19] Revisions on measures adopted for the second installment of the NEEAP in 2012 were also included in the third edition.

assumption favoring the environmental component of the energy policy triangle and, thus, with the German government's emission goals for 2020 and 2050.

4.1.3 Interim Conclusion

In this subchapter, the policies and measures with a significant impact on CO_2 emissions applied by Germany under the framework of their Energy concept since 2010 were analyzed. From the presented literature analysis and the statistical data it can be inferred, that the aggregate of indicators support an overall conservative progress to the realization of the preferences set by Germany in regards to decarbonisation. The method chosen to analyze the utility of the measures implemented was the classical energy policy triangle. The presented qualitative analysis dealt the following results:

	Environmental compatibility	Security of Supply	Economic viability
Nuclear Phase-out	-	+	+
Policies on coal	-	+	+
Energy efficiency and RES policies	+	+	+

Table 3 - Assessment of the utility preferences of German environmental policies

Following the assessment criteria outlined in chapter three, in order to analyze the utility maximization of the respective national governments under the rational choice approach, the dimensions of environmental compatibility, security of supply and economic viability are applied to the qualitative analysis of the data. Additionally, because of the objective of reducing CO_2 emissions for 2050, the dimension of environmental compatibility is assumed to have a higher preference ordering than the other two dimensions.

The analysis of the decision on phasing-out nuclear power and discarding it as a bridging technology for renewable energies was found to be incompatible with environmental targets, however beneficial in the long term for security of supply, since it constituted a threat as a potential nuclear hazard. Furthermore, the measure was found to be economically viable for the government, since the economic consequences of the measure were salvaged by the government using the budget to finance more projects on RES. However, since the utility maximization of the alternatives represent the reduction of CO_2 emissions, the opportunity costs are found to be much bigger for Germany, than if the country kept nuclear power. As a result, this measure is inefficient to the maximization of expected utility.

The environmental policies targeting coal highlighted that the German government had a mixed progress dealing with emissions caused by fossil fuels. Germany's intentions to terminate coal subsidies may have an effect starting in 2018, but due to coal filling in the energy demand left by the phase-out of nuclear power, the share of fossil fuels from the energy mix barely changed from 2010 to 2015 (especially from coal). In this regard, the permanence of fossil fuels in the energy mix is detrimental to the reduction of CO_2 emissions, but positive for the security of supply in terms of maintaining power capacity. However, the future plans for hard coal subsidies may cause a rise in energy imports and not necessarily stop the share of lignite to take over. This would depend on the share of renewable energy and its capacity available by then. Furthermore, the plans to extend mining operations at least until 2030 will secure the economic viability of retaining coal as an energy source. In this regard, the argumentation applied for fossil fuels would be similar to that for nuclear power. The rational decision maker, given the preference of reducing CO_2 emissions, would use nuclear power, an energy source with less CO_2e/kWh than coal and gas, in order to enable a swifter energy transition. Expected utility is, under that premise, not maximized.

From these two findings relating to a similar effect on expected utility, there are two conclusions that can be made: Either, Germany incurred in erratic behavior (e.g. 'ambiguity aversion', 'status quo bias') during policymaking to phase-out nuclear power given the preference ordering favoring carbon emissions reduction, or Germany's preference set during policymaking did not prioritize the reduction of CO_2 emissions in the first place, but another dimension of the energy policy triangle (the aforementioned unfalsifiable 'hidden utility').

Additionally, the presented analysis concluded that the progress done by the government towards energy efficiency and renewable sources was aligned with the dimensions in the energy policy triangle, and, thus, maximized Germany's expected utility.

4.2 United Kingdom

4.2.1 Low-carbon Transition Plan

The British government published the Energy Challenge in 2006, which set the starting goals of reducing CO_2 emissions by 60% of the levels from 1990 by 2050 (DTI 2006). Subsequently, this set up the legislative path towards the Climate Change Act, adopted in November 2008. The Act set a more challenging goal of at least 80% reductions for 2050 and introduced a system of *carbon budgets* which "provide legally binding limits on the amount of emissions that may be produced in successive five-year periods, beginning in 2008" (Climate Change Act 2008, p. 4; DECC 2011a, p. 3). The carbon budgets are presented in the following table[20]:

	First carbon budget (2008–12)	Second carbon budget (2013–17)	Third carbon budget (2018–22)	Fourth carbon budget (2023–27)
Carbon budget level (million tonnes carbon dioxide equivalent ($MtCO_2e$))	3,018	2,782	2,544	1,950
Percentage reduction below base year levels	23%	29%	35%	50%

Table 4 - UK carbon budgets as set by the Climate Change Act 2008 (DECC 2011a)

In July 2009, the British government published The UK Low Carbon Transition Plan. (DECC 2009). The plan emphasized the short-term goal for 2020 to achieve a 40% share of the UK's electricity from low carbon energy sources (p. 4). In order to enable the development of its goals the plan sets five points of action, focusing on three key steps: First, electricity from renewable sources would have to increase to 30% by 2020. For this end, the British government created the Office for Renewable Energy Deployment as a starting point. Second, the government aimed to facilitate the construction of new nuclear power plants. Finally, in order to reduce emissions from existing fossil fuel power plants, especially coal, the government designed a mechanism to enable development and future implementation of CCS technologies (pp. 9-10). Additionally, the plan highlights the importance of energy efficiency measures in transport, industry and households, especially the need to "reduce the amount of energy [homes] use, and produce more of the heat and electricity in a low carbon way, using technologies such as solar power and heat pumps" (p. 78).

On the development of nuclear power, the government released in 2008 its White Paper on Nuclear Power (p. 62). The paper's assessment of the relation between nuclear power and CO_2 emissions concluded that in the life-cycle, the emissions from nuclear power are low and "about the same as those of wind generated electricity [...]. The Government therefore concludes that

[20] The base year is 1990.

new nuclear power stations could make a material contribution to tackling climate change" (BERR 2008, p. 53). As a result, the Climate Change Act aimed as a whole to decarbonise the British electricity supply by creating "a mix including renewable sources, nuclear power and fossil fuels with carbon capture and storage" (DECC 2009, p. 64). However, following the disaster of the Fukushima Daiichi nuclear power plant caused by an earthquake of magnitude 9 and an associated 14m. tsunami, the British government issued a review of its nuclear strategy. A report analyzing the implications of this incident for the UK nuclear industry (2011) found that "the UK approach to identifying the design basis for nuclear facilities is sound for such initiating events" (ONR 2011, p. 139), arguing that the Japanese regulations on nuclear safety are less robust than the ones in the UK. The cause of the accident was "that the site [in Fukushima] was not designed with adequate protection against some foreseeable natural hazards" (p. 137). The report concludes that "flooding risks are unlikely to prevent construction of new nuclear power stations at potential development sites in the UK over the next few years" (p. 153). The then Secretary of State for ECC, Chris Huhne, expressed his disappointment at the quick European judgment of nuclear safety standards without evidence, underlying the effects on investments in nuclear energy after Fukushima (The Telegraph 03/2011). Although the British government was criticized for diminishing the aftermath of Fukushima, in order to protect its nuclear plans (The Guardian 6.2011), it did not change its perspective. As of 2011 nuclear power amounted to 18% of the UK electricity (DECC 2012/089).

In regard to renewable energy, the UK aimed to maintain and consolidate its position as a global leader in offshore wind and marine energy with a financial aid of nearly £200 million to encourage investment (DECC 2009, pp. 124-125). The UK's Renewable Energy Roadmap of 2011 set goals for RES to "ensure that 15% of [national] energy demand is met from renewable sources by 2020 in the most cost effective way" (DECC 2011b, p. 9). To this end, the government amplified its focus on RES to onshore wind power, biomass electricity, heat pumps and renewable transport (p. 7). Additionally, the government, as a small player in the solar PV market, would try to "encourage cost reduction to improve its competitiveness against more established technologies" (p. 15).

The aforementioned goals conform the preference set of the UK for the reduction of carbon dioxide emissions and are, as a result, the comparison base for analyzing their adopted policies between 2010 and 2015. In the following subchapter the UK key environmental measures and policies from this period will be analyzed.

4.2.2 Qualitative Analysis

In 2015, the UK achieved a reduction of CO_2 equivalent emissions from 1990 levels of 38%, three percent points past its 35% carbon budget target and 15% points on top of the European targets for 2020 (DECC 2016a). Furthermore, following its carbon budget system, the UK is in the second carbon budget from 2013 to 2017. During this period, the UK cannot emit more than 2,782 $MtCO_2e$ (DECC 2011a, p. 3). From 2013 to 2015, the government has emitted 1,568 $MtCO_2e$ (Figure 3). Even if the UK emitted in 2016 and 2017 the same amount of carbon dioxide as in the year with the highest emissions in this period (2013), it would still be 100 Million tonnes under its 29% target.

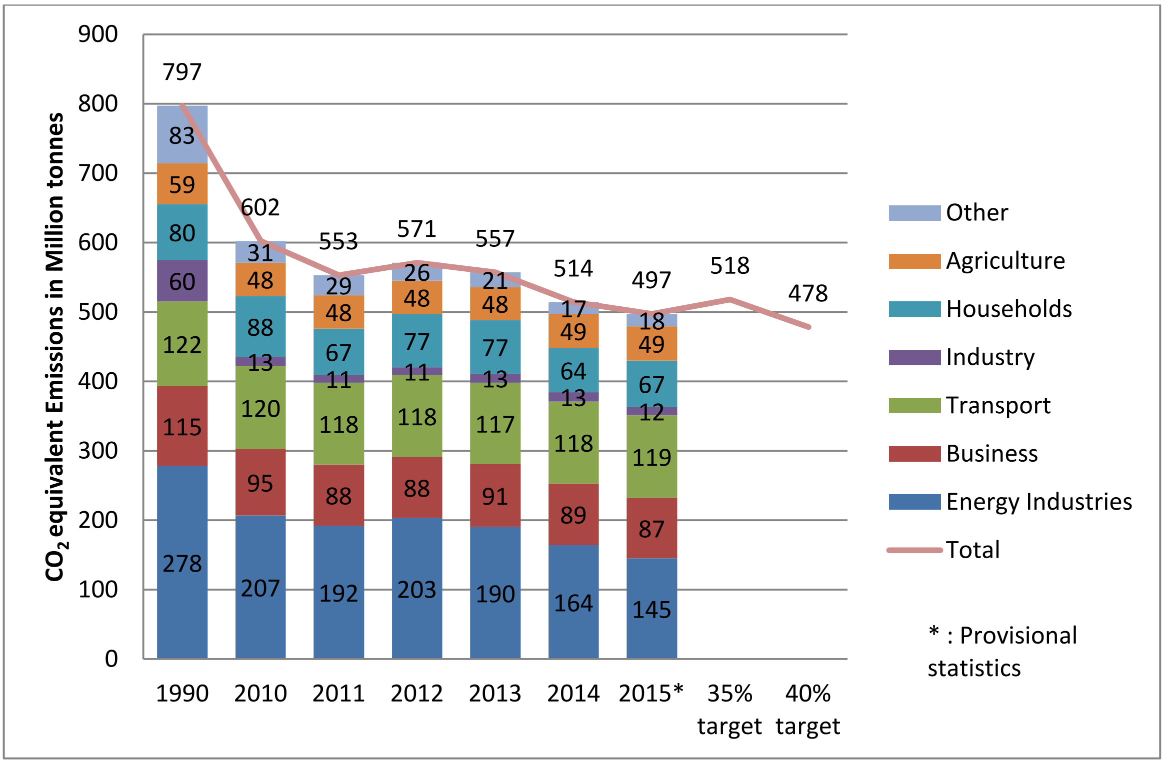

Figure 3 GHG emissions in the UK by source from 2010 to 2015 compared to 1990 levels (own chart, DECC 2016a).

For the third carbon budget period, the UK set out to stay under 2,544 $MtCO_2e$ in five years. This implies an average of 509 $MtCO_2e$ or less per year, in order to achieve a 35% reduction from 1990 levels. From 2010 to 2015 there was only one rise in emissions in 2012, which was mostly due to a large increase in the share of generated electricity from coal (Figure 4), but also due to more consumption of electricity from households, due to lower winter temperatures than in 2011 (CarbonBrief 03/2013). The subsequent drop in emissions since 2012 (Figure 4) was due to a combination of the gradual decrease of the share of electricity generated from coal and the increase of the share of RES and nuclear power (The Guardian 03/2016). There has also been a gradual decline in total power produced since 2005 (DECC 2016b).

The British government's pledge on closing all its remaining coal power plants by 2025, the *coal phase-out*, has raised concerns on possible future power capacity problems (BBC 11/2015). Professor Michael Grubb, at the University College London commented in 2016 on the Guardian, that the UK "[has] seen at least five years of “lights out” headlines, so far without so much as a flicker caused by insufficient capacity" (The Guardian 03/2016). Furthermore, the government has many other energy sources to cover the loss of power from coal, mainly through gas, energy efficiency, RES and nuclear energy (idem.). Not much progress can be observed on emissions caused by transport and households since 2011 (Figure 3), despite the government's intentions to target energy efficiency in these areas since 2009 (DECC 2009, p.10-14).

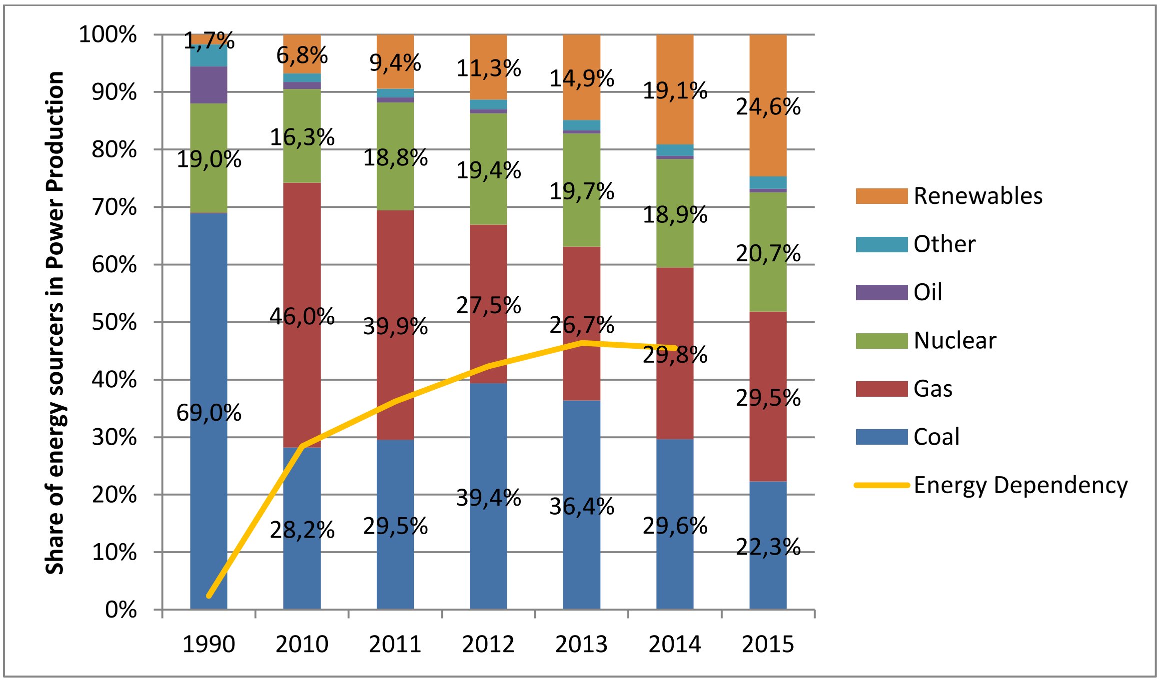

Figure 4 Share of energy sources in power production and energy dependency from 2010 to 2015 compared to 1990 in the UK (own chart, Data: Eurostat 2016b, DECC 2016b).

Nuclear power

In the UK, the Fukushima Daiichi accident delayed the nuclear programme, but didn't cause the government to change its view about using nuclear power as a replacement for power generation from fossil fuels (The Guardian 04/2011). Following the aftermath, the British government issued a report on the details of the nuclear disaster and the implications for the UK, which recommended the government to review its nuclear safety standards and consider the geographical place for the construction of future nuclear plants (ONR 2011). However, the public reaction to the nuclear accident affected investments of "two of the big six power companies [who] announced they would be pulling out of developing new nuclear plants" (The Scotsman 03/2012). The Energy and Climate Change Committee of the House of Commons stated in early 2013 that "the primary major consequence of failing to deliver new nuclear would be the impact on the UK’s ability to reduce carbon emissions and thereby tackle climate change" (HC 117/2013). In the same year, the government published its Nuclear Industrial Strategy, which aimed to increase investments on new nuclear projects, initiatives to reduces costs and increase nuclear innovation (DBIS 2013). For this objective, the UK planned to build 16GWe of new nuclear power capacity for 2030. As of 2016, thirteen power reactors are planned and proposed, amounting to 17.9GWe (World Nuclear Association 08/2016). In the strategy, nuclear power is considered part of the low-carbon energy mix next to RES and CCS (p. 3).

Furthermore, in the government's plan for decarbonisation nuclear power is "shown to deliver a much larger amount of [power] generation than that available now, with the potential to deliver between 16 GW and 75 GW of the UK’s electricity needs" (p. 10). The strategy also takes considerable steps to ensure that nuclear safety will "continue to require partnership working between the [Technical Advisory Panel] regulator and industry to ensure [it] is by far the top priority" (p. 32). Furthermore, although energy dependency has increased by nearly 15% points between 2010 and 2014, this cannot be directly attributed to nuclear power, especially since its power production has only increased (marginally) during the same period (Figure 4). Therefore, measures of the British government to improve its nuclear strategy are considered to be *environmentally compatible* with its preference to diminish its CO_2 emissions, and take into account *security of supply*, not only in regard to their scrutiny concerning nuclear safety, but also to the long-term coverage of the UK's electricity supply.

Additionally, the nuclear strategy established a long-term approach to stimulate economic growth and job creation (DBIS 2013). An in-depth analysis done by Oxford Economics and Atkins (2013) points out that the combination of policy implementation and investments made in the new nuclear industry has the potential to capture 60% of the value of investment for the 16GW programme to 2030 (Oxford Economics 2013, p. 86). The industry investment required for new capacity until 2030 amounts to £60 billion, "equivalent to five new multiple-reactor nuclear power stations each with on average capital investment requirements of around £12.0bn. This compares to an overall cost of around £9bn for the London 2012 Olympic and Paralympic Games" (DECC 2013a, p. 7). The reform of the electricity market in the UK aims to enable long term contracts to support the long-term investments that the high capital costs in nuclear technologies require (p. 5). Therefore, the British nuclear strategy is considered to be *economically viable* for its pursuit of the reduction of emissions, as well.

In contrast with the rational deviation of 'ambiguity aversion' (Machina 1987) that results for some rational decision makers from the rejection of decisions under risk, the UK acted in accordance with their expected preference ordering by keeping nuclear power in order to better achieve its decarbonisation targets. The UK reacted to the rising of possible risks by issuing a report (ONR 2011) on the implications of Fukushima for its nuclear plan. Nevertheless, this only reduced perceived risks, but didn't establish an environment of certainty, since the public reaction still affected investment (The Scotsman 03/2012). In this regard, it can then be inferred, that the UK took a calculated risk into account while deciding to keep its original plan of shifting towards nuclear, and, hence, was maximizing its expected utility under the standard axioms of rationality.

Fossil fuels

A part of the UK's plan to shift its electricity to nuclear is to reduce the share of fossil fuels, especially coal, from the domestic energy supply. In November 2015 the British government announced its intention to shut down its remaining coal power plants by 2025, if they were not able to install CCS technologies by then (BBC 11/2015). In 2012, coal production in the UK decreased to an all-time low of 17 Million tonnes, but "due to the high price of gas, coal used for electricity generation increased to the highest levels seen since 2006" (DECC 2013b). This also explains the lower share of natural gas in electricity generated in the UK in that year. The share of coal from power production in the UK increased in 2012 by 10% points, contributing substantially to the rise in emissions by nearly 20 $MtCO_2e$ (Figure 4). Furthermore, in order to meet the energy demand, coal imports increased by 38% (Figure 4), which contributed to the increase in energy dependency in the same year (DECC 2013b, p. 53).

From 2012 to 2015 power generation from coal gradually decreased by nearly 50% and in 2015 about 52% of the electricity generated in the UK came from fossil fuels, a significant progress from 2010 where it accounted to roughly 75% (DECC 2016b). The demand for gas in the UK started in the 1970s, and grew further between 1990 and 2000 with the privatization "dash for gas" in power generation, which increased primary energy consumption from gas to 43% (Le Fevre 2015, p.4). Since then, the share of gas in energy consumption has fallen through a combination of "a trend away from energy intensive manufacturing, improvements in energy efficiency, increased competition in power generation from coal and renewables" (idem.). As can be seen in Figure 4, the share of gas remained roughly the same after its decline in 2012 until 2015. The overall decrease in the share of electricity generated from fossil fuels is, hence, a side effect of the increase in the share of power from RES. The British Energy Secretary, Amber Rudd, pointed out that by 2025 gas-fuelled power should be able to fill the power void left by the coal phase-out, a statement which corroborates environmentalist concerns about the slow progress done for renewable energies (BBC 11/2015). In general, however the announcement of the phase-out was considered a major step towards reducing carbon emissions. Since the decrease in the share of power from fossil fuels in 2012, there has been a monotonous decrease in carbon dioxide emissions of 74 $MtCO_2e$, from which nearly 80% is due to emission reductions in the energy industry (DECC 2016a). This development shows that the environmental policies for fossil fuels are *environmentally compatible* with the decarbonisation targets of the UK.

Regarding the policy goal of security of supply, concerns about possible power shortages as a result from the coal phase-out and potentially from an uncertain future of gas in the supply mix have risen, as aforementioned (The Guardian 03/2016). Since coal will no longer be a part of the UK's energy mix from 2025, it is critical for another energy source to sustain the gap in the capacity market left by the phase-out (idem.). Rogers (2011) pointed out that gas would retain a central role in the UK's power generation mix until 2025, since the nuclear and coal have lower turndown flexibility to support variability in wind energy (Rogers 2011, p. 84). However, the decrease of power generated from coal coupled with the overall decrease from fossil fuels is likely to rise the levels of energy dependence (idem.; Le Fevre 2015), an effect that can be appreciated in Figure 4. Therefore, measures aiming to decrease the share of fossil fuels from the UK's energy mix are detrimental to the goal of *security of supply*.

Concerning the economic viability aspect of the long-term coal phase-out, the British coal industry started declining after the first World War (Ashworth 1986). The Executive Chairman of UK Coal, Jonson Cox, commented already in 2012 that the decarbonisation and the restructuration of the energy supply would need to relocate under 3,000 workers of the coal industry (The Telegraph 12.2012). However, a report on the coal phase-out for Oxfam (2015) remarked that the "economic viability of coal-fired power plants depends on the interaction of a suite of different instruments that now shape the UK's electricity market framework", while emphasizing that "action on demand reduction should be prioritized alongside flexible technologies for demand response, rather than the provision of subsidies for coal" (Littlecott 2015, pp. 16-18). Furthermore, since natural gas is expected to fill in the decline of coal from the energy mix, economic consequences are not expected for the gas market in the short term. Additionally, offshore oil and gas extraction in 2014 "was the sixth largest contributor to national gross value [...] in the UK economy" (Oil & Gas UK 2015, p. 7). Therefore, given the historic decline of the coal industry and the new shape of the British electricity market, the phase-out of coal for 2025 appears to be *economically viable* for the UK.

While the UK follows its assumed preference ordering by favoring emissions reduction and, thus, maximizes its expected utility as a rational subject, it could be including at some point a 'status quo bias' (Kahneman et al. 1991) in its decision making process. The phase-out of coal by 2025 will need power from gas to fill the electricity demand (BBC 11/2015). The impact of gas is not a priority for the government, since its effect on emissions is half the impact of coal (Gagnon et al. 2002). Furthermore, a report on climate-change mitigation by McGlade and Ekins (2015) pointed out that 50% of gas reserves and 80% of coal reserves had to remain unused by 2050, in order for the developed world to meet its decarbonisation targets in the long term (McGlade & Ekins 2015). In this regard, the share of gas in power generation has marginally increased since 2012 (Figure 4). Since the decrease in coal has been overall responsible for emissions reduction, the effects of a status quo bias for the gas market may not be visible yet until the coal phase-out in 2025. However, following the argumentation by Hodgson (2012), it cannot be concluded if the UK is maximizing an unobserved variable, and in this way incurring in a status quo bias for the gas market. The effects for the CO_2 emissions reduction targets remains positive (Figure 3).

Renewable energy and energy efficiency

The share on renewable energies in the energy supply mix of the UK increased from 6.8% to 24.6% between 2010 and 2015, signalizing success in the engagement of the government to promote investment in RES (Figure 4). In 2014 over 25% of households were powered by wind energy (Energy Hypermarket 01/2015). Regarding energy efficiency, as of 2015 the UK is one of the European countries with the lowest quantity and impact of energy efficiency policies, beating only Spain in the European rankings (Egger 2015). Among all Member States, the "UK experts see the lowest level of progress in building renovation" (p. 101), while regarding measures targeting fuel poverty, "more than 70 % of the experts [interviewed in the survey] see no progress" in the UK (p. 112). This entails opportunity costs for carbon emissions that could have been spared from energy efficiency measures. However, the increase of renewable energy sources in the UK's energy supply mix had a positive effect on emissions. In order to improve this development, the government will need to increase its efforts on energy efficiency for transport and the renovation of buildings (Egger 2015). Overall, the developments on renewable energies from 2010 to 2015 were *environmentally compatible* with the UK's decarbonisation preferences.

The increase in renewable energy would give the UK "much more security [of supply] and a greater degree of energy independence" (DECC 2011b, p. 4). Although there has been an increase in import dependency since 2010, as aforementioned, this is mainly due to the decrease in share of energy supply from fossil fuels, that need to import energy to meet the demand for these fuels (DECC 2013b). Between 2010 and 2014 renewable energy consumption increased from 3.8% to 7% (DECC 2015, p. 58), which is barely under the 17% increase yearly goal of the UK renewable energy roadmap (DECC 2011b, p. 20). Since this increase has been monotonous from 2010, it can be concluded that the measures from the British government targeting RES have been gradually increasing the *security of energy supply*.

In 2010, the estimated cost of meeting the UK's renewable targets for 2020 was over £12 billion per year, which was "considerably above financial analysts' estimates of the capacity of the big six electricity utilities to finance on its own, indicating the need to access new sources of finance" (Fabra et al. 2015, p. 93). The Electricity Market Reform of 2013 introduced for this end the Contracts-for-Differences (CfD) financial mechanism, a 15 year contract that would set a price in £/MWh for low-carbon generation, aiming to aid the finance of energy sources, including RES (Ofgem 2013). There are other forms of financial incentives for renewable electricity suppliers in order to increase their capacity of energy generation, like the Renewable Obligation Certificates (ROCs) or the Feed-in Tariffs (FiTs) (DECC 2015, pp. 55-56). Most of the types of renewable energy sources are successfully financed through the government or financial mechanisms that encourage investment in RES. Therefore, the implemented measures are *economically viable*.

In this regard, the UK's rational behavior appears to be moderately consistent with its preference ordering encouraging environmental compatibility and, hence, with its domestic carbon budgets.

4.2.3 Interim Conclusion

The measures with a significant impact on carbon emissions under the UK's low-carbon transition plan were analyzed from 2010 to 2015. It can be concluded, that the statistical data supports a positive impact on the emissions reduction progress of the UK. The method to analyze the utility of the British measures and policies was the classical energy policy triangle. The qualitative analysis of the data dealt the following results:

	Environmental compatibility	Security of Supply	Economic viability
Nuclear Energy	+	+	+
Policies on coal and gas	+	-	+
Energy efficiency and RES policies	+	+	+

Table 5 - Assessment of the utility preferences of the UK's environmental policies

In order to analyze the effects on the country's utility under the rational choice theory, the dimensions of environmental compatibility, security of supply and economic viability were tested for the respective measures. Considering the decarbonisation targets for 2050, the environmental compatibility dimension was given a higher consideration for the UK's expected utility.

The UK's nuclear strategy as a bridging technology for RES was found to be environmentally compatible with the governments carbon targets. Following the report on the implications of Fukushima issued by the government, extensive precautions were considered to regulate the construction and safety standards of future British nuclear plants. Additionally, the increase in capacity and power generation from nuclear plants would have a positive impact on security of supply. Furthermore, the strategy was economically viable. Since the strategy was found to have a positive impact on all the dimensions of the energy policy triangle, expected utility was considered to be maximized in this regard.

The British policies targeting coal and gas were also found to be environmentally compatible and economically viable. The long term phase-out of fossil fuels will, however, convey an issue of security of supply, since the demand left by them will need to be covered by another energy source, which will doubtfully be renewable energy alone. Nevertheless, the decrease of the share of power generated from fossil fuels is overall favorable to the reduction of CO_2 emissions, and, therefore, the utility of the UK is considered to be maximized.

The analysis of the policies on energy efficiency and renewable energy sources showed that despite the UK being one of the countries with the least energy efficiency measures in the European Union, the substantial increase of renewables in the energy mix meant an overall positive impact for the environmental compatibility of the progress done. These measures gradually increased the security of supply and, because of the continuous implementation of financial incentives from the government, were found to be economically viable, as well. Hence, the overall combination of measures in renewable energies and energy efficiency maximizes the UK's expected utility in regard to the reduction of carbon emissions.

4.3 Concluding remarks

In this chapter the individual case studies were analyzed. The respective climate policies of each country were assessed using the criteria laid out in the methodology chapter, and the preferences of the countries under the assumption of individual rationality and deviations from it were evaluated. Each case study delivered an interim conclusion for their individual analysis, which will be integrated in chapter five. In the following chapter, the overall conclusion will give an in-depth resolution of the significance of my findings for the rational choice theory, environmental policymaking targeting decarbonisation, as well as an explicit answer about the behavior of Germany and the UK while adopting policy for the reduction of GHG emissions.

5. Conclusion

Following the research design by the evaluation of the two case studies, the UK and Germany share many conditions that are considered in the analysis to belong to a similar background e.g. their membership in the European Union, their adoption of ambitious emission targets, both being strong world economies, etc. Furthermore, both countries started from 2010 on similar grounds, having a lower share of renewable energy sources and a substantial share of fossil fuels in their power production. However, the design needs two variables that differ in the comparison between the two cases, an independent variable X and a dependent variable Y. In the presented analysis, the independent variable represented the different measures and policies that the respective countries adopted towards the decarbonisation of their respective economies, which is represented by the dependent variable. The independent variable could entail either favorable or detrimental measures to decarbonisation. The resulting outcome, the dependent variable, portrays the effect of these policies on carbon dioxide emissions since 2010 to the present.

The aggregate of the conclusions drawn from the separate case studies contribute to answering the research question of this research. The evaluation of the domestic progress done towards decarbonisation in 2050 has been addressed individually due to the disparity in the national environmental objectives presented in subchapters 4.1.1 and 4.2.1. The behavior of each individual country was assessed by referring to the energy policy triangle. The triangle gave an insight in the decision making process of the countries and was assumed to set a preference ordering encouraging alternatives maximizing the dimension of "environmental compatibility". This assumption was set to help test the rational choice theory, specifically the expected utility theory, and point out possible deviations resulting from erratic behavior. Both expected results and anomalies were noted at the end of each subsection of policies concerning nuclear power, fossil fuels and renewable energy sources, as well as energy efficiency. The extent of the consistency in the behavior of Germany and the UK favoring the reduction of CO_2 emissions was analyzed in the interim conclusions of each case study in subchapters 4.1.3 and 4.2.3.

The interim conclusions for Germany showed that the country has a mixed strategy towards decarbonisation. While the country's intentions may be the best, their selected path towards achieving decarbonisation as soon as possible is clearly inefficient, or, at best, it forces a substantial effort into developing renewable energies and energy efficiency faster than it would be necessary. A foreseeable issue around increasing power generation from renewable energy so fast, would be the need to develop ways to manage oversupply, like energy storage facilities (Bloomberg 05/2016). However, the rapid development in Germany, and the political pressure that a bigger share of emissions from fossil fuels could exercise, could lead to a path that only requires the government to diminish the amount of coal power plants in the future. Nevertheless, this is dubious for the short term considering Germany's environment minister, Barbara Hendricks' statement in 2014 that "[Germany] must not demonize coal", stating that it is crucial for the country's energy security (Energy Transition 04/2014). This posture corroborates the aforementioned effects of the 'status quo bias' explained by Venkatachalam (2008). The hesitation of the country to follow a distinct efficient path to decarbonisation, without making substantial changes to reduce the emissions from coal could cost it the achievement of its long-term goals. In this regard, if Germany is adamant in generating energy from burning coal, it should implement policies for the regulation and destine a great budget in research and development of CCS technologies. In the light of these findings, the independent variables of Germany, the policies affecting the reduction of carbon dioxide emissions, were found to be for the most part detrimental to the achievement of its goals (Table 3), and, as expected, had a moderate and mixed impact on its dependent variable, the emissions from 2010 to 2015 (Figure 1).

In contrast, the interim conclusions for the UK showed that the government follows a more consistent and, hence, rational path towards achieving its decarbonisation targets. Environmental measures and policies were found to be favorable and utility maximizing for the reduction of carbon emissions. Furthermore, the development of Brexit in 2016, which was not included in the scope of this analysis, will for the most part not affect the current British energy policy. In the aftermath following Brexit, the consulting firm Frost & Sullivan stated in 2016 that "the UK was already ahead of the rest of the EU on reducing its coal generation capacity and carbon emissions, with a commitment to close all coal plants by 2025, and there is no evidence to suggest that this will change" (Frost & Sullivan 2016). However, it is crucial that the UK maintains a time consistent behavior in this regard, since deviations added to the uncertainties that Brexit holds, could potentially cause an aversion in investments for their transition plan and for new technologies. In regard to its case study, the independent variables of the UK, the policies targeting decarbonisation, were found in general to support an efficient achievement of its targets (Table 5), and as a result, there was a positive impact on its dependent variable, the reduction of GHG emissions from 2010 to 2015 (Figure 3).

My observations give some minor insights to the discrepancy between the traditional expected utility theory and the bounded rationality theory, proposed by Simon (1991). The bounded rationality theory proposes that decision makers act as satisficers, rather than maximizers of utility, because their rationality is restricted by their environment, e.g. information asymmetry, time constraints, uncertainty and insecurity. In the light of this research, it could be argued that both Germany and the UK were acting under the restrictions postulated by bounded rationality. However, in comparison the UK seemed to follow a more rational behavior similar to that of maximizing his expected utility (Table 5) than Germany (Table 3). Nevertheless, while the UK was acting under the premises of bounded rationality, it had different restrictions in its environment. It is possible, that the measures of the UK to address the issues concerning nuclear safety and the public opinion succeeded in changing its sensibility to this event, allowing the continuation of its nuclear plans. In this regard, I would argue that a rational subject should try to first revise his cognitive or external constraints (set of beliefs) that limit its decision making process and then make a decision based on the effects of its revised environment. Shepsle (2010) argues that "beliefs may change as the individual acquires experience in his or her external environment" (p. 17). Furthermore, the Bayesian theorem of rational learning expects the rational individual to update its beliefs anticipating upcoming information (Bayes 1764). In this sense, the restrictions imposed by bounded rationality can be controlled if the rational subject recognizes how they impair its judgment and takes measures to update its beliefs, if applicable.

The presented research might, in this regard, bring some insights for policymakers to commit to environmental targets and not shift away from alternatives that might help them better reduce emissions from GHG. In order to tackle ambiguity effects that could cause uncertain scenarios in decision making, governments could opt to address the issue of risk itself by issuing measures that achieve an environment of certainty (like the UK did after Fukushima) (Kahneman et al. 1991, p. 202), instead of complying to advocacy groups or other external factors by changing their preferences, causing inertia in their behavior (Venkatachalam 2008, p. 643). Furthermore, governments should maintain a consistent behavior towards their environmental objectives over time, especially in the long-term, since "time inconsistency preference or 'preference reversal' has larger repercussions on investment decisions of environmentally sensitive development projects" (p. 642), and as such could greatly affect investments in new technologies and the renewable energy market.

In conclusion, the British government shows a much more consistent behavior than Germany aligning its preference to reduce CO_2 emissions and its environmental policy choices. Decisive for this procedural divergence lies mainly in Germany's decision to phase-out nuclear power, and follow its transition strategy maintaining fossil fuels in its energy mix, being coal the energy source with the highest carbon dioxide emissions over its lifecycle (Gagnon et al. 2002). Nevertheless, if Germany takes strict measures to reduce the share of coal from its energy mix in the future, then its strong growth in renewable energy sources and energy efficiency may be able to greatly boost its progress in decarbonisation. The UK, in the other hand, has adopted an efficient but less environmentally safe path towards reaching its goals, that will probably require considerable, but less effort to fulfill.

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